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Special Issue on Cognitive Infocommunications Theory and Applications – Guest Editorial

Péter Baranyi

COGNITIVE infocommunications (CogInfoCom) investigates the link between the research areas of infocommunications and cognitive sciences, as well as the various engineering applications which have emerged as the synergic combination of these sciences. The primary goal of CogInfoCom is to provide a systematic view of how cognitive processes can co-evolve with infocommunications devices so that the capabilities of the human brain may not only be extended through these devices, irrespective of geographical distance but may also be blended with the capabilities of any artificially cognitive system. This merging and extension of cognitive capabilities are targeted towards engineering applications in which artificial and/or natural cognitive systems are enabled to work together more effectively. The special issue presents the latest results in this scientific field.

The first paper of this special issue "Interaction Analysis and Cognitive Infocommunications" investigates the technologies of cognitive infocommunications that have been assimilated into the concept of humanity, such as emotion, gesture, and language. The authors outlined implications for research programs conducted within the CogInfoCom discipline.

The second paper is entitled "Unitas Multiplex. Biological Architectures of Consciousness", and it deals with the consciousness of the organism generated by the encounter of biological and artificial entities (e.g.: humanoid robots, cyborgs). The authors show that several questions emerge from this consciousness. These problems concern: a) the way in which consciousness comes about on the basis of well-defined brain processes; b) how it represents its own organization and not a simple brain function; c) how simultaneously contains multiple distinct contents, each with its own intentionality; d) how it expresses dynamic evolutionary relations and not a set of phenomena that may be isolated; e) finally, how its order is not rigidly hierarchical but is supported by a multiplicity of horizontal levels, each of which is in structural and functional continuum with different phenomenal events.

The third paper of this special issue is entitled "Method to Predict Confidential Words in Japanese Judicial Precedents Using Neural Networks With Part-of-Speech Tags". This paper proposes a method for predicting confidential words in Japanese judicial precedent by using part-of-speech (POS) tagging with neural networks.

The fourth paper is "Examination of the Eye-hand Coordination Related to Computer Mouse Movement", that investigates a general eye-hand coordination task. In the study, an eye-hand tracking system was used to observe the gaze and hand path during mouse cursor movement.

The fifth paper is entitled "Categorization and Geovisualization of Climate Change Strategies Using an Open-access WebGIS Tool". The authors present the power of collaboration of different types of social geography spatial databases in a web environment. The paper presents the development of the Climate Change Strategies of the world's countries (CCS), using open-access WebGIS tools and geoinformatics software.

The sixth paper of this special issue is "Multiple Sclerosis Lesion Detection via Machine Learning Algorithm Based on Converting 3D to 2D MRI Images". This study shows the potential of support vector machines (SVM) in classification of normal and Multiple Sclerosis brain MRI images, to help the diagnosis. This paper also examines the classification of Cellular Learning Automata (CLA), then it expands the research to other methods such as Artificial Neural Networks (ANN) and k-Nearest Neighbor (k-NN) and then compares the results of these.

April 9, 2020

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Interaction Analysis and Cognitive Infocommunications

Carl Vogel and Anna Esposito

Abstract— **Cognitive infocommunications encompasses both scientific and engineering oriented approaches to examining extensions of human cognitive capabilities that may be assimilated within the concept of humanity. Necessary (but not sufficient) conditions for the success of any candidate technology include solving problems within private and public spheres of existence, in thought and communication. Exemplar cognitive infocommunication technologies that have been assimilated in to the concept of humanitiy are examined: emotion, gesture, language. Implications for research programmes conducted within the cognitive infocommunications discipline are outlined.**

Index Terms—**interaction, language, reasoning gesture, behaviour, coginfocom, philosophy of cognitive infocommunications.**

I. Introduction

COGNITIVE INFOCOMMUNICATIONS (coginfocom) has been evolving, conscious of itself as a distinct area of research scrutiny since 2010 [1], if not earlier. Development of the discipline may be tracked through a successful eponymous series of annual academic conferences. To label the subject as a "discipline" is to suggest that substantial unspoken consensus about its nature exists among those who contribute to the field. A discipline is identifiable in the boundaries between it and cognate disciplines, in the primary problems addressed, in how those problems overlap and in how those problems are composed from constituent questions. A purpose of this work is to test that consensus by putting forward specific positions regarding the boundaries and composition of the field.

We think it a basic assumption of coginfocom that humans are prolific at extending their capabilities and assimilating those extensions into what is understood to define humanity. Clothing provides a ready example of a technology that has extended human capabilities and been assimilated into the concept of humanity: clothing offers an infinitely re-configurable means of adornment and self expression; clothing also extends the potential that humans have for survival across a greater span of climate variations than is feasible without clothing. The possibility of adapting to climate variation is an individual level advantage – an adaptation that operates in the private sphere of existence, while the expressive capacity of clothing is available to public view. Within this public sphere, clothing creates new possibilities for signalling group membership and status, among other things. Tattoos also provide a means of expression (although not an infinitely re-configurable one), a public function, but few private advantages follow having one or more tattoos, beyond the potential for self-satisfaction through possession. In ordinary circumstances, people expect other people to have clothing, but do not have an expectation that other people will have tattoos. Clothing has been assimilated into the concept of humanity, but tattoos have not. Clothing is an example of a successful coginfocom technology, but tattoos are not. Not being a successful coginfocom technology means not that the technology is counter-productive,[1] but rather that it is not assimilated into the concept of humanity. Between clothing and tattoos, only clothing solves problems in both private and public spheres of existence.

In focusing on extensions of human capabilities enabled by new technologies, coginfocom attends to both the private and public dimensions of existence. The deployment of language as a system that supports both thinking and communicating is another example of humans achieving innovations and subsequently including the innovation in the concept of humanity. It is a defining property of coginfocom technologies that they enable advantages in both the private (as in thought) and public (as in communication) spheres of human behaviour.

A substantial focus in the coginfocom literature is on more recent technological advances as candidates for being understood as part of humanity: calculators and telephony have been discussed, for example. Calculators and associated technologies are addressed by those who focus on mathability [2]. For many coginfocom technologies, the relevant innovations are nearly universal in availability, if not in adoption. Vision-corrective eye-wear, money and clocks are in this category. At the inception of a new technology, it cannot have had a chance to prove its worth in public and private spheres, and when inspecting new technologies it is natural that many will not have been around long enough to become incorporated into the concept of humanity. Interest in these new technologies within coginfocom partly associates with the proof that they are possible and demonstration that they have efficacy. Sometimes they are developed with particular problems in the public or private sphere in mind, but generally, researchers relish the fact that something developed will be accompanied by affordances that serve unforeseen uses, and therefore solve unexpected problems. So, some will at times focus on technology development and some will focus at times on assessing the likelihood that the solutions provided by

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[1] It does not necessarily create harm to obtain a tattoo.

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technologies in the public and private spheres will fill niches that may lead to their assimilation.

The fact that a technology successfully fills a niche does not entail that the technology will be assimilated. Some promising candidates may be abandoned and some may be overtaken by more general innovations. Examples abound. Photographic slide projectors were popular for decades, have seemingly been abandoned without a replacement taking over their function. People continue to photograph scenes, probably photographing more now than during the age of slide projection, but the spectacle of slide shows appears to no longer be celebrated – co-located sharing of enlarged images is no longer a social fixture. In contrast, wristwatches used to be fairly ubiquitous as personal time-pieces, but time-tracking seems to have been generalized as one of many functions of multi-purpose mobile devices that people keep about their person. Similarly, the technology for replaying recorded music frequently undergoes transformation, but the function of replaying music is one that many maintain in whatever technology of the day enables this.

Many of the extensions to cognitive capabilities that people embrace spawn academic disciplines, sub-disciplines, and inter-disciplines in which researchers attempt to identify and make sense of the fundamental principles of the extensions and how they affect individual and social activities. Some coginfocom researchers seek to develop technologies that are candidates for general adoption. Some study the principles that determine widespread adoption or abandonment of new technologies. Some seek to understand how humans behave with existing technologies.[2] Here, "how humans behave" relates to transitions among psychological and physical states experienced by individuals and groups, with impacts on emotion, reasoning and interaction. Studying how humans behave with technologies that already exist can lead to identification of problems that may be solved with new technologies, but new technologies for their own sake (or for the sake of the profits that may derive from them) are not the target of all research engaged within coginfocom. Indeed, some seek understanding of how extant technologies are used and adapted, and grasp of the principles that differentiate between technologies that will become widely adopted, to the point of assimilation, and those that acquire only limited traction or no traction at all. For such researchers, grasping parameters of human thought and behaviour is essential to their progress. Open questions and challenges across these areas have been catalogued (e.g. [3]).

A goal of the present paper is to contribute our views on what it takes for new technologies to become assimilated into the concept of humanity. We analyze this question this with reference to the thread of cogninfocom that addresses linguistic and behavioural interaction analysis. There is temptation to think that the answer is trivial: successful coginfocom technologies (clothes, language, money, medicine, and so on) are *good*. However, this response is inadequate. Firstly, what constitutes "good" has remained unresolved since Plato recorded Socrates' asking of that question, if not before. Secondly, no instance of successful coginfocom technology is inherently good. One might argue that each example of a successful coginfocom technology is more appropriately considered an infection that has taken hold in humanity and which could cause extensive harm if allowed out of balance, just as bacteria of the gut support healthy living for the bacteria and the host when in the right balance, but can lead to fatality when out of balance. We think that each successful coginfocm technology solves a problem that is at hand or imminent,[3] that the problems evolve, and that the use of the solutions habituate. Having a capacity to solve a problem is a selective advantage over lacking that capacity, and such capacities may be culturally propagated as part of habituation.[4] Solutions are available for adaptation to other purposes: mobile phones were not invented to replace wrist-watches. The semantic field evoked by "infection" is apt in that the innovations that are good enough to be assimilated do so through "contagion" – they "go viral". The coginfocom technologies that assimilate are those which successfully solve problems in both private and public spheres of human existence.

The structure of our argument is as follows.[5] First we analyze thought, emotion, language and gesture as ancient coginfocom technologies that are indisputably assimilated into the concept of humanity. One longstanding thread of coginfocom research, as manifest in tracks in the annual conference series on linguistic and behavioural interaction analysis, have thought, emotion, language and gesture as the primary focus from the perspectives highlighted above (how people use them, how they may be supported, and so on). We note private and public advantages created by each.[6] We discuss thinking as a proxy for the private sphere of human behaviour and communicating as a proxy for the public sphere. We intend that more recent coginfocom technologies should be scrutinized similarly. We also highlight the ethical issues that surround the potential for new technologies that enhance human cognitive capabilities. We conclude with more questions than answers.

II. THOUGHT

Artificial intelligence research has recently given significant attention to neural network models used in learning input-output mappings implicit in enormous data-sets. For many natural language applications, systems based on such models achieve better results than current alternatives. Even as they behave well in response to stimuli on which they are not trained, there is no tendency to describe them as "thinking", in spite of a long tradition of analyzing thought as reducible to configurations of neurons and their electro-chemical behaviours. Many presume that in addition to monitoring input-output relations,"thought" involves at least the willful selection of input-output relations to monitor. Thought appears to have a useful function in guiding the macro-level time course of electro-chemical behaviours among connected neurons, and

[2]Naturally, these categories of researchers overlap.

[3]Some innovations emerge, solving problems people did not know existed.

[4]Thus, aspects of the development and assimilation of coginfocom technologies invoke genetics and epigenetics.

[5]This paper expands on work presented at a recent coginfocom meeting [4]. Although that paper mentioned issues of ethics, the full section on ethics here (§VII) was not included in that work.

[6]For some, either the public and private nature is less obvious than the other.

this seemingly solves the problem of otherwise arbitrarily structured consciousness, as is experienced during dreams.

Self-control of consciousness, a species of free will, is separable from humanity. One who seems to be guided by an entirely predictable stimulus-response mechanism will still be regarded as human. In some jurisdictions, a human lacking in self-control of consciousness is accorded societal protections, not categorized as "not human". A capacity for self-control of consciousness enables the perception of free will. It mitigates problems endemic to functioning in the "blooming, buzzing confusion" that would otherwise constitute experience. However, the fact that many choose to cede control of consciousness by means of chemicals, music, etc., is evidence that self-control of consciousness is not a universal good.

III. Emotion

Neither is emotion necessary to humanity. However, perhaps more strongly than the case of lacking thought, lacking emotion can lead to an individual being labelled "inhuman", but not "not human". The desire to have or not have particular emotions may motivate choice in thought and behaviour. Arguably, shared aspects of embodiment entail that humans potentially experience the same inventory of emotions, even if triggers differ. Perhaps this requires relativization to co-located embodiment, such as when culture and milieu are shared, since, for instance, disgust triggers are not universal, while physical components of disgust response (the oral-nasal reflexes that accompany nausea) evidently are. Desire to experience (or not) a particular emotion motivates self-direction of consciousness upon how to obtain (or avoid) it.

Having an emotion can disrupt aspects of thinking. Reasoning is rational when it is guided by commitment to logically valid arguments and sensitivity to the differences between validity and probability. Emotions have the strength to obscure one's estimation of likelihoods. On the other hand, an emotion-based bias may provide the basis for decision where there is an information deficit, but where decision is essential. In those cases, emotions make decision possible. That emotion-led decision is sometimes useful does not make it logically valid – benefits of using emotions as a guide to making decision do not include situations in which the resulting decisions conflict with valid arguments or with more informative sources of probability estimates. Applying emotion-led decision making beyond its circumscribed area of benefit can be disruptive.

This discussion has emphasized the value and risks of emotions to human thinking. Decision making technology intended to be sensitive to human emotions also risks bias.[7] In emotion classification, it is standard for error analysis to reveal predispositions in classification that can be traced to imbalances in the data [5]. The urgency of this is evident in the analysis of emotion expressed in children's faces [6]: datasets that form the basis of learning sample surprise overwhelmingly more than fear, but the two emotions have common elements. One can easily imagine a children's call-line facility that could depend on accurate emotion classification if it were possible to fully overcome such bias.

Benefits can follow from it being known what emotions one is experiencing. This is true within all sorts of relationships: couples, parents and children, siblings, within communities, between communities. The types of emotions that people discuss corresponds to the sort of relationships they share. Identification of which emotions are shared and which are not shared determines political and romantic discourse, alike.

It is a marvel of professional actors that they are able to convey emotions that they may not be experiencing. In general, humans "wear their heart upon their sleeves".[8] Frequently, when people try to hide their emotions communications on which the emotions have a bearing break down. Since intense emotions more or less declare themselves, and are merely decorated by any language used to express them, mismatch between the decorating language and visible emotions then becomes evident deception, and episodes of deception often undermine successful communication. Many people report that language is insufficiently expressive to represent their emotions accurately and completely [7], and in these cases they may prefer that the intensity of their emotions reveal the emotions directly in communication situations.

IV. Language

Language is a representation system humans use for thought and communication, but is not the sole medium for either.

The primary function of natural languages appears to be thinking. People have more thoughts than they communicate, and they think the thoughts that they communicate before they utter them. Human languages provide powerfully expressive features in support of nuanced thought, and among them are those idealized in logical connectives, such as "if" and "not". People are also capable of non-linguistic thought, including visualization of non-existing possibilities and potential futures of those possibilities. A succinct way to describe a potential development of a non-existing possibility is as a "possible narrative": the word "narrative" denotes the linguistic representation of the happening of possibilities. Human languages support representation of negation that is not supported by visual reasoning about positive possibilities. Conditionals similarly enable representation of hypothetical or counter-factual situations.[9] In addition to enabling the distinction between content that is not visualized and content that is not available to be visualized, between what is not known to be true and what is known to be false, natural language enables the representation of absolute impossibilities and paradoxes: for example, "this sentence is false". Representation is pre-requisite to reasoning.

Because people think in language, human language is also useful in communication, even though it is an imperfect code. People generally know what they mean by what they say, but often misunderstand what others mean when using the same sentences. People do not use even formulaic expressions in the same manner as each other, and people frequently embark

[7]We thank an anonymous reviewer for emphasizing the relevance of the problem of bias in machine learning approaches to AI.

[8]We apologize to Shakespeare; cf. *Othello*, Act 1, Scene 1.

[9]Indeed, it is a move in formal logic to define negation using implication and impossibilities: where $\perp$ denotes logical inconsistency, $p \rightarrow \perp \equiv \neg p$.

on linguistic innovations, such as metaphor. Until telepathy is solved, humans have no way of knowing whether they have trully understood each other. At best, people act as if mutual understanding is achieved when there is no available evidence of misunderstanding (cf. [8], [9], [10]). In the meantime, people use natural languages in communication as if they are successful, and when disagreements arise, sometimes to attempt to verify whether they are using language in different ways or instead have different viewpoints.

V. Gesture

Gestures are bodily movements that accompany language, therefore gesture has a role in thought as well as in communication. We think the role of gesture in thought is more direct than in communication. Here we do not address bodily movements that constitute language, as in sign language. We think of sign language as language, and therefore with all of the limits and affordances described above (§IV).

People gesture in solitude. People are idiosyncratic in their gesturing. We think these two facts are self-evident, and sufficient to prove the claim that the purpose of gestures is not the communication of content. Rather, people gesture in a manner that helps focus their thoughts and represent their thoughts in language. It has been observed that sometimes people "hold" gestures during utterance and thought repair [11]; this is evidence that gesture contributes to thought formulation.

Some gestures are conventionalized beyond idiolects, and many deictic gestures are in this category. Other gestures are created for the nonce. For example, iconic representations are more or less apt because of shared embodiment and shared perception of what is salient in a scene and how a bodily shape matches what is salient. Unconventional deictic gestures also exist and also exploit salience: if something is noteworthy in a situation, moving one's chin in an unusual way and in the direction of the noteworthiness can be successfully understood as pointing toward the salient elements. This, too, requires prior thought, the intention to point.

Gestures are often used to set up and refine representational spaces for illustrating narratives. This supports speakers infinitely more than listeners. A gesture may have clear meaning for a speaker, but are mostly such that no observer could hope to successfully decode the content of a discourse by watching without understanding the accompanying linguistic content.

However, gestures more successfuly serve communication with regard to psychological attitudes of speakers. Attending to gesture will give a witness a reasonable set of cues about the emotions that the speaker has. Possibly this is why mainstream news broadcasters deploy seemingly stylized but simultaneously bizarre gestures while conveying reports on television. This may be a means of obstructing the revelation of their actual emotions towards the content they report.

VI. Linguistic and Behavioural Interaction Analysis

Emotion, thought, language, and gesture are successful coginfocom technologies. We attempt to discover basic facts about these technologies, how people adapt them and how their use interacts. Understanding linguistic and behavioural interactions is important to anticipating new technologies that may arise and extend human cognitive capabilities further. It seems that a pre-requisite for adoption of coginfocom innovations is that they have both private and public functionality, in the same manner that thought is a primarily private function and communication is a primarily public function: the successful proliferation of smart-phones may be attributed to the fact that they have assimilated functions of personal digital assistants and synchronous and asynchronous communication with individuals and groups. The problem solved by the innovation may not be the same in the private sphere and the public sphere, but the duality in spheres of use reinforces habituation.

Reasoning along the lines we suggest here might influence one's thinking about nascent coginfocom technology. Consider dialogue systems. Dialogue systems have been proposed and explored (including by us) for individuals in managing health and well-being. Dialogue systems primarily target private use. Increasingly, online "bots" are used for public communication. Frequently, they have dubious ethical value as they attempt to fool people into thinking that they are not bots, but people, and to spread disinformation widely. Dialogue systems appear to have clear private value but questionable public value. Thus, one might reasonably project that dialogue system technology will not be assimilated by humanity. If public value can be established for dialogue systems, then a lasting future for dialogue systems might be projected. Establishing a means within dialogue systems for them to reveal their nature as artificial dialogue systems, regardless of who deploys them, may be one of the possible paths to deserve and gain trustworthiness – deserved trustworthiness may open clear public value to dialogue systems, and thence a possibility of assimilation.

Fidget spinners offer a solution to the problem of consuming nervous energy. This is a private function. They also had a public function shared with many other fads: namely, using one in public made one visible as someone who had access to a fidget spinner. Being a person who visibly has X is, in general, a limited public function, communicating little else beyond that. For most X, public interest in having X is determined by how easy it is to have X and how long an X lasts. As more people have X, more people want X, up to a point, and then it is no longer differentiating to have X, and therefore possessing X ceases to convey information. One can then expect interest in X to wane. In the case of fidget spinners, if they are re-released in a manner that not just consumes energy but also harvests energy, in support of activities in both private and public spheres, then one might imagine them assimilating.

Much research into coginfocom technologies validates those technologies in either private or public spheres. Naturally, this includes bench-marking the technologies with respect to prior art without directly seeking validation in private or public spheres, given that prior art may have had independent validation along those lines. For example, the role of many natural language technologies is clear within larger systems, therefore it makes sense to seek improvements on fundamental components like part of speech tagging or parsing. Similarly, it makes sense to explore fundamental properties of the public and private spheres themselves, in order to understand where problems in those areas exist. Given that these spheres are private and public with respect to humanity, and given the premise that cogninfocom is about extending the capabilities of humans, it follows that fundamental knowledge about humans behaving in public and private spheres is always a moving target, as new technologies are assimilated. Thus, within coginfocom, one expects to see research that seems to explore technology "for its own sake" and humanity "for its own sake", but which actually, if indirectly, contributes information about the viability of extending capabilities of both.

The discussion so far indicates that for coginfocom technologies to be assimilated as part of humanity, it is a necessary condition that they contribute solutions to problems in the private and public spheres. However, these are not sufficient conditions. A coginfocom technology may well provide useful solutions, while a "lesser" technology out-competes it. As an example, one might reflect again on the role of music. All but a few forms of music were proscribed from *The Republic*, because of the capacity of music to "excite the passions", thus diminishing control over the populace. It appears to be an implicit hypothesis that musical experiences impinge on mental states, and this hypothesis has empirical support [12]. Arguably, if the goal of communication were the revealing and sharing of mental states, one might develop music-based communication technology and anticipate a system that is more effective as a solution than natural language.[10] Crucially, natural language affords the possibility of hiding mental states, through the potential it creates for ambiguity, vagueness, misrepresentation, partial truths and outright lies. On this line, the communicative value of language in the public sphere is precisely in its support of mis-communication. Music might provide a means of supporting thought and communication which is superior to that of natural languages, but natural languages have been more completely assimilated by humanity.

While for a coginfocom solution to become part of humanity it is necessary for it to make contributions to both the private and public spheres, the nature of the contributions may be distinct in each sphere, and further, it is open for the efficacy to be greater in one than the other. It is also open for other considerations to impinge where competing technologies address overlapping problems. While some considerations such as determine the success of fads, as discussed above, may apply, it seems that in general, the "easier" solution wins. Ease may be judged in relation to computational efficiency/cognitive complexity or physical effort. To see that this is a non-trivial empirical hypothesis, it should be contrasted with an alternative criterion, for example, that, in general, the most "beautiful" solution wins. One might argue, again with reference to natural languages, that they are all of approximately equivalent computational complexity (context free or at most mildly context sensitive, and therefore at worst, polynomial-time in the length of the sentence to judge grammaticality) and therefore there is no choice to be made with reference to ease of use, even if there were universal perceptions that some particular language is more beautiful than the rest. Therefore, it makes sense that people, in general, continue to use their native language(s) unless circumstances place them in situations where other languages are useful to them. Others might make reference to smart telephones for an alternative argument that beauty presents criteria at least as powerful as "ease", particularly those who find the explanation of the market success of Apple Corporation's iPhones to be their beauty (and not the issues of exclusivity related to their monetary expense, as with other possible instantiations of X, as discussed above).[11]

As coginfocom technologies are assimilated, they create new problems and offer new affordances for adaptation. They interact with other aspects of humanity and open new questions about human behavior in isolation and within interactions.

VII. Ethics

The prospect of assimilation of technologies that enhance human cognitive capabilities is accompanied by the necessity to explore the ethical ramifications of these technologies [14]. The necessity of attention to the risks associated with such enhancements is embedded in Judeo-Christian creation myth: the extension of cognitive capabilities enabled by eating from the Tree of Knowledge results in being cast out of Eden.

Researchers in medicine study the possibility of pharmaceutical products that can enhance cognitive capabilities [15]. Naturally, this is accompanied by scrutiny of ethical issues raised by such drugs [16]. Some have studied attitudes towards drugs and noted a tendency to be critical of the use of cognitive enhancing drugs where they provide unfair advantages, just as performance enhancing drugs are thought of as "cheating" in athletics [17]. Other researchers provide considered argument that drugs associated with cognitive enhancement should not be deemed unfair *a priori* [18]. The coginfocom discipline has a tendency to focus on coginfocom technologies as those involving computers and robotics, and that is why the focus here on, for example, language, as a coginfocom technology is somewhat jarring, even though computing is often discussed using the label "information and communication technologies".[12] This focus may account for the relative lack of attention to the relationship with medical research on cognitive enhancement. Nonetheless, issues of ethics are shared. However, this does not make it easier to identify the most appropriate ethical framework in which to analyze the issues. Medical ethics is dominated by utilitarian reasoning. Information ethics is a relatively newer approach and sometimes leads to distinctive conclusions [19] – we are not ourselves expert in information ethics but suspect that the framework would endorse developing the cognitive enhancements that coginfocom aspires to while studying their use and supporting regulation of their deployment.

These issues are larger than those addressed by coginfocom researchers in their daily practice. Daily practice for any research involving human participants includes putting it prior

[10] Prosody in natural language may be an example of an adaptation of this technology.

[11] The iPhone is interesting in another respect, as it is an example of a technology for which the perception of need followed its availability (cf. fn. 3), rather than the device filling an obvious need gap. Coginfocom technologies also arise in the other direction, through careful analysis of the user [13].

[12] A Turing machine is equivalent in tangiblity to a language.

independent scrutiny for research ethics evaluation. We think that research ethics committees that evaluate the work of coginfocom researchers dwell on the risks to participants being and their privacy but not the wider issues associated with the acceptability of cognitive enhancements. Indeed, these issues are so wide that they cannot be treated or solved completely within any of those committees, nor here, either. Our tentative conclusion is what we claim above to be consistent with the information ethics perspective: it makes sense to develop new possibilities for cognitive enhancements at the same time as studying how extant ones are used and assimilated and while supporting informed regulation of their deployment. Additionally, we think that regulation of deployment should not absolve potential users of responsibility. It is a persistent risk associated with technology that users may yield responsibility to the technology – whether that means having it make decisions for them or allowing prior abilities to atrophy with dependence on the technologies.[13] For example, from the perspective of cognitive capacity to manage social networks [21], both language and online social media constitute coginfocom technologies. Correlations have been shown between excessive online social media use and psychiatric disorders [22], and evidence of causal links between excessive social media use and efficiency has been produced [23]. Healthy use of cognition enhancing technologies entails being able to moderate that use.

VIII. Related work

We feel that the theory of successful coginfocom technology that we have proposed is consistent with research within coginfocom as well as work within its constituent and cognate disciplines. Our presentation of coginfocom is compatible with definitions provided elsewhere [24], [25], [26] and with prior syntheses of coginfocom research [27], [28]. Recent analysis of prerequisites to future advances in human-computer interaction has presented the view that comprehending, respecting and overcoming human limits are integral to success [29], and interface "efficiency" is identified as a criterion associated with success. It is important to contemplate success criteria.

In the same way that we have discussed emotion, gesture, language and thought as examples of coginfocom technology, other researchers have explored other systems of representation that humans have adopted in support of reasoning; for example, maps are adopted as aids to spatial reasoning [30], [31]. Intersections of topic areas are also addressed in the coginfocom literature. For instance, language use in situations that demand communication of spatial directions has been studied [32], [33], [34]. Some coginfocom researchers have studied linguistic representation of reasoning [35]. The dynamics of human use of gesture during dialogue is a core topic in coginfocom [36], [37], [38], [39], [40], [41], as is emotion [42], the linguistic expression of emotion [43], emotion voicing [44], [45], [46], emotion depiction [47], [48], influence of emotion on reasoning [49], and the synthesis of modalities of expression [50], [51], [52], [53], [54], [55], [56].

At present, most researchers who study topics of relevance to coginfocom were originally trained in one or more of the disciplines that contribute to coginfocom, and continue to provide advances within those disciplines. In advancing the constituent disciplines, they are, by definition, advancing coginfocom. Take linguistics as an example of a constituent discipline. Pursuing linguistics from a coginfocom perspective adds something that is not typically explicit within traditional study of linguistics, through scrutiny of alternative (and additional) technologies that humans may adopt.[14] This is true of each constituent discipline. Coginfocom adds to the constituent disciplines, *inter alia*, focus on each discipline's content as a technology that has been adopted by humans in the past or which might be adopted in the future, whose dynamics in isolation and interaction with other dimensions of humanity requires examination. One could argue that an expansive view of cognitive science or artificial intelligence or, in fact, of any of the contributing disciplines would encompass coginfocom, and we think this argument is correct. If any of the contributing disciplines is expanded in scope to include the perspective that the discipline's content involves a technology that has been assimilated into humanity but which is not essential to humanity it would then be equivalent to a coginfocom perspective on that discipline. We have articulated here theory of successful coginfocom technology, regardless of contributing discipline: for it to be assimilated, it must provide advantages in both the private and public spheres of human existence.

IX. Conclusion

We have explored a theory that viable coginfocom developments are those that operate both in the private and public spheres, enhancing human capabilities for thought and interaction. Coginfocom research may attempt to increase understanding of the interaction of these spheres or properties of the spheres in relative isolation. Research that extends and validates cognition enhancing technologies or that attempts to understand the nature of human cognition or communication, even if in isolation from direct questions of contribution to private and public spheres, still contributes to coginfocom. We think that it is not necessary for each contribution to be contextualized with reference to the totality of coginfocom. The relations may not even be evident at idea inception nor after their validation. It is of primary importance that each contribution advance knowledge with rigorous scholarship. As each makes public the knowledge acquired in private, others may "connect the dots" as inspired by their own insights.

It is indicative of a standard developmental stage of a discipline for it to be open to the exploration of its philosophical principles, at the very least examining whether it creates new ethical dilemmas. The nature of such explorations is that they are never complete. We hope that as coginfocom researchers, we can engage our peers in continuing the discussion.

[13]This is a counterpart to ethical responsibilities of participants in research studies – typically, the focus is on the ethical responsibilities of the researchers, but participants have responsibilities, as well [20].

[14]This does not mean that linguistics who have probably never read a paper published under the aegis of coginfocom do not also contemplate alternatives to natural language. Considering alternatives is, in fact, attested in linguistic theory (e.g. [57, Chr 2 (pp. 8-33), "The Peculiarities of Language"], but this is not the main activity of linguistic theory.

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Unitas Multiplex. Biological architectures of consciousness

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Abstract— **The so-called Posthuman question - the birth of organisms generated by the encounter of biological and artificial entities (humanoid robots, cyborgs and so on) – is now on the agenda of science and, more generally, of contemporary society. This is an issue of enormous importance, which not only poses ethical questions but also, and above all, methodological questions about how it will be achieved on a scientific plane. How such entities will be born and what their functions will be? For example, what kind of consciousness will they be equipped with, in view of the function of consciousness for distinguishing the Self from others, which is the foundation of the interactive life of relationships? Many scholars believe that rapid technological progress will lead to the emergence of organisms that will simulate the functions of the mind, learn from their experiences, decode real-world information, and plan their actions and choices based on their own values elaborated from vast amounts of data and metadata. In the not-too-distant future, it is believed that these entities will acquire awareness and, consequently, decisional freedom, and perhaps even their own unique morals. In this paper, we try to show that the path towards this goal cannot avoid clarification of the problems that neuroscience has ahead of it. These problems concern: a) the way in which consciousness comes about on the basis of well-defined brain processes; b) how it represents its own organization and not a simple brain function; c) how simultaneously contains multiple distinct contents, each with its own intentionality; d) how it expresses dynamic evolutionary relations and not a set of phenomena that may be isolated; e) finally, how its order is not rigidly hierarchical, but is supported by a multiplicity of horizontal levels, each of which is in structural and functional continuum with different phenomenal events. The empirical and theoretical research effort on this topic provides an intensive contribution to the development of IC Technologies.**

Index Terms — consciousness, artificial intelligence technologies, Ascending Reticular Activating System, brain imaging

I. Methodological controversy

The methodology of the study of consciousness should comprise three essential aspects: 1) the search for neurophysiological correlates; 2) the causal analysis of this correlation; 3) the identification of causal links that allow a reproducibility that can confirm the explanatory hypotheses [1]. Naturally, ideal conditions of causality only exist in healthy subjects. Moreover, many structures, each with its own neurophysiological correlates, are involved in such study [2,3] and the extremely complex relations between consciousness and awareness must also be taken into account. In view of these considerations the experimental conditions for approaching an analysis of the neural correlates of consciousness appear rather complex. Although we can only access its contents through relevant verbal reports that can be shared by a third-party [4,5], there are also behaviors, gestures and movements related to neural activities, which can be detected electrophysiologically or by brain imaging. In any analysis, at least three types of neural activity should be considered: one associated with conscious mental representations, one associated with sensory stimuli and one related to behavior [6]. It seems inevitable, therefore, that in the field of consciousness, more than in other scientific investigations, theory must precede and accompany experimentation. Several mechanisms and dynamics generating phenomena of variation and selection (molecular, supramolecular, cellular, cellular networks, networks of networks) are involved in generating living organisms perfectly adapted to the natural environment [7].

An elective method of study of consciousness consists of observing brain activation (PET, fMRI, MEG, event-related potentials), allowing exploration of the central nervous system before and after an adequate stimulus: the presentation of ambiguous visual stimuli, the transition from general anesthesia to awakening, the transition from the vegetative state to the

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minimal conscious state etc. [8]. For example, in a patient first in vegetative state, then 'minimally conscious', the resumption of the activity of the thalamus-cortical circuit at a high oscillatory frequency confirms the importance of connections between the intralaminar nuclei of thalamus and the frontal and parietal associative cortices in the maintenance of consciousness [9].

Because of its crucial evolutionary functions, consciousness cannot be restricted to a limited region of the brain. The classical studies of Moruzzi and Magoun [10] showed that the Ascending Reticular Activating System (ARAS) – a system composed by reticular formation, thalamus and thalamus-cortical projection system – presides over the widespread activation of the cerebral cortex, generating the states of waking and vigilance necessary for the constitution of the contents of consciousness. However, ARAS is not restricted only to the brainstem reticular nuclei [11]. In fact, its structures project downwards to the spinal cord and upwards to the cerebral hemispheres. Furthermore, each of its constituent nuclei has particular anatomical, physiological and chemical characteristics. Circumscribing the ARAS at the midbrain level is, therefore, restrictive [12]. Many brainstem nuclei that modulate the functioning of the cortex reside in the pontine tegmentum, others in the pons and the bulb. It is also relevant that some nuclei of the brainstem go beyond the thalamus to connect directly with the fronto-basal cortex, from which diffuse bilateral projections to the cerebral cortex originate. Moreover, other nuclei go beyond both the thalamus and the fronto-basal cortex to reach wide areas of the cerebral cortex and other nuclei again are connected with the reticular nucleus of the thalamus but not with the intralaminar nuclei [13]. These factors allow us to consider the functions of ARAS as much wider and more complex than the simple 'desynchronisation' of the cerebral cortex, although the latter is essential to the state of alertness and to attention [14], while there are non-specific thalamo-cortical projections, such as the activation of the thalamo-cortical circuit at high oscillatorry frequency, fundamental for the essential functions of consciousness [15].

II. AN ENDLESS DISPUTE

The brain has frequently been represented as a multitude of specialized and distributed microprocessors competing with each other to access a Global Workspace for the coordination and control of information [16]. In this scenario an enormous amount of information would contribute, below the threshold of consciousness, to determining conscious subjectivity. At the foundation of this system would be the thalamocortical circuit which, with upward and downward projections, could transform the distinct contents into expressions of meaning [17]. The Global Workspace – which helps to clarify the nature of the unity of consciousness and distinguish between the conscious global workspace and unconscious levels – is constituted as a stable context-purpose within which consciousness determines its own contents among countless competitive-cooperative interactions and multiple sense-perceptive sources [18]. In the second half of the 1990s, starting from experiments on vision in primates, the idea took form that at the origin of consciousness there is a system similar to the activation of neurons in layers V and VI of the cerebral cortex, mediated by thalamocortical oscillations [19]. At the origin of consciousness would be a form of neural activity of elevated visual areas that would project directly onto the prefrontal areas, creating an intermediate space of representations dislocated between a lower plane of sensations and a higher plane of cognition. Among the phenomenal and cognitive dimensions in which learning, reasoning and intelligence would take place a homunculus, in any case below the conscious level, would perceive the world through the senses, elaborating, planning and performing voluntary actions [20]. This double dimension is present in Edelman's proposed distinction between a primary consciousness (a multi-modal space that brings together different sources of information) and a higher consciousness (contemporary to the birth of language) that would allow the Self to evoke and narrate his own experiences, freeing the organism from the biological constraints of the here and now [21,22]. In this scheme, primary consciousness would connect the axiological-categorical memory to current perceptual organization, while higher consciousness would operate a synthesis between the memory of values and the memory of categories distributed in the temporal, frontal and parietal areas. From the comparison between these two types of neural organization, on one hand there is the non-Self that has sensory relationships with the world through experience, and on the other, the Self that, stimulated by social interactions, acquires rich semantics and a syntactic memory for concepts, would together constitute higher consciousness. Although Edelman [23] is willing, in his most recent works, to consider subjectivity in the conscious sphere, his general theoretical framework lacks references to external subjectivity coding and decoding messages with a symbolic alphabet. Edelman made a distinction between actual information (the number and probability of states making a difference in the Self system) and information which measures the independence of sub-sets through the bipartition of an isolated system. The complexity varies with the neuroanatomical organization: i.e. it would be minimal when the connections are statistically distributed and, instead, maximal when it is connected to defined groups of neurons. In this sense, the higher the information links between the subsets and the system, the greater the complexity. A crucial role in conscious experience would be played by an aggregate of neurons belonging to the thalamocortical system, which operates in a timespan of a hundred milliseconds in collaboration with other areas of the brain, giving origin to phenomena, with variable and dynamic spatial distributions, that are decisive for brain integration. Such integration would not be limited to the work of a subset of neurons, but would vary, from moment to moment, in the same individual and from one individual to another. Thus, it would be unified and differentiated at the same time. Fascinating though it is, this model does not make it clear how consciousness unifies such different and distant modularity [23].

Years ago, the hypothesis of the existence of a dynamic, globally integrated recruitment of representations with characteristics of unity, diversity, variability and competition in a circumscribed neural space was advanced [24]. According to this hypothesis, the work of a set of neurons, up to the constitution of real neural maps, connected each other over short distances (but relatively autonomous), would give rise to phenomena such as vision, language and motility. In this model long axons – particularly abundant in the cortical layers I, II and III – present in large numbers in the prefrontal cortex, dorsolateral prefrontal cortex and inferior parietal cortex. Here, a critical role is played by the frontal lobes, play a relevant role [25]. By subjecting individuals to a multimodal cognitive task (such as the Stroop test) the authors observed that the meaning of the read word was pronounced relatively automatically in accordance with the subject matter, whatever the colour of the ink, and although there was a strong inconsistency between it and the meaning of the word. The effort made in correction would indicate the recruitment of workspace neurons which, through trial and error, would control the processing of information by processors working from the bottom up. The computer simulation of the model would not only clarify the dynamics of global representation, but would be predictive of the dynamics of brain iconography during the execution of the task [26]

The ability of consciousness to integrate information raises the questions of how much a physical system can become conscious and what kind of consciousness it is endowed with. It can be presumed that part of the organization of these cortical areas is responsible for the different quality of resulting conscious experiences. According to Tononi [27, 28] the qualitative question of consciousness can be addressed as a natural extension of the quantitative (neurophysiological) problem. In other words, qualia would indicate the capacity of a system to integrate information (blue, red, etc.) due to the informational connections that bind the elements of a complex, while the types of informational relations would largely be determined by the nervous connections within (and between) each of the different cortical areas of information integration. According to Tononi, with many experimental and clinical neurobiological observations it would also be possible to measure consciousness consistently, just like physical phenomena such as entropy or temperature. According to the theory, in fact, the multiple manifestations of consciousness would be due to the modes of integration of information [28]: levels of consciousness would a be direct function of information integration and vice versa.

III. UNITAS MULTIPLEX

For over two centuries scholars have supported the idea of the unity (and continuity) of consciousness over time [29]. Today, instead, copious evidence shows that consciousness is a multifaceted process that simultaneously contains distinct contents, each with its own intentionality [30, 31, 32]. However, how does this internal plurality unify the different contents and the underlying biophysical-molecular mechanisms that are integrated into the experience? [33, 34]. This model has two possible variants: in the first, consciousness would be generated by a single central neural system: information would be brought to representation and then to consciousness; in the second, consciousness would emerge from the co-activation of programmed contents from distributed structures in the brain which, in a unitary process, would simultaneously process innumerable pieces of information. Yet, if the simultaneous plurality of consciousness is admitted, what is the interface and the relationship between the brain infrastructure and the activity of consciousness? In short, how is the content of the experience integrated into the brain? The distinction between a plural model and a unified theory of consciousness starts from here [35].

However, whether conscious experience is the result of the work of a central neural system, where informer content must be represented in order to be brought to consciousness, or the result of a unitary process of consciousness-creation in which the brain acts by treating many distinct pieces of information simultaneously, consciousness turns out to be a monodrome phenomenon which takes place exclusively in the brain. On the contrary, if the activity of the individual and distinct elements are generated by cerebral mechanisms distributed in the brain, then this gives rise to a plural activity of consciousness. Here, contents independent of each other and exposed to intra-sensory and intersensory influences affect each other and co-determine conscious content. In a plural model, in which the mechanisms of consciousness are multiple and localized, these interactions are perfectly constant. Ramachandran [36] has often insisted on the concrete plausibility of a model that integrates visual, auditory, tactile, proprioceptive and other experiences. These individual spheres can be altered or marginalized, relatively independently, without affecting the others [37].

Evidence on the consequences of lesions and ablation of brain areas shows that it is possible to lose the ability to visually capture motion (while preserving other aspects of visual experience) [38], and that it is possible to lose the sensation of color, while preserving the visual experience and movement. Studies on the degree and type of functional specialization and brain localization in subjects with lesion deficits have shown that the brain works on a large scale, between modes and domains that are reflected in precise anatomical districts (primary visual processing in the occipital cortex, auditory processing in the temporal cortex, design and memory processing in the frontal cortex), while precise functions are performed in well-demarcated anatomical districts and loci: for example, visual motion in V5 and color in V4. The areas of the brain that program particular information content are those in which they come to awareness. For example, different events presented simultaneously in a visual scene are not perceived with the same duration. This widespread asynchrony shows how consciousness, more than a unitary faculty, is the integrated outcome of many micro-events [32, 39]

Yet, if consciousness has this plural nature, why do we perceive ourselves as unitary subjects? And how does the Self emerge from such multiplicity? One could discuss the meaning of the unitary subject and its inner core that we define as Self at length. Without getting into such controversial territory [40], one could say that the Self emerges when the individual events produced by the brain obtain a sufficiently representative, coherent and cohesive form [41]. Under normal circumstances, we experience a structured world of distinct and ordered objects in space within significant spatial-temporal patterns, organized according to regularity and extramodal (colour, shape, etc.) and intramodal (proprioceptive, auditory and visual) content. In reality, representative cohesion is not an invariant feature of conscious experience, but the outcome of a selection through which the brain seeks a path towards its own integration. Thus, the appearance of the Self has to do with an ordering activity of consciousness, which elaborates and sustains this multiplicity of local contents generated by conscious experience, in relation to one another.

A plural model of consciousness could explain the birth of the Self, with a space of centrencephalic functional integration [15, 42, 43] that supports both integration and global communication at its base. Consciousness would thus appear as a multiple unity rather than an undifferentiated unity. Let us be clear: the unification of consciousness is not a matter of uniqueness, but of representative cohesion: a cohesion plausibly operated by cortico-cortical circuits, and one that would explain how a Self emerges from the multiple representative activities of the brain. All conscious experiences are, in fact, unified within a conscious field [44] Hence, unity is implicit in qualitative subjectivity. But if our awareness is determined by infinite parts, what we perceive is not just one subject with different states of consciousness, but many different fields of unified consciousness. In other words, the unity of awareness follows subjectivity and quality, because there is no way to have subjectivity and quality without unity.

It can never be stressed enough that there is a need to distinguish instantaneous unity from the organized unification of conscious sequences that we obtain, for example, from iconic memory [1]. For non-pathological forms of consciousness and memory it is essential that the conscious sequence is organized in a certain order [45]. For example, comprehension of a sentence is determined by the ability to remember its beginning through its duration and to reach its end producing a coherent discourse [46]. Now, if instantaneous unity is part of the definition of consciousness, then unity organized through time (duration) is essential to consciousness, even if it is not necessary for the existence of conscious subjectivity.

IV. CONCLUSION

Despite the prodigious advances in neuroscientific research, the problem of consciousness remains an unsolved mystery. In the history of science, it has often been the case that a solution to a problem raises new questions. This also applies to the consciousness. The more we learn about it, the more we need specific, articulate and refined answers and knowledge about what we do not know yet. In this sense, achieving an adequate understanding of consciousness in all its aspects will require many other developments, both theoretical and experimental [47]. In this paper, for example, we could not consider important distinctions such as between primary consciousness and self-consciousness, nor the close relationship between consciousness and memory or between consciousness and language. We have not even mentioned the great practical difficulties that hinder the measurement of the ability to integrate information in a living brain. Nor has it been possible here to consider the many implications of the equivalence between consciousness and the ability to integrate information. Although it has been on the confines of scientific debate for almost a century, the literature on consciousness is growing day by day with the contributions of thinkers and researchers from different disciplines [48]. So far, the Galilean categories have allowed us great success in the explanation of physical phenomena, but they have proved insufficient so far for understanding the nature of consciousness. No one knows how a physical system (the brain, the nervous system, a set of neurons) is able to generate conscious experience. The brain is, like so many things, a physical object, but we are unable to explain how a certain system can produce conscious experience, whether there is a specific element that gives rise to consciousness, and whether it develops suddenly or gradually. Now, if neuroscience is unable to answer any of these questions, could the way forward be to address the issue through the construction of organisms with "artificial consciousness" [49]? Would it be ethically implausible to try to understand consciousness through refined forms of artificial intelligence?

At the beginning of the third millennium, the decisive turning point in human history - the understanding of consciousness - could be achieved through AI [50]. So far, along with other essential elements, there has been insufficient technological know-how to build an artificial conscious entity, but now that robots are starting to look like human beings – both in terms of computing power and physical structure – the solution may be closer. According to some thinkers, within a few decades the construction of super-intelligent machines will allow us to transcend the human condition [51, 52]. The use of nanorobotic systems will help us to generate creative ideas, to think independently, to expand our memory systems, probably connecting our minds to the cloud, the great and potentially infinite archive of information stored on the Internet [53]. Our very way of thinking will become a hybrid expression of biological and non-biological elements. As the cloud gets more sophisticated, we shall probably update ourselves. With time, the role of non-biological consciousness will become more and more important and, as a result, our way of thinking will become more and more non-biological. Once this level is reached, it is reasonable to think that there will be positive effects in the development of AI-driven devices, which will generate more and more powerful and sophisticated AI [54, 55, 56]. In this sense, the Subsumption architecture model by Brooks takes on interest: it is a control architecture, conceived in opposition to the traditional AI. According to this model, the behaviour of robots can be oriented through symbolic mental representations of the world, combining sensory information with the selection of the action in an intimate and bottom-up way [57]. According to Brooks, the construction of an embodied agent is articulated on different levels: a) an integrated physical control system; b) an internal relation of the behavioral layers directly rooted in the world percieved by robots; c) the interaction of these modules, which generates emerging properties based on the information of the senses. According to Brooks, the construction of an embodied agent is articulated on different levels: a) an integrated physical control system; b) an internal relation of the behavioral layers directly rooted in the world that the robot perceives; c) the interaction of these modules, which generates emerging properties according to an embodied model [58].

As far as the acquisition of new skills through self-learning is concerned, it cannot be excluded that a brain capable of extraordinary calculations may make the development of a new and more powerful sensory sphere possible, even if it will be very difficult to replicate the intricate work done by the long-tried adaptive process of the species and to define the sophisticated processing of information as emotions such as pain or pleasure. But it is not at all senseless to think that the speed of technological change will produce such an impact that it will profoundly change human life [59, 60] and lead to a real discontinuity in the network of human history created by evolution [61, 62].

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Method to Predict Confidential Words in Japanese Judicial Precedents Using Neural Networks With Part-of-Speech Tags

Masakazu Kanazawa, Atsushi Ito, Kazuyuki Yamasawa, Takehiko Kasahara, Yuya Kiryu and Fubito Toyama

***Abstract*—Cognitive Infocommunications involve a combination of informatics and telecommunications. In the future, infocommunication is expected to become more intelligent and life supportive. Privacy is one of the most critical concerns in infocommunications. Encryption is a well-recognized technology that ensures privacy; however, it is not easy to completely hide personal information. One technique to protect privacy is by finding confidential words in a file or a website and changing them into meaningless words. In this paper, we investigate a technology used to hide confidential words taken from judicial precedents. In the Japanese judicial field, details of most precedents are not made available to the public on the Japanese court web pages to protect the persons involved. To ensure privacy, confidential words, such as personal names, are replaced by other meaningless words. This operation takes time and effort because it is done manually. Therefore, it is desirable to automatically predict confidential words. We proposed a method for predicting confidential words in Japanese judicial precedents by using part-of-speech (POS) tagging with neural networks. As a result, we obtained 88% accuracy improvement over a previous model. In this paper, we describe the mechanism of our proposed model and the prediction results using perplexity. Then, we evaluated how our proposed model was useful for the actual precedents by using recall and precision. As a result, our proposed model could detect confidential words in certain Japanese precedents.**

***Index Terms*—confidential word, neural network, Part of Speech (POS) tag, perplexity (PPL), precision, recall**

I. INTRODUCTION

A. Cognitive Infocommunications

Cognitive Infocommunications (CogInfoCom) [1][2] involves a combination of informatics and communications. CogInfoCom systems extend human cognitive capabilities by providing fast infocommunications links to huge repositories of information produced by the shared cognitive activities of social communities [3]. CogInfoCom is expected to become more intelligent, and it would even have the ability to support life. Fig. 1 shows the idea of CogInfoCom. Clearly, privacy is one of the most critical concerns in infocommunications. Encryption is a well-recognized technology used for ensuring privacy; however, encryption does not effectively hide personal information completely. One technique to protect privacy is to determine the confidential words in a file or a website and convert them into meaningless words. CogInfoCom makes a network intelligent and automatically changes confidential words into meaningless words.

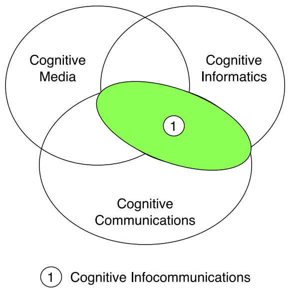

Fig. 1. Infocommunication model

B. IT-Based Court: Cyber Court

Globalization of the economy, international trade, and disputes present new demands on judiciaries worldwide. At the same time, advances in information communication technology (ICT) offer opportunities to judicial policymakers to make justice more accessible, transparent, and effective.

By introducing ICT, many countries have allowed easy access judicial documents easily. Such a justice system empowered by ICT is called a "cyber court." A pioneering study of a cyber court system is Courtroom 21 [4], which started in 1993 in the College of William & Mary as a joint project between the university and the National Center for State Courts in the United States of America.

In Japan, the prototype for the first civil trial was developed in the Toin University of Yokohama in 2004 [5, 6], and its effectiveness was proved particularly to the Japanese citizen judge system [7]. An experiment with a remote trial was also conducted [8]. The Investments for the Future Strategy 2017 by the Japanese Cabinet Office includes ICT conversion for trials to accelerate the trials and improve the efficiency of the judicial system [9].

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C. Predicting Confidential Words

To protect personal information, most precedents are not open to the public on the Japanese court web pages. Confidential words (e.g., personal, corporate, and place names) in open precedents are replaced by other meaningless words, such as a single uppercase letter "A." This operation takes time and effort because it is done manually. Therefore, we would like to predict confidential words automatically to solve this problem.

In recent years, the use of neural networks has advanced in natural language processing. The research includes deriving a vector by considering the word meanings and predicting words that are actively ongoing [10]. We reported earlier that a bi-directional long short-term memory (LSTM) with left–right (LR) (hereinafter Bi-directional LSTM–LR) model is effective to predict target words in Japanese precedents. However, we did not obtain good accuracy for the detection of confidential words [11]. In this research, we attempt to improve the accuracy of predicting confidential words. In the Japanese precedents, we found that the confidential words were mostly proper nouns and various parts of speech (POS). Therefore, we considered a new method by using a POS tag.

In this paper, we propose a new method using a neural network combined with the POS tag to improve accuracy, and we describe the experimental results for predicting the confidential words. Then, we show the probability of applying our model to practical situations.

II. HOW TO ANONYMIZE CONFIDENTIAL WORDS

Japanese precedents include many confidential words, such as personal names, corporate names, and place names. To protect privacy, such words are converted into meaningless words. In Japan, this procedure takes time and effort because it is done manually.

A. Problem of Anonymizing Confidential Words

Some judicial precedents are available on the website of the court [12]. Confidential words in these precedents have been replaced with a letter of the alphabet. (In paid magazines and websites, Japanese letters are sometimes used.) Fig. 2 shows an example of a replaced word. This process is performed manually. These replacements cannot be done easily by using a dictionary of proper nouns because confidential words sometimes have multiple meanings, and it is difficult to distinguish among them. Therefore, the substitutions are done manually by legal experts based on the context.

B. Aim of Our Study

Our purpose is to extract the confidential words in Japanese precedents and automatically replace the confidential words with a single letter of the English alphabet ("A"). There are various methods for predicting confidential words in the judicial precedents. One possibility is to use a dictionary of proper nouns. However, even if the confidential word matched the list in the dictionary, the word may sometimes be used with a different meaning in the Japanese precedent. For example, the word "Yamaguchi" may refer to a city or a person. To solve this problem, we will propose a method for predicting confidential words in a sentence based on the context by using a neural network. Fig. 3 shows the prediction mechanism of the confidential words.

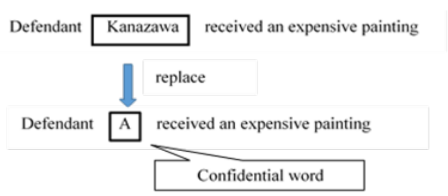

Fig. 2. Anonymizing the confidential word

For the preprocessing, we converted the confidential words contained in the datasets to the uppercase letter "A" and separated the Japanese words with spaces by using MeCab, a Japanese morphological analyzer [13]. When the Japanese precedents (corpus) containing the confidential words replaced by "A" are entered into the neural network, they are learned by the neural network, which then predicts the confidential words.

C. Related Works

Named-entity extraction is a widely used technique to obtain the target words in a sentence. Named-entity recognition (NER) is probably the first step for information extraction to locate and classify the named entities in the text into predefined categories, such as the names of persons, organizations, locations, expressions of times, quantities, monetary values, and percentages. NER is used in many fields in natural language processing [14] [15].

NER extraction is executed mostly by using two methods: the rule-based method (by pattern matching) and the statistical method (by machine learning). The method using pattern matching has a very high cost because the pattern of the named entity dictionary needs to be created and updated manually. Various machine learning methods have been studied to solve the problem. Machine learning methods, such as the hidden Markov model and conditional random fields (CRFs), can learn the pattern of a named entity by preparing the corpus. CRF has proved to be quite successful for NER. Nevertheless, the problem of machine learning is that the cost of manually making a corpus is quite high [16].

III. RESULTS OF PREVIOUS STUDIES

The use of neural networks is widespread even for learning natural languages. Therefore, we will study a neural network to predict the confidential word because the embedding vector of the word used in the neural network is very effective to

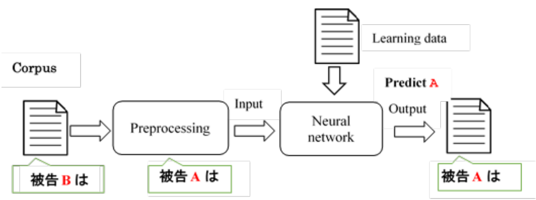

Fig. 3. Prediction mechanism for confidential words

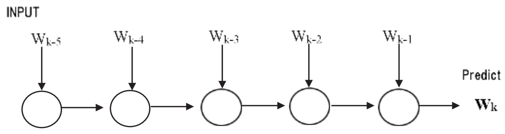

Fig. 4. LSTM model

handle word meanings. We investigated some models of the neural network as described in the following subsections.

A. LSTM Model

A neural network is beneficial in the field of natural language learning. From the words adjacent to the target word, we can decide whether or not the target word is confidential. We found that the most effective model was LSTM), which was an improved model of the recurrent neural network (RNN). The RNN suffers from vanishing or exploding gradient or the exploding problem when the input data is long. LSTM is very useful in long sequential data (Fig. 4) [17].

B. Bi-Directional LSTM-LR Model

We used the Bi-directional LSTM–LR model to imitate the anonymization work done by humans. When humans do this work, they always judge the word after reading the words on the left and right of the target words. We proposed this model at first, as shown in Fig. 5.

For the input order on the backward (right side) of the target word in the reverse order of the sentence, we assume that the influence of the target word increases with increasing proximity of the input word to the target word.

C. Corpus and Experiment of the Bi-Directional LSTM–LR Model

We used 50,000 judicial precedents for the training data and 10,000 judicial precedents for the test data. In these data, the contents of the trials held from 1993 to 2017 were recorded. These were the precedents database provided by the TKC Co. [18]. The various parameters used are shown in Table 1.

Window size means the chunk size, which describes the input word size before or after the target word. Fig. 5 shows the window size as 4 to explain the model; however, in this experiment, we used a window size of 10.

For accuracy, we used the perplexity (hereinafter PPL) that was used in previous studies for predicting the next word. In

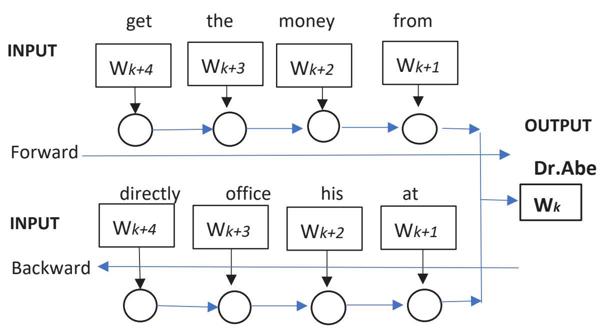

Fig. 5. Bi-directional LSTM–LR model

TABLE 1. PARAMETERS OF THE MODEL

Hidden layer	100
Embedding size	200
Window size	10
Batch size	200
Learning rate	0.001
Loss	Softmax function

TABLE II. Result of the experiment

	Simple LSTM	Bi-directional LSTM–LR
PPL	4.8	4.7
CW_PPL	56.3	37.3

natural language processing, PPL is usually used for evaluating the language model. PPL is defined as follows:

$$PPL = 2^{-\frac{1}{N}\sum_{i=1}^{N} log_2 p(w_i)} \quad (1)$$

In Eq. (1), p is the probability, and N is the total number of the words. PPL represents the number of prediction choices that are narrowed down to neural networks. The smaller the value, the better the prediction results.

D. Analysis of the Experiment Result

CW_PPL is the average PPL for the test data, which is the PPL of the confidential words, whereas PPL is the average for all the test data. The PPL scores are shown in Table Ⅱ.

Our experiment proved that our proposed model using neural networks was effective for predicting the target words. Nevertheless, the CW_PPL score was poor; therefore, the accuracy of predicting the confidential words needed to be improved. One reason was the possibility of paraphrasing words such as "plaintiff," "defendant," "doctor," and "teacher." These paraphrased words could be excluded from the choices based on the results of the calculated probability. We need to review the algorithm for preprocessing the input corpus before inputting the algorithm to the neural network because the difference in the scores between PPL and CW_PPL was too large.

IV. NEW MODEL TO IMPROVE ACCURACY

Our algorithm did not give good accuracy for predicting the confidential word; therefore, we investigated the algorithm of our model and reviewed it. In general, words have meanings and (POS) tags in the dictionary. We found almost all the confidential words had the POS tag of proper nouns. Therefore, if the POS tag is added to the neural network with the words, it may be possible to learn better and improve the accuracy. The most popular tagging tool for Japanese sentences is MeCab.

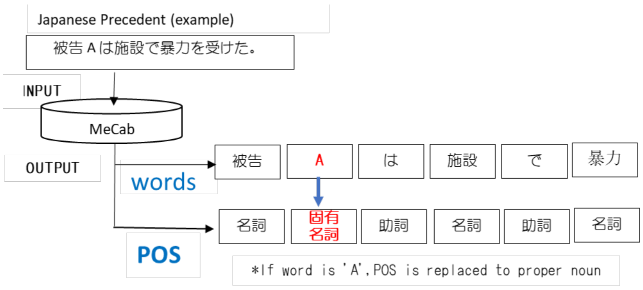

Fig. 6. POS tagging using MeCab

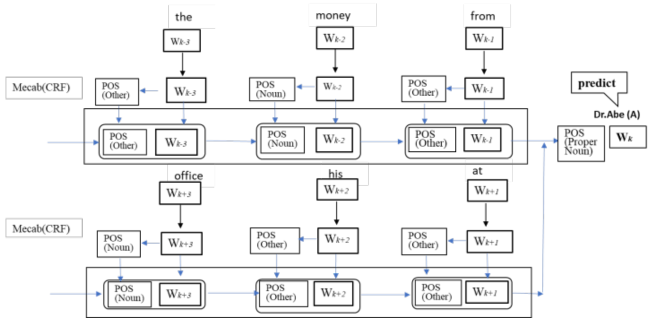

Fig. 7. Proposed model that combined the POS tag

A. MeCab as CRF

MeCab is the most powerful tool to extract the POS tag from the words in Japanese judicial precedents. It is a well-known Japanese morphological analyzer and is a kind of CRF. CRF is a successful named-entity extraction output technique used to label information, such as POS tagging. Japanese sentences have no spaces between words; therefore, MeCab inserts spaces between words and tags the words (using POS). If the word is "A," it is a confidential word. The POS corresponding to "A" is replaced by the proper noun described in Fig. 6.

B. Bi-Directional LSTM–LR Combined With the POS Tag

In our previous model, the corpus (words) were input into the neural network as done for natural language processing. To improve the CW_PPL score, we attempted to input the POS tag corresponding to the word extracted by MeCab (CRF) in the previous model (Bi-directional LSTM–LR). The outline of this proposed model is shown in Fig. 7, and the identification mechanism is shown in Fig. 8. Summary of the algorithm is described as bellows and detail is given in the appendix.

Input data

$$\boldsymbol{L} = (\mathrm{w_i})_{\mathrm{i}}^{\mathrm{bj}} \quad : w_1, w_2, \cdots w_{10} \quad \text{:word(backward)} \qquad (2)$$

$$\boldsymbol{L'} = (\mathrm{w_j})_{i}^{fj} : w_{-1}, w_{-2}, \cdots w_{-10} \quad \text{:word(forward)} \qquad (3)$$

$$\boldsymbol{P} = (p)_{i}^{bj} \quad : p_1, p_2, \cdots p_{10} \quad \text{:POS(backward)} \qquad (4)$$

$$\boldsymbol{P'} = (p_i)_{i}^{fj} \quad : p_{-1}, p_{-2}, \cdots p_{-10} \quad \text{:POS(forward)} \qquad (5)$$

$$\text{Output} \quad \boldsymbol{O_i} = \text{LSTM}\,(\boldsymbol{L} + \boldsymbol{L'} + \boldsymbol{P} + \boldsymbol{P'}) \quad \textbf{\textit{:output}} \qquad (6)$$

MeCab is different from conventional natural language processing technology. Each W*iki* word describes a word, and every other word or every noun is the associated POS tag of the W*ki* word. When the Japanese precedents (corpus) is input into MeCab, MeCab separates the words by inserting spaces and tags them as a POS. If the confidential word ("A") appears in the precedents, then "proper noun" is tagged to the confidential word. Next, we assign a unique index to the POS tag and make a part dictionary by merging them into the input data (word) for the new neural network using an embedding vector.

C. Experiment of the Proposed Model Combined With the POS Tag

We experimented using the proposed model combined with the CRF. We used 10,000 judicial precedents for the training data and 5,000 judicial precedents for the test data from 2013 to 2017. The data was the same as the previous one. However, the number of training data sets was smaller because the data became approximately two times larger than the previous data by adding the POS tag. The various parameters were the same as that in Table Ⅰ. We used the same evaluation method as that in our previous experiment.

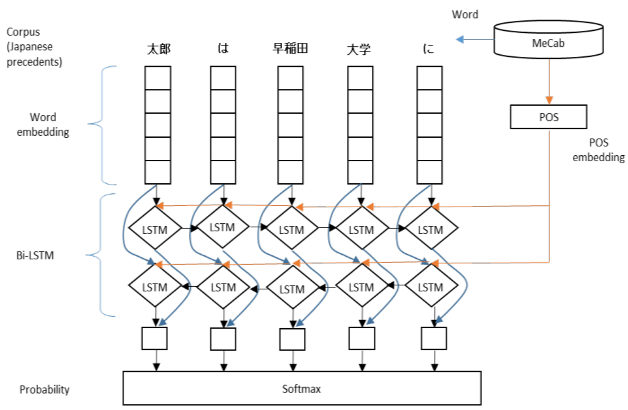

Fig.8. Identification mechanism

The results of this experiment as compared with the results of the Bi-directional LSTM–LR mode using the same input corpus are shown in Table Ⅲ.

The PPL score showed a 23% improvement in accuracy over the previous model (Bi-directional LSTM–LR), and the CW_PPL score also showed a 30% improvement in accuracy.

Therefore, we found that the Bi-directional LSTM–LR model, which combined the words and POS tag, was very effective in predicting the confidential words. However, the CW_PPL score needed further improvement.

D. Improving the Preprocessing Algorithm

Before learning the input corpus by using neural networks, it is necessary to reprocess the corpus.

TABLE Ⅲ. RESULT OF THE SECOND EXPERIMENT

	Proposed model	Bi-directional LSTM-LR
PPL	4.1	5.2
CW_PPL	28.6	40.7

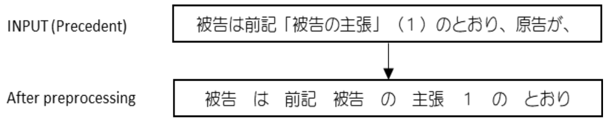

Fig.9. Example of the preprocessing of Japanese precedents

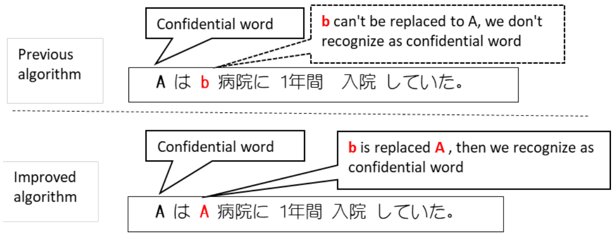

Fig. 10. Example of the improved algorithm

For example, many punctuation marks used for separating words and phrases, such as「」and（）, appear often in Japanese judicial precedents. These marks are only noise for learning; therefore, we omitted them (Fig. 9).

However, punctuation mark "。" was not omitted to prevent the flow of the context. The preprocessing was also done in the first experiment.

In Japanese precedents, confidential words are replaced by not only half-width uppercase letters but also by full-width uppercase and lowercase letters. In the previous algorithm, only when a single half-width capital letter of the alphabet appeared in the precedent, we replaced it with the half-width uppercase letter "A." Therefore, when the lowercase letter "b" appeared in the precedent, it could not replace "A"; therefore, we did not recognize "b" as a confidential word (see Fig. 10).

Therefore, we improved this algorithm by stating that if both single half-width and full-width letters appeared in the precedent, we replaced it by a half-width uppercase capital letter "A" as the confidential word.

E. Experiment Result After Using Improved Algorithm

The results of the experiment after using the improved algorithm are shown in Table Ⅳ.

TABLE Ⅳ. RESULT OF THE EXPERIMENT AFTER USING THE IMPROVED ALGORITHM

	New proposed model after using the improved algorithm	Previous model (Bi-directional LSTM–LR)
PPL	4.1	5.2
CW_PPL	5.1	40.7

CW_PPL showed that after using the improved algorithm, the proposed model accuracy decreased by 35.6 as compared with the previous model (Bi-directional model). We found that the CW_PPL score had improved 88% in accuracy as compared with the previous model.

As a result, we confirmed that our proposed model (Bi-directional LSTM–LR combined CRF) had high accuracy for predicting confidential words.

We got excellent predicting ability with our proposed model; therefore, we needed to confirm whether the model would be practical or not; this is our next step.

V. EVALUATION OF THE PROPOSED MODEL FOR APPLICATION

In an actual legal record, it is essential to evaluate whether the confidential word can be correctly recognized or whether the non-confidential word has also been recognized as a confidential word.

A. Training the Proposed Model Using Anonymized Precedents

We evaluated how our proposed model affects some types of anonymized precedents. We used the following parameters to examine the accuracy.

$$\text{Recall} = \frac{TP}{TP+FN} \tag{7}$$

TABLE V. RESULTS OF THE EXPERIMENT IN VARIOUS TYPES OF ANONYMIZED PRECEDENTS

Item	Total words	Confidential word			Normal word			**Recall**	**Precision**	**F1**
		Appear (TP+FN)	No-hit (FN)	Hit (TP)	Appear (TN)	Hit (FP)	No-hit			
Rental contact	7800	52	29	23	7748	623	7125	44%	4%	7%
Land contract	9600	1588	751	837	8012	806	7206	53%	51%	52%
Traffic accident	2600	67	10	57	2533	280	2253	85%	17%	28%
Traffic accident	8400	100	35	65	8300	831	7469	65%	7%	13%
Rental contract	4000	76	11	65	3924	250	3674	86%	21%	33%
Injury case	12800	543	169	374	12257	1624	10633	**69%**	19%	29%
Land contract	1800	34	26	8	1766	90	1676	24%	8%	12%
Investment receivables	17600	777	177	600	16823	1960	14863	**77%**	23%	36%
Employment contract	11600	152	31	121	11448	1045	10403	**80%**	10%	18%
Information disclosure	1600	30	7	23	1570	164	1406	77%	12%	21%
Stock claims	14200	529	82	447	13671	1439	12232	**84%**	24%	37%
Moving trouble	5200	79	58	21	5121	715	4406	27%	3%	5%
Building surrender	1600	4	0	4	1596	88	1508	100%	4%	8%
Facility admission fee	5800	2	0	2	5798	360	5438	100%	1%	1%
Contract receivables	3800	31	15	16	3769	328	3441	52%	5%	9%
Road maintenance guarantee	8600	34	8	26	8566	516	8050	76%	5%	9%

$$\text{Precision} = \frac{TP}{TP+FP} \quad (8)$$

$$\text{F1} = \frac{2Recall \times Precision}{Recall+Precision} \quad (9)$$

TP: True Positive (i.e., when the actual word and predicted word are positive)

TN is a true negative (i.e., when the actual word and the predicted word are negative). FN is a false negative (i.e., when the actual word is positive, but the predicted word is negative).

FP is a false positive (i.e., when the actual word is negative, but the predicted word is positive). The actual positive is "TP + FN," and the total predicted positive is "TP + FP." "Recall" is the index that indicates the fraction that was correctly predicted among all the words that were positive. "Precision" is the index that shows the fraction of positive words among all the words that were predicted to be positive. F1 is the index that shows the balance of recall and precision. The results of the experiment in various types of anonymized precedents are shown in Table V.

If the CW_PPL of the confidential word ("A") was lower than 60 (the threshold), we defined it as the correct word (TP). If not, it would not be recognized (FN). As a result, the recall score showed good values for some types of precedents. In particular, when similar phrases appeared multiple times in some precedents, our proposed model could recognize the confidential word well. Also, if we had more total words in one precedent, the recall score was good ranging from 69% to 84%.

The confidential words were sometimes replaced with non-English letters, such as the Greek letters γ or β; then, our proposed model could not predict them as confidential words. However, if they are replaced as "A" during preprocessing, the recall score would be good. Fig. 11 shows how our proposed model anonymized the confidential word for the original non-anonymized precedents.

All the experiments described so far used test data that included the confidential words converted to "A." Our final goal is to automatically replace the anonymous words in the actual precedents to the capital letter "A" by using our proposed model. Therefore, we used the test data as the original precedent in which the confidential words were not converted to "A"; we experimented with this model to examine whether the model was practical or not.

B. *Experiment with Proposed Model Using Non-Anonymized Precedents*

In this case, we defined that if the CW_PPL score was less than 100 (the threshold), our proposed model was correctly predicted as the confidential word. We experimented with our proposed model in some actual non-anonymized precedents, as shown in Table VI.

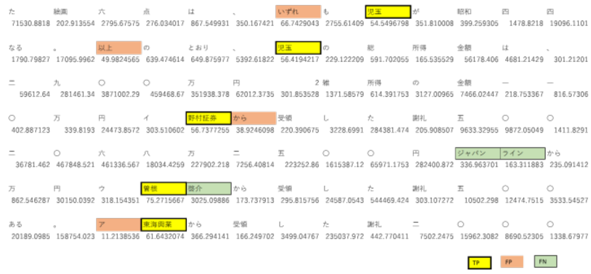

Fig. 11. Example of practical use in the Japanese precedent

In the case of the "Lockheed case," the recall was 62%, and the precision was 12%. One reason why the recall score was low was because our proposed model could not predict the name in an address correctly as a confidential word, especially because the addresses in the precedents were often very long. Another reason was that MeCab sometimes could not extract a person's name correctly when the full name appeared. In the case of "Traffic accidents," the recall score was 76%, which showed that our model was effective for practical use. In this case, if a person's name appeared in the precedent, our model could predict them correctly.

From these results, we can conclude that our model is not practical enough at present. However, if many confidential words appeared in the precedents, our proposed model was able to predict the confidential words correctly because the same phrases appeared in the Japanese precedents. Furthermore, if MeCab could accurately extract the personal name and another proper noun, our proposed model could prevent the false detection of confidential words that were not true. For the instances when our model could not predict long address that included numbers, such as 103-123–24-55, it will be effective to replace the long numbers with the letter "A" as the confidential word during preprocessing. Then, it would be possible to increase the possibility of practical use.

VI. Conclusion

Privacy is one of the most critical concerns in communication. If we can automatically hide confidential words, the communication becomes safe. Therefore, we developed a technology to predict confidential words that would use target data from Japanese judicial precedents.

However, it is not easy to completely anonymize confidential words such as personal names and locations. NER is probably the first step for information extraction; it seeks to locate and

TABLE VI. Result of the experiment in actual precedents

Item	Total word	Confidential word			Normal word			Recall	Precision	F1
		Appear (TP+FN)	No-hit (FN)	Hit (TP)	Appear (TN)	Hit (FP)	No-hit			
Lockheed case	10000	286	109	177	9714	1297	8417	**62%**	**12%**	**20%**
Traffic accident	6000	189	46	143	5811	547	5264	**76%**	**21%**	**33%**

classify the named entities in Japanese precedents into predefined categories, such as the names of persons and locations. Nevertheless, the problem is that the cost of manually making such a corpus is very high.

One technique to protect privacy is to find confidential words in a file or on a website and convert them into meaningless words. Researchers have used the NER technique to extract the anonymous word. However, they need to prepare a proper noun dictionary that is updated to the latest issue; this is an expensive affair.

However, a neural network is useful for predicting the confidential words, and it is intelligent enough to anonymize confidential words automatically. Using Japanese judicial precedents, we have already proposed a recognition technique for confidential words using a neural network.

First, we proposed the Bi-directional LSTM–LR model that was effective for detecting the target words in long sequential words. However, the accuracy for detecting the confidential words (CW_PPL) in the precedents was poor [19]. To improve the CW_PPL score, we attempted to add additional information to the neural network called the POS tag. Two types of information (words and POS tags) needed to be entered into the neural network for learning. Then, we proposed a new model in which the Bi-directional LSTM–LR model was combined with the POS tag extracted by MeCab and a Japanese morphological analyzer.

Further, we reviewed the algorithm of preprocessing. We found that many confidential words replaced by a wide-width letter had been missed in the previous algorithm. Therefore, we improved upon the algorithm and experimented by using the new model. We found that the CW_PPL score had improved substantially. We obtained an accuracy improvement of 88% for detecting the confidential word (CW_PPL) and a 21% improvement for detecting the target word (PPL) as compared with the previously proposed model (Bi-directional LSTM-LR). Then, we evaluated our proposed model with the evaluation index, such as "recall" or "precision," to determine whether our proposed model could have practical applications.

As a result, we confirmed that our proposed model could predict the confidential word for practical applications in some precedents, and the recall score improved from 69% to 84%. However, the overall results were not satisfactory. We experimented with the non-anonymized precedents to investigate the model for practical use. Our model is not good enough for practical use at present. If this model works well by making improvements (i.e., improvements in preprocessing and upgrading the MeCab), we will establish an automatic detector tool for confidential words in the future. Our proposed model will be a low-cost tool for detecting confidential words; therefore, it will be a valuable contribution in cyber courts.

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Appendix A

The algorithm of the Bi-directional LSTM combined POS tag

Input data

Input corpus : Japanese precedents

Preprocessing

Input data

$w_1^j = w_1 w_2, \cdots\cdots w_j$ (no space)

*data cleaning # deleate punctuation mark and unnecessary words

*insert space between word (w_1)and word (w_2)

*extract the POS tag of the word

Output data

$w_1^j = w_1, w_2, \cdots\cdots, w_j$ (with space) : *word*

$p_1^j = p_1, p_2, \cdots\cdots, p_j$: *POS*

*p_1 is a POS corresponding to w_1

Main process

Input data

/parameter

hidden_layer_size = 100
batch_size = 200
chunk_size = 10
epochs = 100
learning_rate = 0.001
forget_bias = 1.0

/Word

Backword data $(w_i)_i^{bj}$: $w_1, w_2, \cdots w_{10}$

Forword data $(w_i)_i^{fj}$: $w_{-1}, w_{-2}, \cdots w_{-10}$

/POS

Backword POS data $(p)_i^{bj}$: $p_1, p_2, \cdots p_{10}$

Forword POS data $(p_i)_i^{fj}$: $p_{-1}, p_{-2}, \cdots p_{-10}$

#chunk size (window size) =10

Step1→ Initialize LSTM

Step2→ get the embedding vector for input data
for j in range (chunk_size)

$\boldsymbol{X_b} = (w_b)_{i=1}^j$: *Word(backword)*

$\boldsymbol{X_f} = (w_f)_{i=1}^j$: *Word(forword)*

$\boldsymbol{Y_b} = (p_b)_{i=1}^j$: *POS(backword)*

$\boldsymbol{Y} = (p_f)_{i=1}^j$: *POS(forword)*

Step3→ Ready lstm cell (tensorflow)

bw_ lstm = BasicLSTMCell ($\boldsymbol{X_b}$) :word (backword)
fw_ lstm = BasicLSTMCell ($\boldsymbol{X_f}$) :word(forword)
p_bw_ lstm = BasicLSTMCell ($\boldsymbol{Y_b}$) :POS (backword)
p_fw_ lstm = BasicLSTMCell ($\boldsymbol{Y_f}$) :POS(forword)

:backword_outputs $h_t^{(b)} = Wh_t + Wh_{t+1} + b$

:forword_outputs $h_t^{(f)} = Wh_t + Wh_{t-1} + b$

:POS_backword_outputs $s_t^{(b)} = Ws_t + Ws_{t+1} + b$

:POS forword outputs $s_t^{(f)} = Ws_t + Ws_{t-1} + b$

*W: weight, b:bias

Output

#the last output is the model's output

outputs=concat(bw_outputs,af_outputs,H_bw_outputs,H_fw_outputs)

outputs $\boldsymbol{Y} = (h_t^{(b)} + h_t^{(f)} + s_t^{(b)} + s_t^{(f)})$

output= Y [outputs] $\times W + b$:loss

$Y = (y_i)_i^j = (y_1, y_2, \cdots\cdots\cdots, y_j)$: $word$

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Answer to the reviewer's comments

1. Please make sure that for all those articles that are cited, and has an existing DOI (at CrossCiteRef), the DOI is actually referenced in your paper.
→ OK! We added the DOI in reference paper (DOI included)

2.1 The main contribution must be specified.
→ We added our contribution in abstract

2.2 The motivation of the approach based on neural networks and the treated architectures must also be specified in the context of other similar modeling approaches. Authors' strong past papers in the field ought to be mentioned in this discussion.
→ we described in conclusion as additional sentence.

2.3 Discussion of related work on other nonlinear modeling approaches should be extended with the following papers, which recently came into my attention because they proved to be successful in various applications:
→ Thank you for presenting a reference paper. We think so that these technique is excellent, however, the cost of our proposed model is not high compared to these technique.

2.4 The paper contains some grammar problems. Their correction is needed
→ Thank you for your check. We revised our paper.

2.5 Please organize the modeling approach as an identification algorithm with clear steps. What about the convergence of the identification algorithm? Please discuss.
→ We described the identification algorithm at end of the paper body.

2.6 How is the network trained? Please present details on that in relation with the network architecture and the comment 5).
→ This is also described in the identification algorithm.

2.7 It is also not clear how the testing and validation are done.
→ This is also described in the identification algorithm.

2.8 The very good accuracy might indicate overfitting. Please comment.
→ We input the various kinds of precedents randomly to prevent overfitting. However, we think it is necessary to continuing more actual precedents. If overfitting would occur, we adopt the dropout layer
.

2.9 The validation would be better supported if you would add a link to the programs and datasets. In other words, you could save the programs and datasets in a webpage/repository and next cite the link to that webpage or repository in the paper body. This will ensure a sound validation, which is important in neural network and modeling approaches. This will also solve a part of the above and below comments
→ OK！I add the program in repository in the paper body.

2.10 This is an application paper. It is not clear how the theory from the previous sections is applied in Section V. More details are necessary. The comment 9) helps.
→ OK！

2.11 Transitions from section to section should be smoother. The comments 3) and 9) help.
→ OK！I add the program in repository in the paper body.

２.1２ The number of references is rather low for a strong journal paper. The comment 3) helps.
→ Thank you for your suggestion.

2.1３ Do you have random parameters in the algorithms? If yes, which are their effects?
→ Yes. We experimented changing the various parameter. However, we had get no effective results.

2.1４ Do you have comparisons with other modeling approaches including neural network-based ones? Please discuss
→ No, there are some paper regarding with the detecting the confidential word using named extraction method (using dictionary) but I couldn't find paper using the neural network only for detecting the confidential word.

Examination of the eye-hand coordination related to computer mouse movement

Tibor Ujbányi, Attila Kővári, Gergely Sziládi and József Katona

Abstract—**Eye-hand coordination means the ability to combine seeing and hand movement. Eye-hand coordination is a complex process consisting of a series of conscious actions. The fine motor skills of the hand were not born with us but learned. The development of eye-hand coordination has begun in infancy through various ball games, construction games and puzzle games. Co-ordinated work of eye and hand movement is the basis for many activities. The proper functioning of eye-hand coordination is necessary for many everyday activities such as writing, reading or driving. The joint work of the eyes and hands is vital for certain forms of movement (ball-catching, kicking). The eye plays an essential role in regulating fine movements. In this paper a general eye-hand coordination task is examined in relation to mouse cursor movement on computer screen. An eye-hand tracking system was used to observe the gaze and hand path during the mouse cursor movement and the acquired data were analyzed by statistical t-test.**

Index Terms—**statistical evaluation, paired t-test, eye-hand coordination, eye-tracking, hand tracking.**

I. Introduction

EYE-HAND coordination is the ability to perform activities that require the simultaneous use of our hands and eyes as an activity that uses the information (visual-spatial perception) perceived by our eyes to control our hands. These activities are prerequisites for learning all kinds of activities, including writing and reading. [1]

The eye is used to transmit visual information. The hand is used to perform a specific task based on visual information received from the eye. Eye-hand coordination consists of a complex process, the decay of reflexes, and the practice of conscious action. [2] In our daily life, we use eye-hand coordination almost continuously. A skill that is essential in everyday life. Eye-hand coordination can be associated with motoric skills. [3]

Motoric skills are conditions for carrying out a motion action that can be traced back to the genetically determined components and components by learning. There are three types of motoric skills [4]:

- conditioning skills;
- coordination skills;
- joint mobility.

Motion coordination is the alignment of the motion phases and sequence of the partial movements. There are three types of basic motion coordination skills [5]:

- motion control skills;
- motion adaptive and motion adjuster skills;
- ability to learn the motion.

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The three basic skills can be further subdivided into abilities that result in motion order based on information that facilitates motion coordination. For example we use eye-hand coordination when writing. As we write the lines, our eyes send visual information to the brain about the position of the hand. With this information, the brain prepares instructions on how the hand should move in order to create appropriate lines of shapes, resulting in letters. There is a similar order when typing on a keyboard. The type of movement is different, but we still use visual information to tell the brain how to control our hands or if we need to fix an error [6]. Besides, we use eye-hand coordination while performing active activities (sports) that require motoric coordination.

We use eye-hand coordination during work, for example working on a material. We follow the shape of the workpiece with our eyes and we constantly transform it with our hands. It happens several times a day to open or close a door. Placing the key in the door lock and turning it in the right direction also requires eye-hand coordination. One of the most common examples is driving. We follow the road with our eyes while cornering and turn the steering wheel with our hands. [7]

The main aim of this paper to examine a general eye-hand coordination task in relation to mouse cursor movement on computer screen. The results can be used to compare the efficiency of computer mouse and gesture-based cursor position control by the perspective of eye-hand coordination. An eye-hand tracking system was used to observe the gaze and hand path during the mouse cursor movement and the acquired data were analyzed by statistical t-test.

II. Methods the detect of eye motion and hand tracking

Many different techniques have been used in the past to track eye movement. Of these, there are essentially three techniques that we can find in researches. These techniques are:

- Electro-oculography (EOG),
- Video-oculography (VOG).
- Video-based infrared (IR) pupil-corneal reflection (PCR)

Electro-oculography (EOG) devices use electrodes placed around the eye to detect eye motion. The eye motion can be analyzed by the change of the electrode potentials. [8]

Video-oculography (VOG) is a video-based method of measuring the movements of eyes using a head-mounted mask that contains small cameras. The cameras send images to the computer for image processing. [9]

Video-based tracking contains a video camera that records the movements of the eyes and a computer that processes and analyses the gaze data like The Eye Tribe tracker (see below).

In order for a computer to perceive body language, it must follow the movement with a physical device. Many of the motion tracking systems have been developed over the years. Among the earliest was the DataGlove in 1980s. DataGlove is a multi-layered glove, equipped with multiple flex sensors, ultrasonic sensors to determine hand position and orientation. The metal strips in the sensor are measured for resistance to bending. One of the most popular gesture controllers among the new generation devices is the Kinect (Microsoft, 2016) based system which is developed for the latest generation of Xbox 360, Xbox One gaming consoles and desktop computers. The tool is now being developed by Microsoft. Its predecessor was the Xbox Live Vision system. The Leap Motion device uses cameras to detect hand and fingers position and there are some other open-source solutions using web cameras (see details under *Test environment for analyzing eye and hand tracking data* section). The Leap Motion Controller promises submillimeter accurate detection. In their article Weichert et al. the main focus of attention was on the evaluation of the accuracy and repeatability. It can be summarized that it was not possible to achieve the theoretical accuracy of 0.01 mm under real conditions but a high precision (an overall average accuracy of 0.7mm) with regard to gesture-based user interfaces. Comparable controllers in the same price range, e.g., the Microsoft Kinect, were not able to achieve this accuracy. [10]

Some researches were born in the past related to eye-hand coordination. Previous related researches have examined the relationship between eye-hand coordination in several aspects. Twardon et al used eye-hand coordination for an intuitive remote manipulation system that allows even non-expert users to operate a robot safely without prior experience. [11] Carrasco et al. in their article propose use of a visual sensor which allows the simultaneous analysis of hand and eye motions in order to recognize the reach-to-grasp movement to predict the grasping gesture. [12] Chiang et al in their study explore health benefits in somatosensory video games in case of older adults with wheelchairs based eye-hand coordination. [13] Renata et al has been shown the correlation between eye movement and reaction time under mental fatigue influence. [14] Johns et al examined the reaction time of the hand is influenced by the appearance of a visual signal. [15] Martin et al examined the features of head, eye and hand movement when driving. [16] Fischer et al. discovered that hand movement will be initiated when both eye and hand movement mental preparations are completed. [17] Dean et al. confirm the suggestion that the correlation between visual and reach reaction time exists. [18]

In our article, we conducted a comparative study between traditional cursor movement and gesture-based control while observing eye movement data. Based on our previous experience, when observing the mouse cursor movement with the help of Leap Motion, the test subject is more attentive and more closely observing the current position of the cursor than with the mouse cursor movement. This is probably due to the fact that moving the mouse cursor is a routine operation and therefore requires less continuous tracking of the cursor position during movement. We want to examine whether this assumption is true, whether the gaze is constantly following the mouse cursor movement, and whether it is constantly focusing on the mouse cursor movement using Leap Motion.

Two gaze mouse parameters can be examined with O.G.A.M.A. The first reports the number of fixations until the first mouse click (Gaze Mouse Path) and the second calculates the average distance between gaze and mouse path in pixels (Average Gaze Mouse Path Distance). The two related parameters were analyzed.

The purpose of the study is to examine the gaze mouse distance for two types of mouse cursor movement to provide a statistically detectable difference between the two control methods based on within-subjects design. For the correct application of the t-test, a number of conditions must be met. There should be no significant outliers. [19] The distribution of the differences in the dependent variable between the two related groups should be approximately normally distributed. We talk about the dependent t-test only requiring approximately normal data because it is quite "robust" to violations of normality, meaning that the assumption can be a little violated and still provide valid results. [20]

The eye movement sensor we use is located at the bottom of the screen. The position of both the screen and the eye movement sensor are fixed during the test and not move. We use a relatively large screen for better results (if the angle of the eye movement large across the screen, the relative error due to the angle of detection will be small). Touch screens are smaller and harder to fix. It is difficult to keep the screen-to-head distance required for testing, and the biggest difficulty is that in this case, when you touch the screen, the arm / hand can partially obscure the eye tracking image, so there will be insufficient data for evaluation. Therefore, touch screen testing was not included in the evaluation.

A. *Test environment for analyzing eye and hand tracking data*

The Eye Tribe portable eye tracker (Fig. 1.) was used to examine the gaze point of the test subjects. The tracker consists of two main components: a camera and a high-resolution infrared LED lamp. The camera tracks the user's eye movements and operates in 30 Hz and 60 Hz sample rate with an average accuracy of 0.5°. Its operational range varies between 45 and 75 cm. [21-22] The Eye Tribe Tracker, contrary to its cost-efficiency, can be well-used in psychological researches. [23]

Fig. 1. The Eye Tribe tracker
(source: https://i.ebayimg.com/images/g/YjwAAOSwNYFdGn1G/s-l300.jpg)

The Leap Motion controller (Fig. 2.) is a small USB device that supports hand and finger motions as input without touching. The device using two monochromatic IR cameras and three infrared LEDs, the tool observes a roughly hemispherical area, to a distance of about 1 meter. The cameras generate almost 200 frames per second of reflected data. It is an optical hand tracking module that captures the movement of users' hands and fingers so they can interact naturally with digital content. Small, fast, and accurate, the Leap Motion Controller can be used for productivity applications with Windows computers, integrated into enterprise grade hardware solutions or displays, or attached to virtual/augmented reality headsets for AR/VR/XR prototyping, research, and development. The controller is capable of tracking hands within a 3D interactive zone that extends up to 60cm (24") or more, extending from the device in a 120×150° field of view. [24] Leap Motion's software can discern 27 distinct hand elements, including bones and joints, and track them even when they are obscured by other parts of the hand. With a 120Hz refresh rate and low-latency software, the time between motion and photon falls beneath the human perception threshold. [24]

Fig. 2. The Leap Motion controller
(source:
https://upload.wikimedia.org/wikipedia/commons/thumb/d/df/Leap_Motion_Orion_Controller_Plugged.jpg/440px-Leap_Motion_Orion_Controller_Plugged.jpg)

To analyze gaze point and mouse pointer location data the O.G.A.M.A software was used. It can co-operate with several eye-tracking systems like The Eye Tribe. [25] It uses database-driven pre-processing and filtering of eye movements and mouse motion data. Data can be displayed and evaluated in several methods because the software contains 10 analyzer modules. [25]

Fig. 3. The test environment with Eye Tribe Tracker and Leap Motion Controller
(source: own edited)

The test environment is based on a laptop with a higher than average Intel Core i5 processor. The Eye Tribe Tracker and Leap Motion Controller was connected via USB 3.0 ports. The test environment can be seen in Fig. 3.

III. RESEARCH CONDITIONS

The goal of the research is to examine the differences between the point of gaze and the location of the mouse pointer when the mouse pointer is controlled by traditional computer mouse and Leap Motion-based hand position detection. The test was performed using OGAMA with two similar test slides that can be seen in Fig. 4.

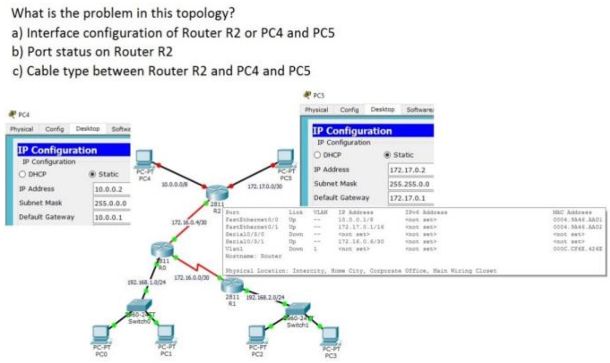

Fig. 4. Test slide
(source: own edited)

The test subject had to select one of the answers moving the mouse pointer over the selected answer (Fig. 5.). The average gaze mouse path distance was analyzed in the case of the mentioned two mouse pointer control method. The goal of the research is to examine, whether there were differences in the average gaze mouse path distance.

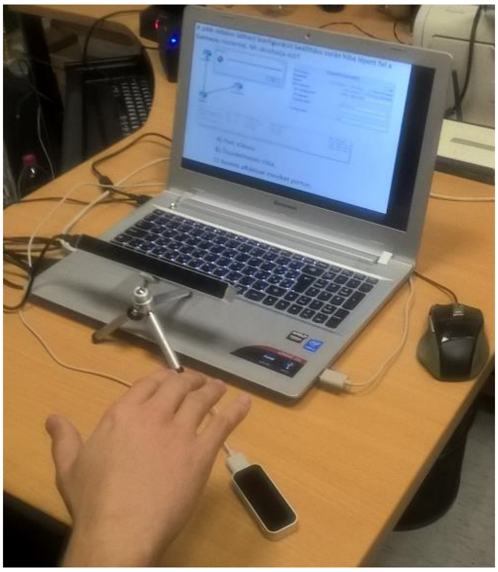

Fig. 5. Test subject while performing the task
(source: own edited)

A. Test subjects

32 graduated or school-leaver IT specialists participated in the research on voluntary basis. The participants of the study were primarily representing the younger generation, and there was also a foreign students among them. The gender distribution of the students: 28 males and 4 females. Their age all varied between 20 and 30. The examination was performed in the afternoon in a closed room without disturbances.

B. Methods

Before the beginning of the test, testing subjects had to sit in front of the computer performing eye tracking. Then, using the OGAMA software, a calibration was performed first. If the calibration was successful, the test was performed. During the test, the test slide appeared on the display, where the correct answer could be selected by moving the mouse cursor by different control methods: first with a traditional computer mouse, second with Leap Motion hand motion control on two slightly different test page. The two test pages consist of similar questions the two tests were slightly different. The study was within-subject type and all subjects performed the task in the same order - firstly using a mouse, secondly using Leap Motion. The post-processing of the gaze point and mouse cursor data were performed following the tests.

The gaze point and mouse cursor data were evaluated using statistical analysis based on within-subjects design. The statistical evaluation of data was performed using the SPSS 25 software package. In the case of normal data distribution, Shapiro-Wilk (S-W) normality test was performed. Statistical evaluation of average gaze mouse path distance was performed using Paired Samples t-test, p <= 0.05 value was considered as significant.

C. Main Results

Using the Paired t-test analysis the means between two measures on the same continuous variable is compared. The dependent variable, average gaze mouse path distance is measured at the interval level. The independent variable consists of two categorical "matched pairs" according to mouse pointer motion control by computer mouse and hand controller.

D. Outliers

First the outlier, data point that does not fit the general trend of your data, is detected by plotting the differences on a graph and visually inspecting the graph for outlier points. Descriptive and Boxplot is used to identify outliers as extreme values. In the analysis a step of 1.5 × Interquartile range (IQR) is used to detect extreme values. The Boxplot is shown in Fig. 6.

According to descriptives of differences the Mean=40.59, IQR=37.5, Maximum=87 and Minimum=5 and figure of Boxplot there is no outliers.

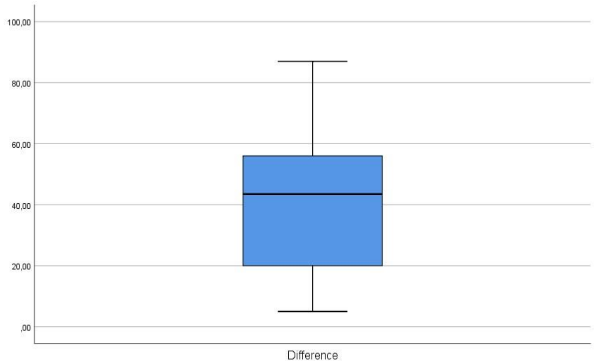

Fig. 6. Boxplot of differences between the two related groups on average gaze mouse path distance in pixels (source: own edited)

E. Normality

Differences of average gaze mouse path distances should be approximately normally distributed. The Paired Samples t-test requiring approximately normal data because it is quite "robust" to violations of normality.

The normality is analyzed using graphical Q-Q Plot and numerical Shapiro-Wilk test because this test is more appropriate for small sample sizes (less than 50 samples). The Q-Q plot is shown in Fig. 7.

A Shapiro-Wilk test indicated no significant violation of normality, W(32) = 0.963, p = 0.324.

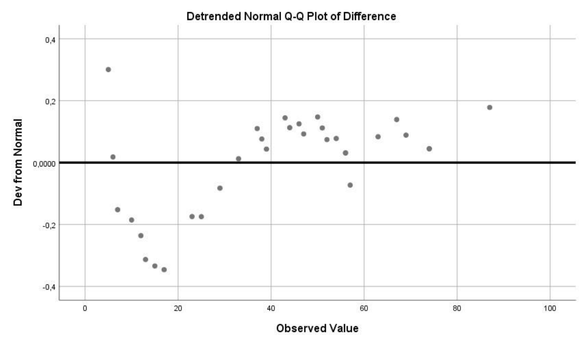

Fig. 7. Q-Q Plots of Difference on average gaze mouse path distance in pixels (source: own edited)

According to Shapiro-Wilk Tests the significance values are greater (0.324) than 0.05, so the data is normal. Also it can be seen in the Q-Q Plots, the data points are close enough to the diagonal line, not stray from the line too much, so the data is approximately normally distributed.

F. Paired Samples t-test

According to the results of previous tests it can be assessed for the differences there is no outlier and data is normal so the Paired t-test can be applied.

A paired-sample t-test indicated that the average gaze mouse path distance was significantly higher for the computer mouse (M = 407.875, SD = 23.46411) than for the gesture control (M = 367.2813, SD = 14.12898), $t(31) = 10.166$, $p < 0.001$.

It can be seen that the means of average gaze mouse path distance at computer mouse and hand control statistically significantly different because the significance value (2-tailed) is less than 0.05. Looking at the Statistics table, it can be seen that hand control had an average gaze mouse path distance.

IV. Conclusions

This study found that who controls the mouse pointer by traditional computer mouse has a statistically significantly greater average gaze mouse path distance (407.9 ± 23.46) compared to who use Leap Motion hand control (367.3 ± 14.12), $t(22) = 10.166$, $p<0.005$. The results are probably due to the fact that computer mouse movement is a routine practice, so it requires less attention than hand motion mouse cursor control. In the case of hand motion-based mouse cursor control, the proper movement is less routine, so the path of the mouse cursor should be more closely tracked by the eyes in order to the desired controlled movement can be realized.

The results obtained with the Test environment can provide more information to identify some coordination problems, so it can provide useful information, for example, in the analysis of certain human hand activities. Based on the monitoring the process of proper handheld and visual attention, the individual coordination difficulties can be identified and corrected.

If the development of the learning environment is analyzed in terms of changes in human behavior it can be seen that a new generation is developing whose members are devotees of online education. [26-28] As a result of the influence of the above described modern, day to day changing world, higher education has tried to adapt to the new generation attitude, habits, learning style of students and started to switch over to electronic-based educational systems labeled with the term e-learning. [29-30]

The results presented in this article can be used for CogInfoCom researches which focuses of the development of approaches and methodologies for the synthesis of new human ICT capabilities based on engineering principles. [31-32]

The results obtained can assist in the development of increasingly popular 3D virtual spaces in education. Students are eager to see these new technologies because ICT is already an integral part of their culture. [33] The desktop virtual realities can serve as an effective virtual workspace which helps to expand the human cognitive capabilities. [34] VR spaces not only provide an attractive visual experience, but also the formation of new memories psychology [35], eg. ads in VR evoke better memory [36]. The results could help developing VR spaces, 3D applications which allows for better learning and has more research and testing capabilities. [37-38] VR spaces (eg. Maxwhere) allows for information to be shared and understood more quickly than when using traditionally 2D interfaces. [39-40]

However in 3D virtual space managing, accessing, and performing certain functions can be sometimes difficult and require a higher level of user routine. The results obtained can help to overcome the limitations of control to select the optimal input device (gesture-based or conventional control) for a given situation or allow the combination of the two to take advantage of their advantages to increase the effect on higher education.

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Categorization and geovisualization of climate change strategies using an open-access WebGIS tool

Emőke Kiss, Marianna Zichar, István Fazekas, Gergő Karancsi, and Dániel Balla

Abstract—**The focus of our paper is to present the power of collaboration of databases in a web environment, where data contain or are related to different types of social geography spatial data. Implementing different data gained from the Climate Change Laws of the World, the United Nations Treaty Collection, the World Bank and The World Factbook, we ourselves developed the Climate Change Strategies of the world's countries (called CCS). Our purpose is to publish and demonstrate the spatial visualization and categorization of the climate change strategies (CCS) of the world's countries, and also highlight the power of geovisualization in terms of cognitive InfoCommunications, using open-access WebGIS tools and geoinformatics software. The evolved geographic database is able to provide information for users about the different types of climate change strategies of the world's countries in a visual way, but can also be extended by uploading new data.**

Index Terms—**adaptation, CogInfoCom, GIS, mitigation, webmap**

I. Introduction

The increasing demand for information in today's society has meant that the scientific community has published their results on the web during the last two decades, adapting to national and international requirements. Due to the rapid expansion of the Internet and the development of web-based or regional spatial information systems, access to spatial data on various themes and of varying quality has become significantly easier. As a result of the data harmonization of national and international databases, these robust systems are available for everyone, making accessible the knowledge stored in databases. In the age of the information society, the web is an unavoidable platform for efficient and fast data sharing, be it public or private. The tools provided by the web unwittingly offer us a development trajectory with regards to transmitting information. The possibilities offered by the world wide web increase the available data regarding geographical locations in two ways. Different applications provide various possibilities in many forms for publishing research results. Furthermore, the appearance of online map services has significantly altered the interpretation and visualization of geographical data on the web.

The concept of visualization of spatial data appeared as early as the 1950s in the cartography literature of the United States [1]; however, it received more attention only during the 1980s when researchers from different fields started to focus on the potential applications of scientific visualization [2-4]. As McCormick et al phrased it, the goal of scientific visualization is the graphical demonstration of the data collected by researchers, which helps the interpretation of the information coded in the data [5]. Naturally, visualization applied in the scientific field is not limited to spatial data - it is used in several other fields, as well (e.g. diagnostic imaging, 3D visualization of molecules, 3D printing etc.). Other concepts which are strongly related to scientific visualization are information visualization and geovisualization (data related to spatial location). Information visualization mostly revolves around interactive demonstration and thereby helps human cognition. However, scientific and information visualization is different from geovisualization since its goal is to develop demonstration methods for spatial data using maps [6]. MacEachren coined the word geovisualization by contracting the expression "geographic visualization"; its essence is a new approach to the use of maps. One of its features is that a map is not created for the public but for individual use and its primary purpose is to provide new insights from the data. It supposes an intensive interaction between people and maps in the sense that we can directly manipulate the spatial data to be mapped. If we are talking about visualization, we do not use maps alone, but in combination with other visual aids (charts, tables, photographs, 3D models etc.) [7]. In this sense visualization and communication are complementary events during map use. It is the responsibility of the map user to decide whether the visualization or the communication aspect should be emphasized [8].

The complexity of the term cognitive InfoCommunications (CogInfoCom) closely reflects its multidisciplinary characteristics. According to its first and still the most relevant definition, it "explores the link between the research areas of InfoCommunications and cognitive sciences, as well as the various engineering applications which have emerged as a synergic combination of these sciences" [9-10]. Since the birth of this special field it has already become known in many disciplines, as is proved by several scientific papers containing sections examining the cognitive aspects of the results, as well. Due to this increased interest, a comprehensive overview of cognitive InfoCommunications is already available in the form of a book, which also provides an outstanding theoretical foundation for the topic [11-29].

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Based on the above, our purpose is to publish and demonstrate the spatial visualization and classification of the climate change strategies (CCS) of the countries of the world, and also highlight the power of geovisualization in terms of cognitive infocommunication, using open-access webGIS tools and geoinformatics software.

II. Material and Methods

A. Background to the classification of CCS according to global databases

Climate change is caused by the excessive amount of anthropogenic greenhouse gases emitted into the atmosphere, leading to the constant increase of the global mean temperature [30]. The phenomenon first received attention from the scientific community at the end of the 1980s; today is the most urgent global problem [31-36]. Since then, the number of publications written in the subject has been constantly increasing, and global, national and subnational level databases have been created to foster the spread of information.

B. Climate Change Laws of the World

The Grantham Research Institute on Climate Change and the Environment (GRI) and the Columbia Law School Sabin Center on Climate Change Law (SCCC) together established the Climate Change Laws of the World online database which is a freely accessible resource for the policies and laws of countries related to climate change and environmental protection [37].

The GRI is a research institute founded in 2008 by the London School of Economics and Political Science. It aims to publish information internationally on climate change and environmental protection which are relevant to policies.

The goal of SCCC is to develop legal methods to combat climate change and to publish up-to-date information about climate change regulations.

C. United Nations Treaty Collection

The United Nations (UN) is an international organization working to solve problems concerning humanity (climate change, sustainable development, safety, peace, human rights, terrorism, food safety etc.). The UN also has several specialized organizations. For the development of our database, we used the information regarding the legally binding documents related to climate change (United Nations Framework Convention on Climate Change, Kyoto Protocol, Paris Agreement) [38].

D. World Bank

The World Bank Group is a global institution whose primary objective is to achieve the prosperity of developing countries and diminish poverty, as well as foster sustainable development. The organization publishes open-access and free statistical data in which searches can be performed by countries or indicators. In our database we used the Total population table from which we extracted the population data from 2017 [39].

E. The World Factbook

The World Factbook is an online, freely accessible up-to-date database compiled by the Central Intelligence Agency (CIA) providing information on the countries of the world. For our database, we used the Government type data from the Government database of the countries. [40].

F. Climate Change Strategies of the World countries (CCS)

For the compilation of our CCS database, we first selected the documents related to climate change from the Climate Change Laws of the World data by country. Then we grouped the documents according to the fields they applied to, thus creating the following types: 1. Adaptation, 2. Mitigation, 3. Complex (adaptation and mitigation goals in one document). After this grouping, we listed the types associated with the countries and established categories: 1. Adaptation, 2. Mitigation, 3. Complex, 4. Partial adaptation, and 5. Partial complex documents. In the case of partial documents, the contents of the documents apply to a certain subfield, such as agricultural adaptation, energy economics adaptation and mitigation etc. If, for a certain country, adaptation and mitigation documents could be found, we named the category adaptation + mitigation. In practice, 14 potential categories can be distinguished.

As a second step, we connected our database to the data of World Bank Population, then the United Nations Treaty Collection data, and finally the Factbook Government type, thereby creating our own database, named Climate Change Strategies of the World's Countries (CCS).

G. Data mining and geoprocessing

The implementation itself has three main stages (Fig. 1). We collected data from the Climate Change Laws of the World, the United Nations Treaty Collection, the World Bank and The World Factbook web platforms. The geodatabase containing the boundaries of countries was downloaded as a vector file (.shp) from EUROSTAT. The classification made on the basis of the previous section created arrays containing climate change strategy in fourteen classes. During the geoprocessing, we added related attributes data from the EUROSTAT database to the created Climate Change Strategies (CCS) database by spatial location. Following this, the next step was geoinformatics processing using QGIS 3.6 software. We used the QGIS QGIS2Web module for geovisualizing [41]. This plugin exports the classified vector data to a map appearing in web browser. The final step was to publish the web map and data with a query interface online.

When selecting the spatial database, the main consideration was to use freely available databases containing information which users can access easily, and which can be interpreted by visualization. In this way, users can acquire more information about various climate change strategies around the world.

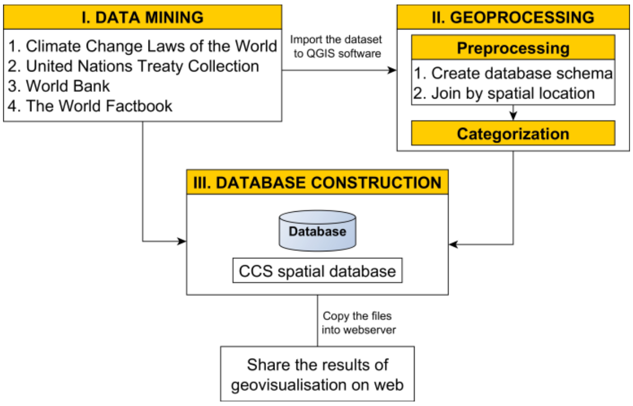

Fig. 1. Process of geovisualization.

III. RESULTS

We attached four databases to the CCS and made them accessible for free [42]. The classified database shows the climate change strategies of the world according to the CCS in a third-generation web map (Fig. 2). During the visualization of the climate change strategies of the world countries, we published two thematic maps (the climate change strategies categorization and the database containing the list of countries ratifying the Paris Agreement). As the default setting, the loaded web map shows the classified database which can be freely zoomed in and out, and the length of the specified routes can be calculated. In addition to navigating on the map, we can control the visibility of each layer. Furthermore, there is a *Search by location* function integrated into the interactive surface which we can use to navigate to the desired geographical location in the web map, thereby informing the user about the type of the climate change strategy. The visibility of the layers can also be controlled by use of the menu located in the right upper corner. Information about the CCS can be queried by clicking, and results showing the appropriate data from the attribute table are visible to users in a window and in the query interface, with descriptive statistics and charts.

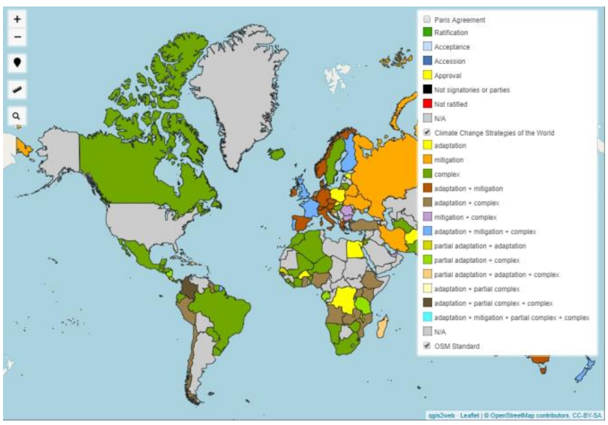

Fig. 2. Interactive webmap interface of CCS.

During our research we investigated the data of 200 countries. The national level climate change strategies tend to have three pillars: decreasing the degree of the emission of greenhouse gases (mitigation), adapting to the inevitable consequences (adaptation), and shaping public awareness to acquire the knowledge and to adopt the mentality and lifestyle necessary for achieving the above. In accordance with the above, the strategies can target mitigation or adaptation goals, or can be complex strategies in which all three areas are represented in a complementary fashion. In the case of partial strategies, the contents of the document apply only to a specific area (e.g. agricultural adaptation, energy economics adaptation and mitigation etc.).

Fig. 3 shows the distribution of documents by category. The most frequently occurring category is N/A (where no strategy can be found) with 63 countries - the proportion of countries in this category is 31.5%. Of these 63 countries 24 are located in Africa. This is followed by the complex category with 47 countries, representing 23.5% of all countries. The adaptation + complex category has 29 countries, or 14.5% of all countries. The most rarely occurring three categories are the adaptation + mitigation + partial complex + complex, the adaptation + partial complex, and the adaptation + partial complex + complex, which each include 1 country. Furthermore, there are 3 countries in each of the following categories: the partial adaptation + adaptation, and partial adaptation + adaptation + complex, and 5 countries each in the mitigation + complex, and partial adaptation + complex categories.

Regarding the proportion of the world's population in each category, 32.12% (2.4 billion) and 24.11% (1.8 billion) of the population of the investigated countries can be found in the complex category and the adaptation + mitigation + complex category, respectively. The category with the lowest population (26.9 million), representing 0.36% of the entire database, is the partial adaptation + adaptation category, while the mitigation + complex category has 0.61% of the population (45.6 million). It should be emphasized that 12.05% (i.e. 902 million people) of the world's population live in investigated countries which do not have any strategies at all (N/A). This highlights the fact that even though climate change is a serious global problem, in several countries appropriate methods have not been developed, neither for mitigation nor adaptation. According to prognoses, the impacts of climate change will continue to increase, therefore it is likely that the number of strategies will grow, and more and more countries will compile their own strategies.

The most recent milestone of global climate policy is the Paris Agreement, which was accepted at the Conference of the Parties (COP 21) to the United Nations Framework Convention on Climate Change (UNFCCC) and came into effect on November 04, 2016. The Paris Agreement is a legally binding, internationally harmonized framework to arrest climate change, but it does not include obligatory regulations. It aims to prevent the global mean temperature from exceeding the +2 °C considered to be an irreversible turning point relative to the pre-industrial era, and to achieve control even with a +1.5 °C increase [43]. Of the investigated countries, the Agreement was ratified by 114 countries in 2016 and further 48 countries in 2017. In 2018 and 2019 10 and 1 additional countries also signed the Agreement, respectively. Therefore, by 2019 173 of the investigated countries had ratified, and 13 countries had not ratified the Agreement (Fig. 4). Furthermore 6 countries had Acceptance, 3 countries had Approval, and 2 countries had Accession status. The Vatican is not a signatory nor a party to the UNFCCC and for 2 countries there were no data available (Antarctic, Western Sahara).

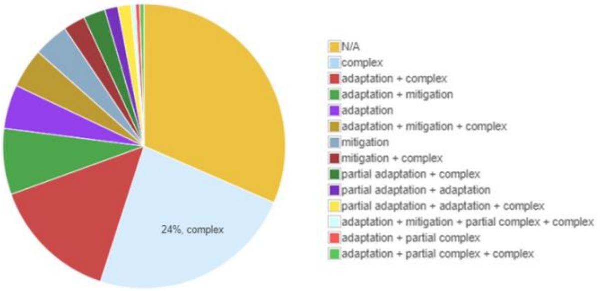

Fig. 3. Distribution of the CCS categories in percentages (%) based on the database.

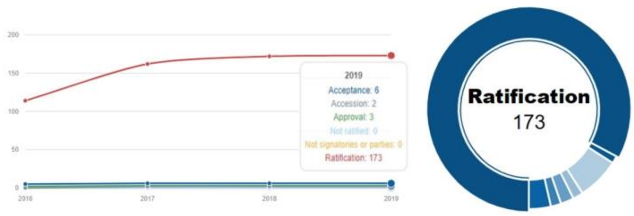

Fig. 4. Status types of the Paris Agreement.

IV. COGNITIVE ASPECTS OF THE STUDY

The goal of this paper is to study how cognitive processes co-evolve with interactively based infocommunication GIS tools, while the human brain is extended through these devices and also interacts with various artificial cognitive systems. In this context our paper focuses on the benefits of the geovisualization of spatial data in terms of cognitive infocommunications. These benefits are: easier identification of the relationship between climate change strategies and their location, easier capture of spatial pattern and types of CCS related documents, and also support for the cognitive perception of the digitally stored data.

V. CONCLUSION

In conclusion, we can state that use of free data makes it possible to publish geospatial information by applying the QGIS QGIS2Web module. Nevertheless, we have to pay attention to questions of whether the data are up to date and reliable when selecting which data to use. The global databases used are representative in themselves; however, by combining these databases and applying the categorization method we developed, we were able to assess climate change strategies and their spatial configuration from a new perspective.

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Multiple sclerosis Lesion Detection via Machine Learning Algorithm based on converting 3D to 2D MRI images

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***Abstract*— In the twenty first century, there have been various scientific discoveries which have helped in addressing some of the fundamental health issues. Specifically, the discovery of machines which are able to assess the internal conditions of individuals has been a significant boost in the medical field. This paper or case study is the continuation of a previous research which aimed to create artificial models using support vector machines (SVM) to classify MS and normal brain MRI images, analyze the effectiveness of these models and their potential to use them in Multiple Sclerosis (MS) diagnosis. In the previous study presented at the Cognitive InfoCommunication (CogInfoCom 2019) conference, we intend to show that 3D images can be converted into 2D and by considering machine learning techniques and SVM tools. The previous paper concluded that SVM is a potential method which can be involved during MS diagnosis, however, in order to confirm this statement more research and other potentially effective methods should be included in the research and need to be tested. First, this study continues the research of SVM used for classification and Cellular Learning Automata (CLA), then it expands the research to other method such as Artificial Neural Networks (ANN) and k-Nearest Neighbor (k-NN) and then compares the results of these.**

Keywords*— *Support Vector Machines (SVM); Cellular Learning Automata (CLA); MS lesions Detection; 3D Images; MRI Images; Simulated Brain Database (SBD); SVM Tools; Machine Learning Techniques;

I. INTRODUCTION

CogInfoCom, the research field based on the synergy between info communications and the cognitive sciences, is driven by the continuously entangled landscape in which Information and Communications Technology (ICT) and humans interact and generate intermingled cognitive capabilities [1], [2]. CogInfoCom capitalizes on this intermingled environment and promotes existing synergies creating a more effective combination of engineering and theoretical applications. A primary output of these synergies improved in a way that does not provide just sensory communications but also the way information is stored in the brain. [3], [4], [5], [6].

This study is the continuation of a previous research which aimed to create artificial models using support Vector machines (SVM) to classify MS and normal brain MRI images, analyze the effectiveness of these models and their potential to use them in MS diagnosis. The previous study concluded that SVM is a potential method which can be involved during MS diagnosis, however in order to confirm this statement more research and other potentially effective methods should be included in the research and need to be tested [7], [8].

Multiple sclerosis (MS) a chronic autoimmune neurological disease of the Central Nervous System (CNS) which appears with great variability in its clinical manifestation [9]. MS adjust the morphology and the structure of the brain and can lead to disability in young adults (Loizou et al., 2011) [10], [11], [12]. However, with early recognition and treatment, quality of life can be highly improved and the relapse of MS lesions in the CNS can be experienced (Miller, 2019) [13], [14].

Magnetic Resonance Imaging (MRI) can detect the multifocal lesions in the CNS mainly associated with MS. In the previous research a simulated database of 2D images was used, which were generated from simulated 3D dataset, acquired from Brainweb database [15], [16]. This dataset contains 76 grayscale images classified into four classes, samples with normal brain images, mild MS samples, moderate MS samples and severe MS samples [17], [18], [19].

First, this study continues the research of SVM used for classification and then it expands the research to other method such as artificial neural networks (ANN) and k-nearest neighbor (k-NN) and then compares the results of these [20], [21], [22].

II. DATASET

In the previous study the dataset used for model training and model testing was randomly generated, 70% (53 images) of the images used for training and 30% (23 images) for testing and the

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process was repeated 10 times. In this case since the intention is to try more methods and compare them, the same dataset should be used for each test [23], [24], [25]. To achieve this the indices of the test dataset for each run are saved into a file. For each run, this file is read, processed and the samples which indices are contained in the file are used to test the methods, while the samples which indices are not contained in the file are used to train the models [26].

III. RESULTS OF USING SVM

SVM is one of the most widely used machine learning method for binary pattern classification. SVM aims to construct a hyperplane set in an infinite dimensional space and find the hyperplane which represents the largest separation (margin) between the binary classes, so the goal is to find the maximum-margin hyperplane if it exists (Chao and Horng, 2015) [27], [28], [29], [30].

In the previous study two approaches were used since SVM is a binary classifier, however the current dataset can be divided into four mutually exclusive classes. In order to resolve this, in the previous study One-Against-One (1A1) and One-Against-All (1AA) techniques were introduced. The goal of 1AA technique to divide the N class dataset into N two-class cases, while 1A1 approach creates a model for each pair of classes so N(N-1)/2 models are built. In the previous study each method had an equal vote (Gidudu, Hulley & Marwala, 2007) [31], [32].

These approaches were reused for the new, fix dataset and to be able to compare the results of the methods the implementation was rerun to build models using the new trainsets and test-sets. For building the model MATLAB® fitcsvm function was used with linear kernel function and with standardized predictor data (Table I.).

The average accuracy of the 1AA model is slightly worse compared to the previous model, however the 1A1 model produced a slightly better result. For the 2AllResult (the accuracy of the 1AA models), the previous average accuracy of the models was 0.77826087 while for 2OneResult (the accuracy of the 1A1 models) models was 0.765217391. so this run, 2OneResult has a slightly better average result and so far, it produced the best results in this run. Another interesting fact that in these runs no sample has been assigned to the 'more_results' flag, so in this case with equal votes for each method resulted in a deterministic result, however the number of no results in the case of 1AA method has a significant grow. In the previous study a rule for a voting system could be determined, which could have been tested in this study. This was not explained in the previous study, but the system would have been the following:

- 1AA method is used for the primary decision.
- if 1AA resulted in more results, the more severe result should be used.
- if 1AA resulted in no results, the 1A1 result should be used.
- if 1A1 has more results, the more severe should be used.

This rule should be rejected, because of the 1A1 has produced a slightly better result compared to the 1AA method and because no sample got more results in this case, so using such a technique wouldn't improve the overall results. For SVM, a different

TABLE I. SVM RESULTS USING LINEAR KERNEL FUNCTION

ID	*2All Result*	*2One Result*	*2AllMore Result*	*2OneMore Result*	*2AllNo Result*	*2OneNo Result*	*Differences*	*ST. DEV*
1	*0.739130435*	*0.652173913*	*0*	*0*	*6*	*0*	*0.391304*	*0.061488*
2	*0.739130435*	*0.782608696*	*0*	*0*	*6*	*0*	*0.26087*	*0.030744*
3	*0.695652174*	*0.739130435*	*0*	*0*	*7*	*0*	*0.304348*	*0.030744*
4	*0.826086957*	*0.826086957*	*0*	*0*	*4*	*0*	*0.173913*	*0*
5	*0.782608696*	*0.782608696*	*0*	*0*	*5*	*0*	*0.26087*	*0*
6	*0.739130435*	*0.782608696*	*0*	*0*	*6*	*0*	*0.26087*	*0.030744*
7	*0.739130435*	*0.739130435*	*0*	*0*	*6*	*0*	*0.26087*	*0*
8	*0.695652174*	*0.75*	*0*	*0*	*7*	*0*	*0.304348*	*0.03843*
9	*0.782608696*	*0.826086957*	*0*	*0*	*5*	*0*	*0.217391*	*0.030744*
10	*0.695652174*	*0.782608696*	*0*	*0*	*7*	*0*	*0.304348*	*0.061488*
AVG	***0.743478261***	***0.766304348***	***0***	***0***	***5.9***	***0***	***0.273913***	***0.01614***

TABLE II. SVM RESULTS USING RBF KERNEL FUNCTION

ID	*2All Result*	*2One Result*	*2AllMore Result*	*2OneMore Result*	*2AllNo Result*	*2OneNo Result*	*Differences*	*ST. DEV*
1	*0.739130435*	*0.782608696*	*0*	*0*	*6*	*0*	*0.260869565*	*0.030744*
2	*0.739130435*	*0.782608696*	*0*	*0*	*6*	*0*	*0.260869565*	*0.030744*
3	*0.695652174*	*0.739130435*	*0*	*0*	*7*	*0*	*0.304347826*	*0.030744*
4	*0.826086957*	*0.826086957*	*0*	*0*	*4*	*0*	*0.173913043*	*0*
5	*0.782608696*	*0.826086957*	*0*	*0*	*5*	*0*	*0.217391304*	*0.030744*
6	*0.739130435*	*0.739130435*	*0*	*0*	*6*	*0*	*0.260869565*	*0*
7	*0.739130435*	*0.739130435*	*0*	*0*	*6*	*0*	*0.260869565*	*0*
8	*0.695652174*	*0.782608696*	*0*	*0*	*7*	*0*	*0.304347826*	*0.061488*
9	*0.782608696*	*0.826086957*	*0*	*0*	*5*	*0*	*0.217391304*	*0.030744*
10	*0.695652174*	*0.739130435*	*0*	*0*	*7*	*0*	*0.304347826*	*0.030744*
AVG	***0.743478261***	***0.778260870***	***0***	***0***	***5.9***	***0***	***0.256521739***	*0.024595*

kernel function can be tested to examine the method efficiency [33]. This kernel function is the radial basis function (rbf) and the result can be seen in (Table II).

For the 1AA method the rbf kernel function produced exactly the same results compared to the linear kernel function, however in the case of 1A1 the results are slightly better for these tests. These runs also did not produce more results for any of the elements of the datasets.

IV. RESULTS USING NEURAL NETWORKS

A neural network (NN) is built from simple, connected processors called neurons which form a sequence of real-valued activations. Special type of neurons, called input neurons are activated through the environment, other neurons are activated through the connected previously activated, weighted neurons. The learning process of a neural network is finding the optimal weights to be able to perform the desired results (Table III). The construction of a network depends on the problem and how the neurons are connected (Schmidhuber, 2015) [34].

MATLAB® provides easy to use, flexible tools to create, test and analyze neural networks. In this study a simple artificial neural network (for the exact parameters see Appendix A), with 15 layers and 10 max epochs were trained using the sample train- and test datasets which were used to build the SVM models.

The average accuracy of the NN network is significantly worse compared to the SVM models, however the 9th NN test produced an especially low accuracy. Here the model supposedly did not conver-gate, so the whole test was repeated using 50 max epochs.

This modification significantly improved the results of the NN and for test 2 and test 9 the model reached 100% accuracy. However, this could imply that the models are over-trained, which means that they produce the desired results for this sample, however for different samples they would not perform this well. Cross validation technique is used to avoid this situation, however more independent tests with additional samples would be needed to confirm or reject the case of overtraining [35], [36], [37].

TABLE III. ACCURACY OF NN USING 10 AND 50 MAXIMUM EPOCHS

ID	*Accuracy (10 epochs)*	*Accuracy (50 epochs)*
1	*0.82608696*	*0.95652174*
2	*0.82608696*	*1*
3	*0.60869565*	*0.82608696*
4	*0.69565217*	*0.86956522*
5	*0.7826087*	*0.95652174*
6	*0.60869565*	*0.7826087*
7	*0.86956522*	*0.86956522*
8	*0.69565217*	*0.82608696*
9	*0.26086957*	*1*
10	*0.82608696*	*0.95652174*
AVG	***0.7***	***0.90434783***

So far NN reached the best average accuracy and supposedly the NN result would be improved if the number of epochs would be increased. In case of neural networks, the challenge is to determine the structure of the network, for instance should it be feed forward or recurrent and other important structural decisions also highly effect the desired behavior of the networks, for instance the number of layers, the type of this layers, the number of neurons in each layer etc.
For k-NN MATLAB® provides a complex framework to train the models and use the models for prediction [38].

The models are created using the "fitcknn" function which provides a highly parameterizable, flexible solution for model training. In the study, several parameters are used, the number of neighbors and the distance metrics were called "Minkowski" distance and Euclidean distance were used.

Minkowski distance was tested with $k = 3..7$ values. Compared to the SVM and the NN, the average accuracy produced by k-NN is the worst. The best result was reached with $k = 4$, however a tendency can be observed, with increasing k the average accuracy was decreased [28], [39], [40], [41].

V. RESULTS USING K-NN

It is reasonable to expect those samples which are close using an appropriate metric can be classified into the same class and it is also applicable to assume, that one unclassified observation can be classified to the class where its closest neighbors are classified (Dudani, 1976) [21]. The simplest k-nearest neighbor (k-NN) computes the distance (or similarity) between the sample and the values in the training set (Table IV)., restricts the maximum number of neighbors to k training samples and assign the class to the sample which the majority of the k neighbors belong (Grudzinski, 2008) [42], [43], [44].

The k-NN test was repeated with $k = 1..7$ and using Euclidean distance as the distance metrics. The results can be seen in (Table V).

Using the Euclidean distance for building the model did not improve the average accuracy for $k = 3..7$, however the average accuracy for $k = 1$ is significantly better compared to other k values. This can be due to the variety which can be experienced in MS lesions in the dataset, however more analysis would be needed to prove that.

TABLE IV. K-NN RESULTS USING MINKOWSKI DISTANCE WITH $k = 3..7$

ID	*Accuracy3*	*Accuracy4*	*Accuracy5*	*Accuracy6*	*Accuracy7*
1	*0.695652*	*0.695652*	*0.695652*	*0.652174*	*0.652174*
2	*0.565217*	*0.565217*	*0.565217*	*0.521739*	*0.565217*
3	*0.478261*	*0.478261*	*0.478261*	*0.521739*	*0.434783*
4	*0.695652*	*0.869565*	*0.73913*	*0.695652*	*0.478261*
5	*0.695652*	*0.521739*	*0.521739*	*0.478261*	*0.521739*
6	*0.565217*	*0.565217*	*0.521739*	*0.478261*	*0.478261*
7	*0.521739*	*0.521739*	*0.521739*	*0.478261*	*0.478261*
8	*0.608696*	*0.652174*	*0.565217*	*0.565217*	*0.565217*
9	*0.608696*	*0.608696*	*0.565217*	*0.521739*	*0.26087*
10	*0.434783*	*0.478261*	*0.434783*	*0.478261*	*0.521739*
AVG	***0.586957***	***0.595652***	***0.56087***	***0.53913***	***0.495652***

TABLE V. K-NN RESULTS USING EUCLIDEAN DISTANCE WITH K=1..7

ID	*Accuracy1*	*Accuracy2*	*Accuracy3*	*Accuracy4*	*Accuracy5*	*Accuracy6*	*Accuracy7*
1	*0.826087*	*0.695652*	*0.695652*	*0.695652*	*0.695652*	*0.652174*	*0.652174*
2	*0.782609*	*0.652174*	*0.565217*	*0.565217*	*0.565217*	*0.521739*	*0.565217*
3	*0.782609*	*0.565217*	*0.478261*	*0.478261*	*0.478261*	*0.521739*	*0.434783*
4	*0.913043*	*0.782609*	*0.695652*	*0.869565*	*0.73913*	*0.695652*	*0.478261*
5	*0.826087*	*0.695652*	*0.695652*	*0.521739*	*0.521739*	*0.478261*	*0.521739*
6	*0.826087*	*0.565217*	*0.565217*	*0.565217*	*0.521739*	*0.478261*	*0.478261*
7	*0.782609*	*0.521739*	*0.521739*	*0.521739*	*0.521739*	*0.478261*	*0.478261*
8	*0.913043*	*0.695652*	*0.608696*	*0.652174*	*0.565217*	*0.565217*	*0.565217*
9	*0.826087*	*0.608696*	*0.608696*	*0.608696*	*0.565217*	*0.521739*	*0.26087*
10	*0.73913*	*0.478261*	*0.434783*	*0.478261*	*0.434783*	*0.478261*	*0.521739*
AVG	***0.821739***	***0.626087***	***0.586957***	***0.595652***	***0.56087***	***0.53913***	***0.495652***

VI. Comparing the results

The best average accuracy was produced by NN however that is not the only tool to compare results. In this case, the ratio of fake positive and fake negative values also can be counted. In this case the dataset contains four classes, however it can be simplified by assuming that normal is negative and MS effected samples are positive. Therefore, fake positive is, when the classifier assigned a positive class to the sample, however it is actually negative and fake negative is a sample which the classifier assigned a negative value, but it is actually positive. Using this assignment differences between the severity of MS do not counted, just the difference between normal and MS samples and the goal is to minimize these values. The below table (Table VI.) contains the average number of fake positive and fake negative values for every method tested in this study.

NN using 50 maximum epochs managed to minimize the average number of fake positive results and k-NN using Euclidean distance metrics with $k = 1$ and all SVM models also reached good average results. In case of fake negative, 1AA SVM models managed to minimize the average values with zero fake negative results in the samples 1A1 SVM and NN with epoch 50.

Table VI. Average number of fake positive and fake negative result by method

Method	*Fake positive*	*Fake negative*
1AA SVM linear	*1.5*	*0*
1A1 SVM linear	*1.5*	*0.8*
1AA SVM rbf	*1.5*	*0*
1A1 SVM rbf	*1.5*	*0.9*
NN epoch 10	*2.2*	*3*
NN epoch 50	*1*	*1*
k-NN Euclidean k=1	*1.1*	*0.7*
k-NN Euclidean k=2	*3*	*1*
k-NN Euclidean k=3	*3.1*	*0.9*
k-NN Euclidean k=4	*3.1*	*1.2*
k-NN Euclidean k=5	*2.9*	*1.7*
k-NN Euclidean k=6	*3.2*	*1.3*
k-NN Euclidean k=7	*3.3*	*1.5*
k-NN Minkowski k=3	*3.1*	*0.9*
k-NN Minkowski k=4	*3.1*	*1.2*
k-NN Minkowski k=5	*2.9*	*1.7*
k-NN Minkowski k=6	*3.2*	*1.3*
k-NN Minkowski k=7	*3.3*	*1.5*

VII. Conclusion

SVM is a useful tool for MS disease diagnosis process. In order to be able to make more appropriate and satisfactory assumptions, more tests are required. Brainweb dataset is a useful source of data to generate images with different parameters, which can change the parameters such as brightness, contrast and etc. of the images. Tests with SVM, NN and k-NN proved that with the current results NN is the method which should be widely investigated, however SVM also should not be dropped because of it can minimize the number of fake negative values. For further investigation a new dataset could be built using different simulation parameters. Even artificial neural networks for the 3D simulations can be built if the proper hardware resources are available, but naturally the best dataset would be the data of real MS patients. The current idea is to focus on neural networks, however SVM should be used to confirm the results of NN.

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X. APPENDIX A

```
layers = [
    imageInputLayer([217 181 1])

convolution2dLayer(3,8,'Padding','same')
    batchNormalizationLayer
    reluLayer
    maxPooling2dLayer(2,'Stride',2)

convolution2dLayer(3,16,'Padding','same')
    batchNormalizationLayer
    reluLayer
    maxPooling2dLayer(2,'Stride',2)

convolution2dLayer(3,32,'Padding','same')
    batchNormalizationLayer
    reluLayer
    fullyConnectedLayer(4)
    softmaxLayer
    classificationLayer];

 options = trainingOptions('sgdm', ...
    'InitialLearnRate',0.01. ...
    'MaxEpochs',50. ...
    'Shuffle','every-epoch', ...
    'Verbose',false);
```

Phase-Code Shift Keyed Probing Signals with Discrete Linear Frequency Modulation and Zero Autocorrelation Zone

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***Abstract* — Modern synthesized aperture radars (SAR), e.g. space SARs for remote sensing of the Earth, use signals with linear frequency modulation and signals with phase-code shift keying (PCSK) coded by M-sequence (MS) as probing signals. Utilization of PCSK-signals permits an essential improvement of the radar image quality at the stage of its compression on azimuthal coordinate. In this paper, probing signals with zero autocorrelation zone (ZACZ) are synthesized, which signals represent a sequence of two PCSK-pulses with additional linear frequency modulation of sub-pulses in the pulses. A comparative analysis of the correlation characteristics of the synthesized signal and the PCSK-signal coded by MS has been performed. It is shown that in ZACZ, at a mismatch in the Doppler frequency, the level of all side lobes (SL) of the autocorrelation function (ACF) of the synthesized signal is less than the ACF SL level of the PCSK-signal coded by MS. The total ACF of the ensemble of 4 signals has zero SL along the whole time axis τ, and at a mismatch in frequency in ZACZ, it has a lower SL level than the total ACF SLs of the ensemble of 4 PCSK-signals coded by MS.**

***Index Terms*—Ambiguity function, autocorrelation function, complementary sequences, pulse train, zero autocorrelation zone.**

I. INTRODUCTION

Synthesized aperture radars (SAR), e.g. space SARs of the Earth remote sensing, due to their operation principle, impose the following requirements on probing signals:

- they must be coherent within the limits of the time interval equal to the aperture synthesis time to provide a high spatial resolution on the azimuth co-ordinate, which is directed along the velocity vector of the space vehicle;
- they must have an intra-pulse modulation to provide a high value of the average emission power and, at the same time, a good spatial resolution on the elevation co-ordinate, which is orthogonal to the space vehicle velocity vector direction. This requirement implies the utilization of the so-called complex signals in SARs, for which signals the product of the effective frequency band and the duration of the probing signals is much higher than 1;
- together with other SAR parameters, they must provide the quality of the radar image, as required in the specifications.

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Among various classes of complex signals, only two main classes have yet found practical application in space SARs - these are signals with linear frequency modulation (LFM) and signals with phase-code shift keying (PCSK). Space SARs for remote sensing of the Earth have been using LFM-signals up to now [1 – 5]. This situation is determined historically, as LFM-signals were the first complex signals to be used in radar technology, and their properties were studied in detail a long time ago. PCSK-signals were used as probing signals in space SARs mounted on Venus-15 and Venus-16 automatic interplanetary stations designed to provide a radar map of the Venus in 1983-1984 [6], [7]. Truncated M-sequences (MS) were used as the code of those signals.

At the same time, we would like to note a growing interest of radar experts in PCSK-signals [8 – 11]. This results from the fact that utilization of discrete coding of the coherent ensemble of probing signals in SARs opens the prospect for significant improvement of the radar image quality in terms of parameters related to the properties of total correlation functions of the ensemble. PCSK signals have a number of fundamental advantages:

- the ambiguity function (AF) of the PCSK-signal has a “thumbtack” form, which is close to an ideal one, as opposed to the AF of the LFM-signal, which has a form of a “comb”;
- correlation characteristics of the coherent train of reflected probing PCSK-signals can be significantly improved at the stage of signal compression in azimuth when an ensemble of different orthogonal codes is used;
- when the operation of pulse compression by range is performed, no “window” processing is required for the ensemble of PCSK-signals.

Nevertheless, PCSK-signals have shortcomings in comparison with LFM-signals. For instance, a single PCSK-signal for short code sequences has a higher level of the maximum side lobe (SL) of the autocorrelation function (ACF) and a higher integral level of the ACF SL.

In view of the aforesaid, it is expedient to consider PCSK-signals with zero autocorrelation zone (Zero Autocorrelation Zone - ZACZ) [12 – 15] in the area of the central ACF peak as probing signals for SARs. These signals are a periodic sequence (a train) of $M \gg 1$ coherent pulses coded (shift-keyed by phase) by ensembles of complementary or orthogonal sequences.

In space SARs, pauses between the emission of probing signals are used for receiving echoes reflected from the Earth surface, i.e. signal reception and transmission with the same

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antenna are alternated. Therefore, signals with ZACZ considered in [12 – 15] are not suitable for this purpose, as they have a large number of pulses in the train.

Signals with ZACZ considered in [16] and [17] consist of a minimum number of pulses in the train, i.e. two pulses; however, at mismatch in the Doppler frequency, they have a high enough ACF SL level.

The object of this paper is the synthesis of probing signals with ZACZ consisting of two PCSK-pulses in the train $(M = 2)$ and having, at mismatch in the Doppler frequency, an acceptable SL level of the ACF both for single probing signals and the total ACF of the ensemble of PCSK-signals used in the aperture synthesis mode.

One of the varieties of such a signal was considered in [18]. There, the signal is a sequence of two PCSK-pulses with additional linear frequency shift keying of sub-pulses in pulses. In this paper, we consider an additional linear frequency modulation of sub-pulses in pulses.

II. Formation of the ZACZ-signal with Linear Frequency Modulation of Sub-pulses in Pulses

$$\mathbf{A}_{2,N} = \left(\mathbf{A}_{2,N/2}^{(1)} \quad \mathbf{A}_{2,N/2}^{(2)}\right);$$
$$\mathbf{A}_{2,N/2}^{(1)} = \begin{pmatrix} \mathbf{D}_{1,N/2}^{i} \\ \mathbf{D}_{1,N/2}^{j} \end{pmatrix}; \mathbf{A}_{2,N/2}^{(2)} = \begin{pmatrix} \mathbf{D}_{1,N/2}^{i'} \\ \mathbf{D}_{1,N/2}^{j'} \end{pmatrix}; \quad (3)$$
$$i, j, i', j' = 1, 2, ..., N/2,$$

where sequences $\mathbf{D}_{1,N/2}^{i} = \left\| d_{i,n} \right\|_{n=1}^{N/2}$, $\mathbf{D}_{1,N/2}^{j} = \left\| d_{j,n} \right\|_{n=1}^{N/2}$ and $\mathbf{D}_{1,N/2}^{i'} = \left\| d_{i',n} \right\|_{n=1}^{N/2}$, $\mathbf{D}_{1,N/2}^{j'} = \left\| d_{j',n} \right\|_{n=1}^{N/2}$ are complementary sequences (CS); i, j and i', j' are numbers of paired CSs; i' is the number of the CS, which is adjacent to the CS with the number i, and j' is the number of the CS, which is adjacent to the CS with the number j [19].

The PCSK-signal (2) coded by rows of the matrix $\mathbf{A}_{2,N}$ from (3) is called a coherent complementary signal (CCS). We call this signal “coherent” because the coherence of PCSK pulses must be maintained in the train. In addition, we call it “complementary” because the pulses are encoded by complementary sequences.

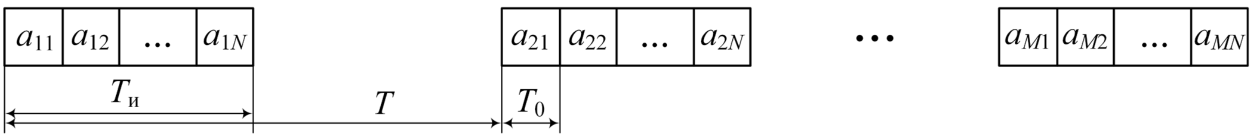

Fig. 1. An envelope of a train of *M* PCSK-pulses

Let us consider a radar signal representing a sequence (a train) of *M* pulses (Fig. 1) shift-keyed in phase by an ensemble of *M* sequences [18]. Each pulse with the duration T_p consists of *N* sub-pulses (discretes) with the duration of $T_0 = T_p/N$ each. The pulse repetition period is $T = qT_p = qNT_0$, where $q \geq 2$ is the off-duty factor of the pulses. The ensemble of *M* sequences can be defined by the following matrix:

$$\mathbf{A}_{M,N} = \left\| a_{i,n} \right\|_{i,n=1}^{M,N}, \; a_{i,n} = \exp\left(j\pi \tilde{a}_{i,n}\right), \quad (1)$$

where $\tilde{\mathbf{A}}_{M,N} = \left\| \tilde{a}_{i,n} \right\|_{i,n=1}^{M,N}$ is the matrix of the binary code.

A complex envelope of the signal under investigation will have the following form:

$$\dot{u}(t) = \sum_{i=1}^{M} \sum_{n=1}^{N} a_{i,n} S_n\left(t - (n-1)T_0 - (i-1)T\right), \quad (2)$$

where $S_n\left(t - (n-1)T_0\right), (n-1)T_0 \leq t < nT_0$, is the envelope of the *n*-th discrete of the pulse.

At $M = 2$, the coding matrix (1) can be written as follows [18]:

Let us consider CCSs with additional frequency modulation of the discretes of train pulses under the linear law (CCS-LFM), as shown in Fig. 2.

The frequency variation law within the limits of the *n*-th discrete is as follows (taking into account Fig. 2):

$$f_n(t) = \begin{cases} \dfrac{F_S}{T_0} t, \text{ for } n = 1, ..., N/2; \\ F_S - \dfrac{F_S}{T_0} t, \text{ for } n = N/2 + 1, ..., N, \end{cases} \quad \text{at } 0 \leq t < T_0, \quad (4)$$

where $n = 1, 2, ..., N = 2^{k+1}$ is the number of the discrete in the CCS pulse; $F_S = b/T_0$ is the width of the CCS-LFM spectrum.

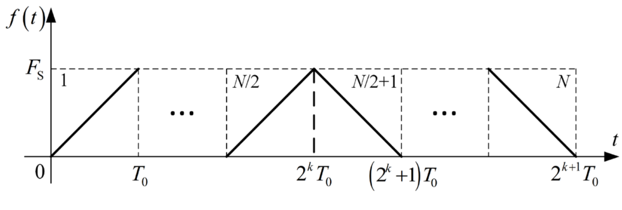

Fig. 2. LFM law of discretes within the limits of the CCS pulse

Then, the phase variation law within the limits of the *n*-th discrete is as follows:

$$\varphi_n(t)=\begin{cases}\pi b\left(\dfrac{t}{T_0}\right)^2, \text{ for } n=1,...,N/2;\\ 2\pi b\dfrac{t}{T_0}-\pi b\left(\dfrac{t}{T_0}\right)^2, \text{ for } n=N/2+1,...,N.\end{cases} \quad (5)$$

Thus, the complex envelope (2) of the CCS-LFM is as follows:

$$\dot{u}(t)=$$

$$=\begin{cases}\sum_{n=1}^{N}S_0\left(t-(n-1)T_0\right)\exp\left\{\mathrm{j}\pi\left(b\left(\dfrac{t}{T_0}\right)^2+\tilde{a}_{1,n}\right)\right\}+\\ +\sum_{n=1}^{N}S_0\left(t-(n-1)T_0-T\right)\exp\left\{\mathrm{j}\pi\left(b\left(\dfrac{t}{T_0}\right)^2+\tilde{a}_{2,n}\right)\right\},\\ \text{for } n=1,...,N/2;\\ \sum_{n=1}^{N}S_1\left(t-(n-1)T_0\right)\exp\left\{\mathrm{j}\pi\left(2b\dfrac{t}{T_0}-b\left(\dfrac{t}{T_0}\right)^2+\tilde{a}_{1,n}\right)\right\}+\\ +\sum_{n=1}^{N}S_1\left(t-(n-1)T_0-T\right)\exp\left\{\mathrm{j}\pi\left(2b\dfrac{t}{T_0}-b\left(\dfrac{t}{T_0}\right)^2+\tilde{a}_{2,n}\right)\right\},\\ \text{for } n=N/2+1,...,N.\end{cases} \quad (6)$$

where $\|\tilde{a}_{i,n}\|_{i,n=1}^{2,N}$ is the matrix composed from the adjacent pairs of the binary D-code [17, 19], $a_{i,n}=\exp\left(\mathrm{j}\pi\tilde{a}_{i,n}\right)$, $\mathbf{A}_{2,N}=\|a_{i,n}\|_{i,n=1}^{2,N}$ from (3).

III. Analysis of the Correlation Characteristics of CCS-LFM

Let us perform a comparative analysis of CCS correlation characteristics without modulation of discretes (further simply CCS) with correlation characteristics of CCS-LFM. To compare the relative SL level of these two signals, it is necessary to provide the same level of main lobes of their ACF, which is equal to the number of discretes in two train pulses. We consider CCS and CCS-LFM with the number of discretes in the pulse $N=256$. The base of the linear frequency modulation of the discrete is four, i.e. $b=4$. Both signals have the same off-duty factor $q=2$. Thus, both signals have the same level of the ACF main lobe equal to 512.

Fig. 3 shows ACF $R(\tau)$ of CCS and CCS-LFM. The ambiguity functions $R(\tau,F)$ of CCS and CCS-LFM are shown in Fig. 4 and 5, respectively. The ZACZ width is $Z=NT_0(q-1)$ [16], [17].

In Fig. 4 and 5, $M=2$ is the number of pulses in the train, and $T=qNT_0$ is the pulse repetition period. A half of the main lobe width of the AF section with the plane $\tau=0$ $R(0,F)$ at the zero level is equal to $\Delta F=1/(MT)=1/(qMNT_0)$. A minimum SL level in the delay-frequency plane (τ,F) of the AF at $|\tau|<Z$ and $|F|<\Delta F$ needs to be provided.

Table 1 provides the values of the correlation characteristic of CCS and CCS-LFM for three AF sections with planes $F=0$, $F=0.3\Delta F$ and $F=0.5\Delta F$. In Table 1: $R_{\max}$ and $R_{\mathrm{z\,max}}$ are relative levels of maximum ACF SLs outside and inside of ZACZ, respectively; R_{rms} and $R_{\mathrm{z\,rms}}$ are relative rms ACF SL levels outside and inside of ZACZ, respectively.

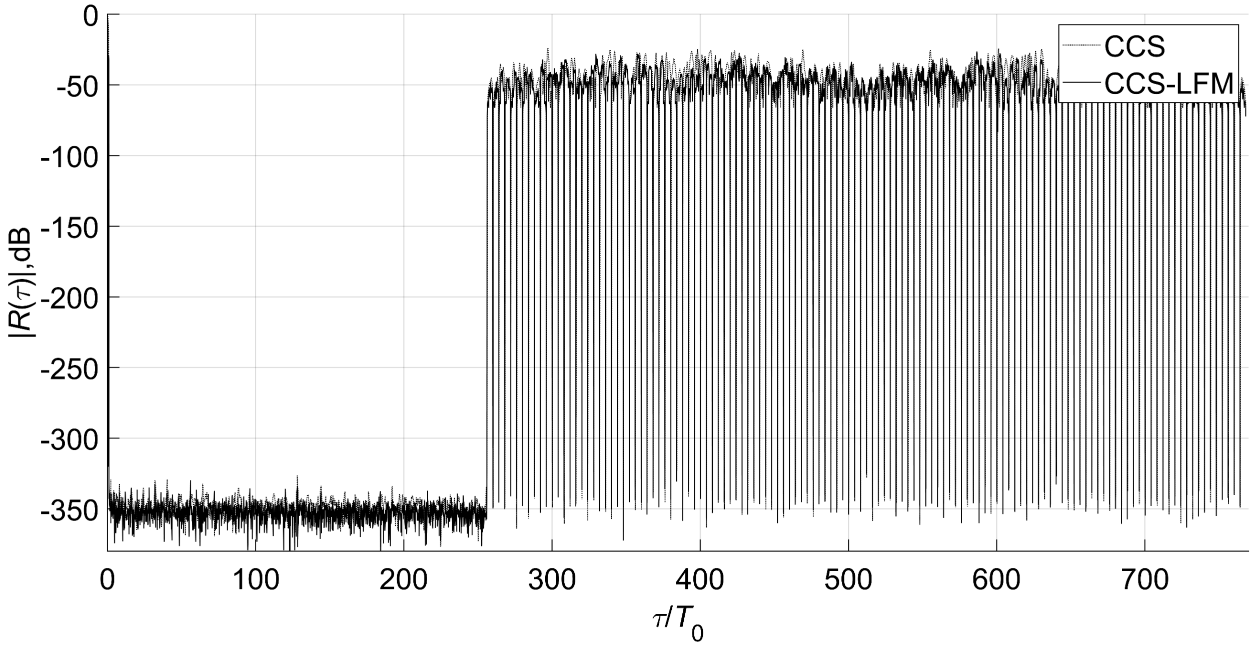

Fig. 3. ACF of CCS (dotted line) and CCS-LFM (solid line)

It follows from Table 1 that in case of a mismatch by frequency, the maximum ACF SL level of CCS-LFM in ZACZ is lower than the maximum ACF SL level of CCS more than by 6.5 dB, and the rms SL level – more than by 6 dB. Besides, outside ZACZ, the rms ACF SL level of CCS-LFM is lower than the respective ACF SL level of CCS more than by 6 dB.

From [14], [20], we know that pseudo-noise signals are the optimum discrete signals, i.e., signals with a minimum level of the maximum ACF SL. The most known and widely used example of such signals is a truncated M-sequence, in which the minimax SL level of the normalized ACF aspires to $1/\sqrt{N_\text{M}}$ with N_M growth, where N_M is the period of the M-sequence.

TABLE 1
VALUES OF CORRELATION CHARACTERISTICS OF CCS, CCS-LFM AND MS

F		0	$0.3\Delta F$	$0.5\Delta F$
R_max, dB	CCS	-23.8	-23.8	-23.8
	CCS-LFM	-26.3	-26.3	-26.4
	MS	-27.3	-27.8	-25.2
R_rms, dB	CCS	-34.9	-34.8	-34.7
	CCS-LFM	-41.2	-41.1	-41.0
	MS	-35.2	-33.8	-32.4
$R_{\text{z max}}$, dB	CCS	-330	-24.7	-20.8
	CCS-LFM	-329	-31.5	-27.7
$R_{\text{z rms}}$, dB	CCS	-343	-38.6	-34.7
	CCS-LFM	-349	-44.9	-41.0

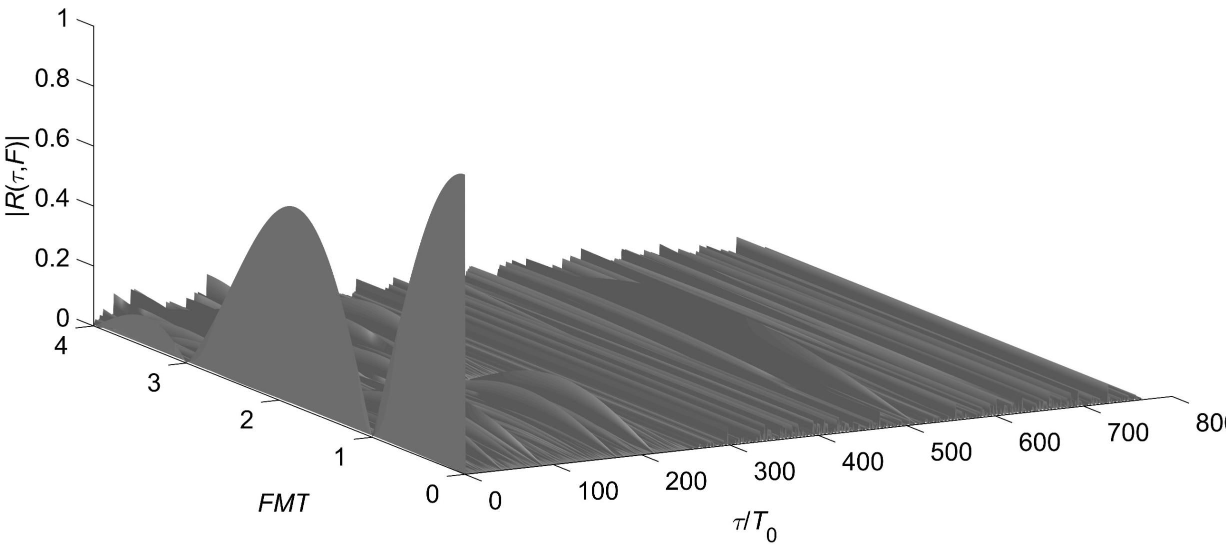

Fig. 4. The ambiguity function of CCS

Let us perform a comparative analysis of the correlation characteristics of considered CCSs with the PCSK-signal modulated in phase by an M-sequence (further simply MS) with the period $N_\text{M} = 511$. To align the levels of the ACF main lobes of CCS and MS, we will add one element from the adjacent period to its period, i.e., the number of discretes in the MS pulse will be $N = N_\text{M} + 1 = 512$.

Table 1 provides values of the correlation characteristics of the considered MS for three sections of the AF with planes $F = 0$, $F = 0.3\Delta F$ and $F = 0.5\Delta F$, and Fig. 6 shows ZACZ for the examined CCS and CCS-LFM signals and a part of the MS ACF at a mismatch in frequency $F = 0.3\Delta F$.

It follows from Fig. 6 and Table 1 that in case of a mismatch by frequency $F = 0.3\Delta F$ and $F = 0.5\Delta F$, the maximum and rms SLs levels of the ACF of the CCS-LFM in ZACZ are less than the corresponding SLs levels of the ACF of the MS. Modeling results showed the validity of this result at $|F| < \Delta F$.

IV. COMPARATIVE ANALYSIS OF TOTAL ACFS OF THE CCS-LFM ENSEMBLE AND CYCLIC MS ENSEMBLE

As we mentioned earlier, in space SARs, PCSK signals modulated in phase by truncated MSs were used as probing signals. However, in adjacent sensing cycles, for maximum ACF SL suppression depending on the necessary time for the aperture synthesis and other SAR parameters, MSs with different generating polynomials and/or different cyclic shifts were used [6].

The maximum SL suppression of the total ACF of the MS ensemble is achieved by utilization of the complete cyclic MS ensemble with the number of discretes in the pulse equal to its period, i.e., at $N = N_\text{M}$. In addition, the adjacent MSs are shifted to each other for one element, and the number of MSs in the ensemble is equal to N. Then, for the total ACF of the complete cyclic ensemble of N MSs with the length of the one period, the following equation may be formulated:

$$r_m^+ = \sum_{i=1}^{N} r_m^i; \quad |m| = 0, 1, ..., N-1, \qquad (7)$$

where r_m^i is non-normalized ACF of i-th MS.

After formulating equations for ACFs of each of the N MSs and summing them up according (7), we will find out that

$$r_m^+ = \left(N - |m|\right)\left(r_m + r_{N-m}\right), \tag{8}$$

where $r_m = \sum_{n=1}^{N-m} a_n a_{n+m}$ is the aperiodic ACF of the current part of the MS with the length of one period; $r_{N-m} = \sum_{n=1}^{m} a_n a_{n+N-m}$ is the aperiodic ACF of the adjacent (from the right) part of the MS.

cyclic ensemble of 511 MSs and the cyclic ensemble of 4 MSs for three AF sections with planes $F = 0$, $F = 0.3\Delta F$ and $F = 0.5\Delta F$. In this table, $R_{\Sigma\,\max}$ and $R_{\Sigma\,\mathrm{rms}}$ are the relative maximum SL level of the total ACF and the relative rms SL level of the total ACF, respectively. From Table 2 we can see that the maximum SL level of the total ACF of the complete cyclic ensemble is lower than the maximum SL level of the cyclic ensemble of four MSs more than by 15.5 dB, and for rms SL level – more than by 12 dB.

Further, we will look at the values of the total ACF of the CCS-LFM ensemble. According to (3), there is a total of

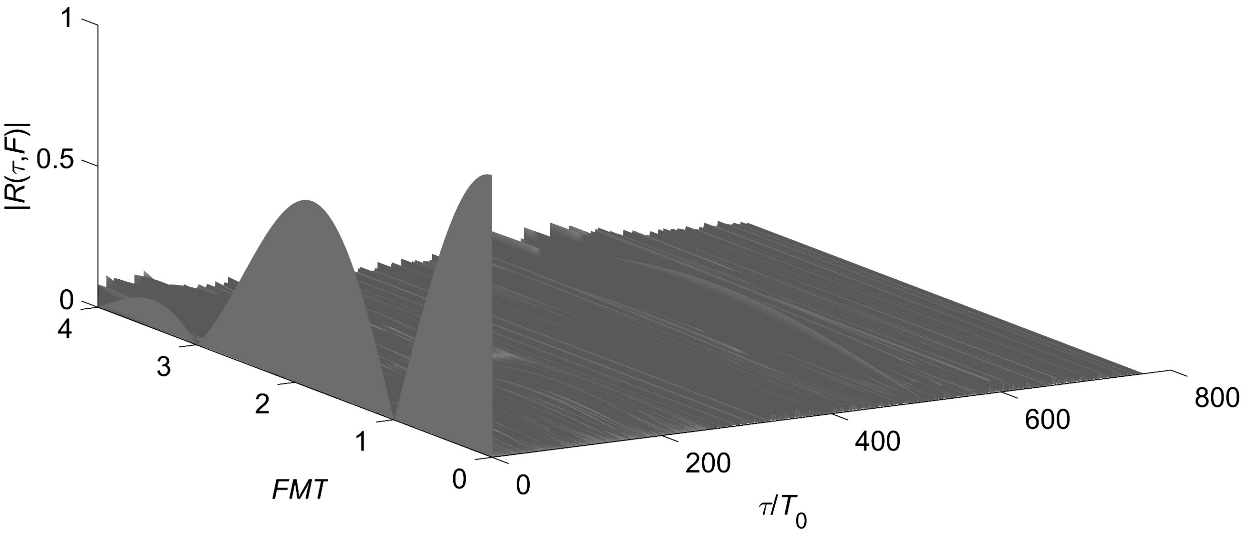

Fig. 5. The ambiguity function of CCS-LFM

It is known from [20] that the sum in (8) determines the periodic ACF of the MS with a period $N = N_{\mathrm{M}}$, i.e., $r_m + r_{N-m} = r_m^{\mathrm{p}}$, where $r_m^{\mathrm{p}} = \sum_{n=1}^{N} a_n a_{n+m}$ at $|m| = 0,1,...,N-1$. It is also known that for MS $r_m^{\mathrm{p}} = -1$ at $|m| = 1,2,...,N-1$.

Thus, from (8) we obtain that

$$r_m^+ = \left(N - |m|\right) r_m^{\mathrm{p}} = -N + |m| \text{ at } |m| = 1,2,...,N-1, \tag{9}$$

from which the normalized total ACF of the complete cyclic ensemble of MS is:

$$R_m^+ = -\frac{1}{N} + \frac{|m|}{N^2} \text{ at } |m| = 1,2,...,N-1. \tag{10}$$

The SL level of the total ACF of the complete cyclic MS ensemble can be considered as the minimum possible limit. The lesser MSs the cyclic ensemble contains, the higher SL level of the total ACF is. We shall consider an ensemble consisting of four MSs shifted to each other for 128 elements to be the cyclic ensemble with the maximum SL level of the total ACF.

Table 2 provides the values of the total ACFs of the complete

$N/2 = 2^k$ CCSs formed from the adjacent AS pairs of the k–order and forming the complete CCS ensemble with the number of discretes in the pulse $N = 2^{k+1}$.

TABLE 2
VALUES OF THE TOTAL ACF OF ENSEMBLES OF
511 MSS, 4 MSS AND 4 CCS-LFM

F		0	$0.3\Delta F$	$0.5\Delta F$
$R_{\Sigma\,\max}$, dB	4 MS	-38.6	-39.9	-39.8
	511 MS	-54.2	-55.5	-58.1
	CCS-LFM	-324	-30.7	-26.4
$R_{\Sigma\,z\,\max}$, dB	CCS-LFM	-327	-43.5	-35.4
$R_{\Sigma\,\mathrm{rms}}$, dB	4 MS	-46.7	-46.7	-46.6
	511 MS	-58.9	-59.7	-61.1
	CCS-LFM	-348	-57.3	-52.9
$R_{\Sigma\,z\,\mathrm{rms}}$, dB	CCS-LFM	-345	-67.0	-59.3

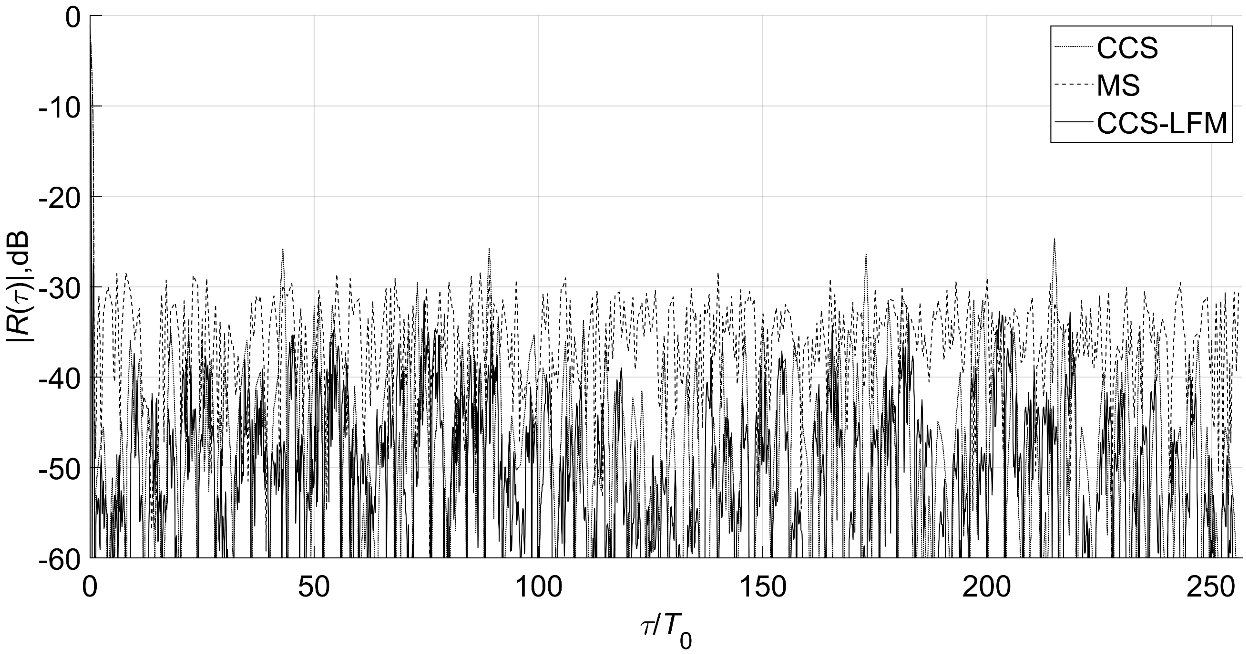

Fig. 6. ZACZ of CCS, CCS-LFM and a part of the MS ACF at $F = 0.3\Delta F$

Modeling results show that the total ACF of the ensemble of four CCSs (with and without modulation of the discrete) with adjacent numbers in the complete ensemble has zero SLs along the whole time axis τ of the ACF. In this case, the number of the ensemble *j* of four CCSs with the number of discretes in the pulse being $N = 2^{k+1}$ is connected with the CCS number i in the complete ensemble of $N/2$ using the following equation:

$$j = \left\lfloor \frac{i-1}{4} \right\rfloor + 1;\ i = 1,2,...,2^k;\ j = 1,2,...,2^{k-2}, \qquad (11)$$

where $\lfloor z \rfloor$ is the integer part of the number *z*.

Fig. 7 and 8 show the total ACF $R_\Sigma(\tau)$ and the total AF $R_\Sigma(\tau, F)$ of $j = 1$ ensemble of four CCS-LFM with the number of discretes in the pulse $N = 256$ and the base $b = 4$, respectively. The off-duty factor is $q = 2$.

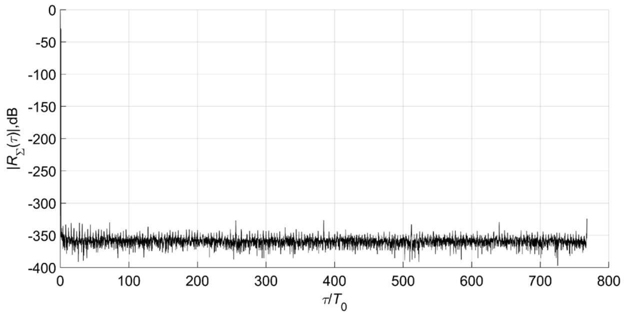

Fig. 7. Total ACF of the ensemble of 4 CCS-LFM

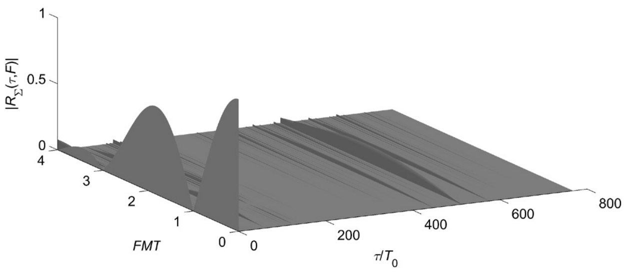

Fig. 8. Total AF of the ensemble of four CCS-LFM

Table 2 also provides the values of the total ACF of the ensemble of four CCS-LFM under consideration for three AF sections with planes $F = 0$, $F = 0.3\Delta F$ and $F = 0.5\Delta F$, and Fig. 9 shows the total ACF of the ensemble of four CCS-LFM, cyclic ensemble of four MSs and complete cyclic ensemble of 511 MSs at mismatch in frequency $F = 0.3\Delta F$. In the Table 2, $R_{\Sigma\,\max}$ and $R_{\Sigma\,z\,\max}$ are relative maximum SL levels of the total ACF outside and inside of ZACZ, respectively; $R_{\Sigma\,\mathrm{rms}}$ and $R_{\Sigma\,z\,\mathrm{rms}}$ are relative rms SL levels of the total ACF outside and inside of ZACZ, respectively.

It follows from Fig. 9 and Table 2 that in case of a mismatch by frequency $F = 0.3\Delta F$, the maximum and rms SLs levels of the total ACF of the ensemble of four CCS-LFM are less than the corresponding SLs levels of the total ACF of the ensemble of four MS. Modeling results showed the validity of this result at $|F| < 0.35\Delta F$.

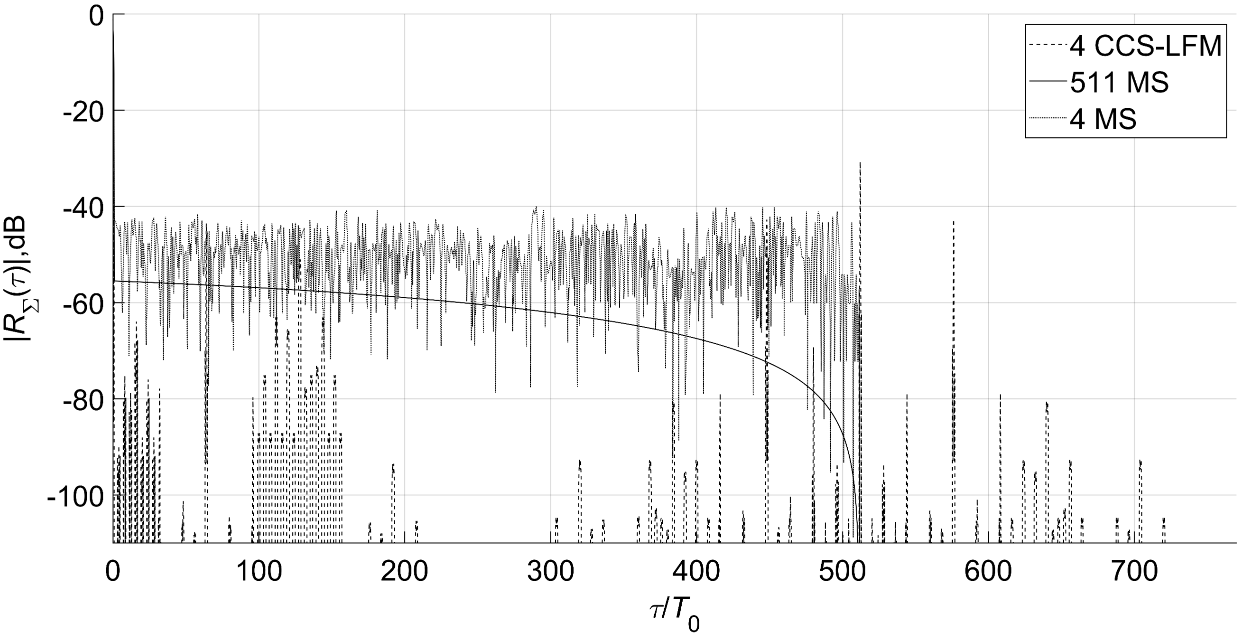

Fig. 9. Total ACFs of the ensembles of four CCS-LFM (dashed line), four MSs (dotted line) and 511 MSs (solid line) at $F = 0.3\Delta F$

V. CONCLUSION

This paper addresses probing PCSK-signals (train type) having a zero autocorrelation zone (ZACZ) and called coherent complementary signals (CCS). We prove that such signals have ZACZ and determine requirements to the coding matrix. Since ZACZ exists for CCS at zero mismatch in the Doppler frequency only, and a mismatch in frequency causes rather a high side lobe level in ZACZ, CCS with additional frequency modulation of closed sub-pulses (discretes) of the train pulses under linear law (CCS-LFM) have been considered for possible suppression of the SL. A comparative analysis of the correlation characteristics of CCS-LFM and CCSs without modulation of discretes at mismatch in the Doppler frequency has been performed. For this, we have assumed the same quantity of discretes in the train pulses. Our analysis has shown that in case of a mismatch by frequency in ZACZ, the maximum ACF SL level of CCS-LFM is lower than the maximum ACF SL level of CCS more than by 6.5 dB, and the rms SL level – more than by 6 dB. We have also performed a comparative analysis of the correlation characteristics of CCS-LFM and CCSs without discrete modulation with PCSK-signal shift-keyed in phase by M-sequence, which has the same number of discretes in the pulse with the number of discretes in two pulses of the CCS train. The analysis has shown that in case of a mismatch by frequency $F = 0.3\Delta F$ and $F = 0.5\Delta F$, the maximum and rms SLs levels of the ACF of the CCS-LFM in ZACZ are less than the corresponding SLs levels of the ACF of the MS. Modeling results showed the validity of this result at $|F| < \Delta F$. We have also performed a comparative analysis of the total ACFs of the CCS-LFM ensemble and the cyclic M-sequence ensemble at mismatch in the Doppler frequency. This analysis has shown that the total ACF of the ensemble of four CCSs (with and without discrete modulation) with adjacent numbers in the complete ensemble has zero SLs along the whole time axis τ of the ACF. The analysis has shown also that at mismatch in frequency in ZACZ, the maximum and rms SLs levels of the total ACF of the ensemble of four CCS-LFM are less than the corresponding SLs levels of the total ACF of the ensemble of four MS. Modeling results showed the validity of this result at $|F| < 0.35\Delta F$.

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Real-time Processing System for a Quantum Random Number Generator

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***Abstract*—Quantum random number generators (QRNG) provide quality random numbers, which are essential for cryptography by utilizing the unpredictable nature of quantum mechanics. Advancements in quantum optics made multiple different architectures for these possible. As part of a project aiming to realize a QRNG service, we developed a system capable of providing real-time monitoring and long term data collection while still fulfilling regular processing duties for these devices. In most cases, hardware validation is done by simply running a battery of statistical tests on the final output. Our goal, however, was to create a system allowing more flexible use of these tests, realizing a tool that can also prove useful during the construction of our entropy source for detecting and correcting unique imperfections. We tested this flexibility and the system's ability to adequately perform the required tasks with simulated sources while further examining the usability of available verification tools within this new custom framework.**

***Index Terms*—quantum computing, quantum random number generation, statistical testing.**

I. Introduction

RANDOMNESS is used as a resource in a wide variety of applications nowadays. Numerical simulations, as well as several cryptographic use cases all, depend on quality random numbers for reliable operation [1], presenting a need for quality high-speed generation schemes. The inherently unpredictable nature of quantum mechanics poses an attractive foundation for potential solutions. While most quantum computing applications apart from quantum key distribution [2] are still in the experimental phase, quantum random number generation is already well established, with existing commercial products [3]. Advancements in quantum optics made many different theorized realizations feasible [4], possibly leading to new and better generation methods.

Under the framework of a Hungarian quantum technology project, our goal is to realize a quantum random number service which provides reliable random numbers. For this, a physical entropy source has to be built, paired with an adequate processing system to provide verified, quality output. While most processing systems mainly only consist of a single algorithm to extract a uniform output from the raw data coming from the hardware, our goal was to create one that can also realize real-time monitoring and collect long term statistics, allowing it to also aid the development of the physical architecture by providing a custom tool capable of detecting possible imperfections arising due to construction mistakes. Part of this project, there are multiple proposed physical entropy sources under construction currently. Our main goal was to create a system that is capable of supporting all of these. In this paper, we present one such system. Furthermore, due to the required flexibility, our solution can also be used with most other types of generators.

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II. Random number generators

A. Generation approaches

Generally, random number generators can be categorized into two main groups: deterministically operating algorithm based pseudo-random number generators (PRNG) and true random number generators (TRNG), which utilize some physically proven nondeterministic phenomenon as their entropy source. PRNGs are usually easy to use and can provide on-demand high-speed bit generation, however, their deterministic operation presents an exploitable vulnerability to potential attackers [5][6]. Knowing a particular algorithm, it's inner state can be deducted after collecting a sufficiently large amount of output data. Once this state is known, the operation of the generator can be accurately simulated, all future and present outputs can be predicted, thereby rendering them useless for most use cases. To combat this, these generators can be used in conjunction with other, more easily accessible, albeit worse quality outside entropy sources [7], using their limited entropy to reinitialize their inner state. In this mode, they effectively function as randomness extractors (or more accurately randomness expanders) for weak entropy sources [8]. True random number generators, on the other hand, have no such inner state governing their operation. Each generated bit should be independent. Typically, these generators work by sampling some appropriate physical phenomena like radioactive decay, photoelectric effects or noises like avalanche, thermal or shot noise. The source of randomness for all of the mentioned cases can be traced back to the laws of quantum mechanics. This is good news, as quantum unpredictability has been experimentally verified numerous times [9][10][11]. The main challenge is the actual error-free construction and operation of these generators. No unwanted unknown outside bias or noise polluting the measurements is allowed. Another limiting factor for this approach can also be speed. The examined state of the underlying phenomena often can't change instantaneously. To avoid correlation between samples, adequate restrictions to sampling frequency have to be enforced. Their operation mode, therefore, is often referred to as ”blocking” compared to the ”non-blocking” nature of PRNGs, meaning that for each batch of output data the user first has to wait for enough of the sampled physical events to occur, thereby presenting a speed limit independent of processing power. Detecting faulty operation states can present another potential problem. Due to the expected random nature, all possible output strings can occur during normal operation, making it impossible to tell with full certainty if a given output is the product of nominal or faulty operations. Fortunately, with the help of correctly designed statistical tests, some statements can still be made even in this case.

B. Planned generator architectures

Improvements in optical technologies have led to the emergence of several possible quantum random number generator architectures [4]. Most QRNGs today, as well as the proposed entropy sources our system needs to be able to support, rely on quantum optics as the quantum nature of states of light allows for many different implementations. For the processing system, information about the most probable error cases associated with these sources is relevant since these errors are expected to be detected. Another important factor is the maximum generation rate with which the system needs to be able to keep up. We briefly examine these for the proposed sources our system is designed to work with in the future.

1) Branching path generator: The first proposed architecture is a variant of one of the earliest quantum optical solutions [12]. It puts a single photon into path superposition using a beam splitter. Assuming this splitter has an ideal 50:50 split ratio, with detectors for each possible path, the resulting which-path information provides uniform randomness. With the introduction of some delay on only one of the paths and by rejoining them later, the difference of the possible paths can be seen from their arrival times. This allows for using only one detector, which is advantageous because bias coming from the difference in detectors becomes a non-factor. Notable possible error and bias sources in this construction are:

- Imperfection of the beam splitter can introduce bias.
- The additional delaying element in one of the paths means a higher chance of photon loss, leading to slightly reduced detection rates from that path, causing bias.
- Dark count rate of the detector.
- Source producing multiple or no photons.
- Losses in other parts.

Imperfections that lead to no detection or multiple detections (last two points) only affect output rate, not quality. Therefore, only effects that introduce unwanted bias need to be detected and corrected. Typical achievable bit rates for these generators are in the Mbps range.

2) Photon counting generator: Using a continuous light source, one can follow an approach similar to radioactive decay based generators [13]. The expected number of photons that arrive from the source during a given window of time follows a Poisson distribution. This is not the sought after uniform distribution, but various methods exist to transform it into that [14]. Notable possible processing challenges for this case can be the following:

- Poisson instead of uniform distribution.
- Other bias originating from imperfections, like less detection due to losses, detector efficiency, and dark count rate, etc...

These generators can reach speeds of 50 Mbps or more depending on used post-processing.

3) Time of arrival generator: Measuring the time difference between each detection instead of the number of photons, a similar scheme to the photon counting case can be realized. This statistic is also exponential, which is not the ideal uniform distribution, however, similarly to the previous case, there are options to remedy this. One way is to compare the time between the detection of the first and second, and second and third photons, then assign our output bit the result of this operation. Notable possible error sources are the following:

- Detector dead time.
- Accurate time measurement.
- Other bias originating from imperfections.

Generation speeds of these architectures can reach up to more than 100 Mbps [15], setting the highest expectation for real time testing in the processing system.

TABLE I
POSSIBLE OUTCOMES OF STATISTICAL TESTS

Reality	Conclusion	
	Accept H_0	Accept H_a
Data is random	No error	Type I error
Data is not random	Type II error	No error

III. STATISTICAL TESTS

Defining randomness is more of a philosophical problem due to the very nature of it. Deciding with certainty if a given output is indeed random or not, is therefore quite problematic. Consequently, in most practical approaches, we settle for less than absolutely certain, but most probable. Being able to state for a given output that it's much more probably a result of faulty operations than not, is good enough.

Randomness is a probabilistic property, so we can use statistical tests to make these statements. Each test examines a statistical property and decides whether it's within our expectations or not. Since there are infinitely many ways a series can be non-random and one test only looks for one of these, usually multiple tests are run in parallel until we say the results are good enough. Another interesting fact is that for a truly random output the tests are expected to fail from time to time. The decision about a given bit string is generally made according to hypothesis testing. Our null hypothesis (H_0) is that the output originated from a perfectly random source. Our alternate hypothesis (H_a) is that it did not. We gather some evidence trying to decide between our competing hypotheses, typically by investigating some probabilistic value with known theoretical distribution calculated from our string (calculate a p-value), then check if it exceeds some a priori defined critical value. If it does we reject our null hypothesis (H_0) and accept the alternative (H_a). This is the general principle behind the widely used NIST tests [16] too.

Table I shows the possible resulting cases regarding our decisions and their relations to reality. Type I error happens when we decide a random sequence to be non-random. For real applications, this may result in speed loss, as detected error states are not allowed to reach the user, and execution of other unnecessary actions associated with error states. Since even during nominal operations some of these errors are expected, overreaction to these states should be avoided because dropping everything that is not in our predefined critical range can lead to a skewed distribution. Type II error is the failure to detect real errors. It is much more dangerous than Type I because it potentially means a vulnerability unknown to the operator, so no action is taken to correct it, thereby propagating this vulnerability to everything that uses the generated randomness later. This type of error is the one we strive to minimize. The probability of Type I and Type II errors share a relation to each other and the length of the examined string. A commonly chosen value for Type I error probability is 0.01, as recommended by the NIST Statistical Test Suite (STS).

The two most widely used statistical test collections nowadays are the NIST Statistical Test Suite (containing 15 tests) and the Dieharder [17] test collection, which is an extension of the 1995 Diehard [18] tests, containing more than a hundred different tests, including the ones already in the STS too. Running tests is computationally expensive, so when choosing a set of them to use, an additional goal is to have tests orthogonal to each other, meaning that each of them investigates independent properties from one another. This is explicitly stated in the STS documentation, while the Dieharder pack aims to provide the most all-round and deep examination possible. Other new, less adapted approaches for testing [19] also exist, but the common main problems with currently available solutions in our case are that they don't support flexible, real-time monitoring and are computationally expensive.

Tests are good for finding unexpected error sources, for reliable system validation, however, they cannot be used. Proper analysis of the built architecture should never be skipped. The NIST recommendations for generator design [20], [21], [22] aim to provide a reliable baseline for this topic. In them, they specify certain expectations to be met for architectures. The general layout of a generator according to this can be seen in Figure 1. These recommendations specify different tests to be run at the start of the system, during operation, and occasionally when requested from the outside, while the three main error states expected to be detected are: entropy decrease, source error, implementation error. Our system realizes all the steps in Figure 1 after digitization while fulfilling these recommendations.

IV. System architecture

A. Specification

The processing system should take care of everything from digitization to providing the final output to the outside world. The following are the main points to fulfill and consider:

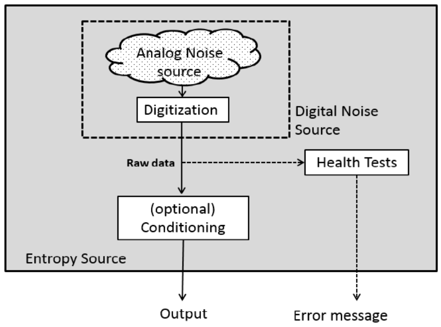

Fig. 1. General layout of a random number generator according to the NIST recommendation.

- Real-time monitoring: The system needs to detect potential errors when they happen during operation, and if they do, block the output. This requires real-time monitoring and testing of the bitstream coming from the hardware.
- Correct the potential bias of the input and perform the required processing to be able to provide a uniformly distributed output.
- Test the uniform output for processing errors.
- Long term validation of the whole system (hardware and processing): Store the required data for long term statistics and run specialized tests on them.
- Ability to easily change the processing system according to the specific needs of different hardware architectures. Enabling custom solutions tailored to the specifics of each physical source would also be beneficial, so flexibility is a plus.

Considering these goals, we focused on creating a system mainly to solve the real-time monitoring challenge while allowing it to be adapted to the needs of all three planned possible hardware layouts.

B. Realization

For the various expectations to be met, multiple tests and other processes need to be executed during various stages of processing. Two main approaches can be chosen here: all the needed components work together as part of a larger program, or all the components form smaller independent individual programs that can communicate and work together to get the same result. We chose the latter option as this allows for more flexibility. Furthermore, in the case of some software malfunction, only the corresponding smaller part is affected, leading to higher redundancy. The whole system is realized as a Linux virtual machine. This allows for relatively easy testing and development. Smaller processing parts can be run as individual daemons, permitting the use of tried and tested management tools offered by the system for communication and resource management. The block diagram of the relations between processes can be seen in Figure 2. Input data is read from the network via UDP. We assume that a safe local network is shared with the hardware so no additional safety measures are needed in this step. Should the need arise, different, more secure methods can easily be implemented.

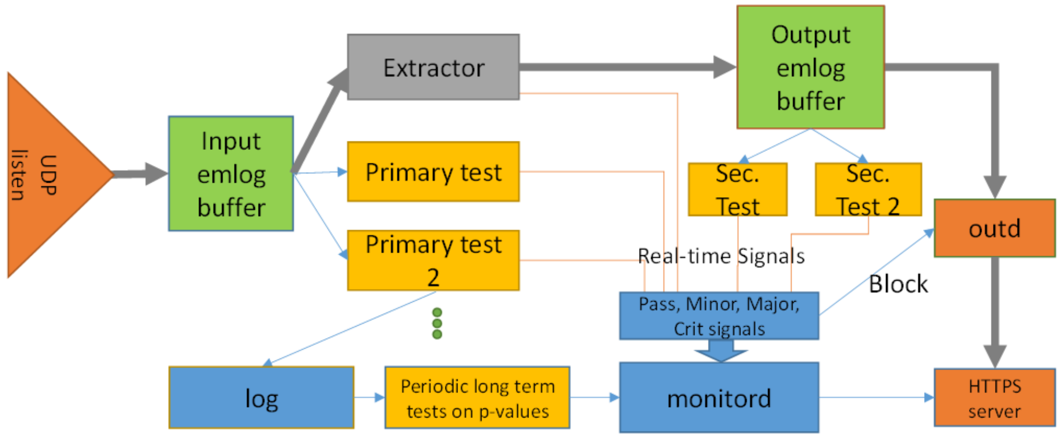

Fig. 2. Layout of the system and relations of the processes within. The thicker arrows show the path of the input data.

The data then gets read into a special cyclic emlog device buffer [23]. The cyclic nature here is important, as this allows for the independent operation of tests giving each process a separate file descriptor, thus allowing multiple different tests with different speeds to operate on the same buffer. (Solving the problem of synchronizing tests with different processing requirements and speed, leading to efficient resource utilization.) The size of this buffer can be chosen to be as big as 1 MB, meaning that even slower tests can always access sizeable continuous data. The processed stream is written to another cyclic buffer, from which the dedicated *outd* daemon can provide output to the outside world through https. With these two buffers, testing both the incoming raw data and processed output is possible. Components of the system are written in C/C++ to allow for easy adaptation of tests used in major open-source suites, which are mainly written in C. These components communicate with the *monitord* daemon responsible for monitoring the system via real-time signals while also logging their activities to their respective log files. A real-time status report is constructed in *monitord* with configurable parameters for deciding when to allow or block output. The log files can later be used for long term analysis of the whole system.

V. Tools available in the system

A. Extractors

Removing unwanted bias from the output is the main goal of entropy extractor algorithms. Several different of these exist, some even specially recommended for use with quantum generators [24]. During operation, these algorithms take in a chunk of bits and output a usually smaller chunk with better properties. They are mostly designed for correcting weaker entropy sources and are computationally expensive. When working with a specific good quality source some custom options are possible [25], but for our simulated case, more general solutions are preferred first. We used the SHA hash (recommended by NIST) for this purpose because hardware acceleration is supported for it in many modern processors.

B. Statistical tests

In the system, each statistical test can be done with a single function call, following a mostly standardized format. Each test gets the bits to test (also defining test length if there are more variants available), the critical threshold value for failure, and in some cases, other optional parameters, then returns its decision and the calculated p-value used for said decision. This permits us to easily define multiple tests to be run sequentially in our processes while also simplifying the code needed for singular test cases. For this to work and better support continuous operation, existing statistical tests had to be reimplemented using a custom bit container class. Readily available sources and sufficient existing documentation made this task straightforward. All 15 tests contained in the NIST STS have already been adapted this way to our architecture.

Different tests look for different vulnerabilities, but generally, they follow the same structure: first they transform the data into a more suitable format, then calculate a statistical value, which is later compared to a reference distribution resulting in a p-value. If this p-value is below some critical threshold, the test fails. By changing the reference distribution or the way the statistical value is calculated, tests can be created for non-uniform distributions too. This can be especially useful when our hardware has some mathematically describable known bias, making testing the raw, unprocessed, biased input possible. To demonstrate this, a generalized monobit test (expected ratio of ones and zeros can differ from 50:50) is also implemented in our system.

C. Long term statistics

Long term statistics can be calculated using relevant information collected from the processes, which is stored in the form of log files. Whenever a test is executed, the resulting p-value and the length of the tested string is saved. In some cases, other test specific auxiliary values are collected too. This can allow for the construction of tests similar to the one from which the data is collected, but spanning a wider range of data, effectively realizing an expanded version of the original. In the case of the monobit test, for example, it means the following: The test uses an internal sum calculated from the difference between the number of ones and zeros in the examined sequence, adding +1 to it for each bit which is one, and -1 for each zero. The p-value is then calculated from the normalization of this sum by the square root of the sequence length. By saving this sum and the number of examined bits, an extended monobit test can be constructed for the whole log file, aggregating the information from all the smaller tests. Similar extended versions can be made from other tests that use easily extractable metrics for calculating their results. From the 15 STS tests these are:

- Runs test: sequence length, ratio of ones, number of runs.
- Test for the longest run of ones in a block: length and number of tested blocks, counts in internal cells.
- Binary matrix rank test: number of blocks, number of full rank and full rank-1 matrices.
- Cumulative sums (cusums) test: sequence length, largest excursion, excursion at the end of the sequence.
- Random excursions test: sequence length, internal excursion statistics, excursion at the end of the sequence.

Another more generalized way to summarize information is the use of KS tests [26][27]. The expected distribution of p-values is uniform, so statistical tests can be run to verify this. The KS test is one such test, examining the deviation of the actual results from this expectation and producing a new p-value accordingly. When enough of these new values are collected the test can be run on them again, resulting in p-values representing more and more tested data. Theoretically, for non-random sources, the results of these repeated tests tend to zero over time. Keeping track of how many bits of data each p-value represents and only testing values representing the same amount of data together, a hierarchical structure can be followed for aggregation. Ideally with this method limitless data can be summarized, however, due to limited computational precision and errors adding up more and more, this is not possible for practical use cases as the results get skewed by these factors. These operations are also computationally quite expensive, so depending on generator speed and available resources, suitable compromises for choosing logged data to be tested this way might have to be made.

VI. TESTING THE SYSTEM

Since the proposed hardware architectures in Section II-B are still under construction, we tested our system with available software PRNGs. For most test cases we used AES_RNG with the Crypto++ C++ library [28]. The main expectation towards the test generator is good enough short term behavior to pass initial randomness testing, which it satisfies, allowing us to test error detection capabilities. (The nominal operation of the generator must produce good enough randomness to not be seen as errors to the system.) In long-term statistics, the weaknesses of this generator can be seen however, as the results from KS testing start to tend to zero after some hours of operation. This is most probably due to the combination of using a deterministic algorithm with the relatively weak internal entropy source of the test computer. Interestingly, for the log data of short monobit tests, the resulting aggregated

TABLE II
TEST RESULTS FOR THE 49:51 UNEVEN INPUT DISTRIBUTION

Test	Pass	Fail	Percent
cusums	109	3	2.7%
dft	3	0	0%
longest_runblock	108	4	3.6%
monobit	441	7	1.6%
monobit_long	6	9	60.0%
monobitblock	111	1	0.9%
runs	15	0	0.0%
serial	27	1	3.6%

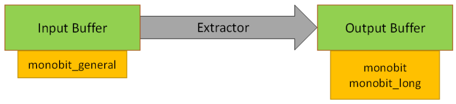

Fig. 3. Configuration for testing modified monobit test and error correction with extractor

p-values reached zero for all KS tests (using 10000 samples each), while in other weak cases only a tendency towards zero is observed. This implies that this phenomenon is not due to the weakness of the generator. One possible explanation is that a monobit test processing an n bit long sequence can only have n different outputs as p-values, resulting in only n different samples for the KS tests, leading to a non-uniform distribution. The NIST input size recommendation for the monobit test is minimum 100 bits, however, results from our longer 1024 bit variant still exhibit this when used directly for long term statistics calculations. Using the special, extended version of the monobit test utilizing auxiliary logged information, creating p-values for bigger chunks of data before KS testing can solve this problem.

To achieve effective real-time monitoring, possible hardware faults have to be detected as they occur. One such fault may be the sudden shift of the ratio of ones and zeros. This is easily simulated and can be a likely error type, especially for the first proposed hardware architecture. (For example, by some unexpected photon loss in one of the paths.) We simulated two error cases: one with the ratio of 45:55 and another with 49:51. In the first simulation, the difference from uniformity is so big that most tests fail (which is expected). The results from the second simulation can be seen in Table II.

Only faster tests (low latency) are shown in the table. We expect the monobit test to be the most sensitive to this error type, so we ran two instances of it. One with 1024 bit sequence length and another with 32768. The results show the longer version of the monobit test to be the most sensitive, while other test statistics are getting much closer to normal, surprisingly including its shorter version too. This demonstrates that for detecting even finer differences, longer, higher latency tests are needed, thereby calling for a compromise between detection speed and sensitivity.

With this simulated error, the generalized, modified for this non-uniformity variant of the monobit test can also be examined. A block diagram of this can be seen in Figure 3.

This layout also shows the correct operation of the implemented extractor. We used the 45:55 ratio error case as it represents a bigger deviation to be fixed. The results can be seen in Table III.

TABLE III
RESULTS FROM THE TEST CASE CORRESPONDING TO FIGURE 3

Test	Pass	Fail	Percent
monobit	6473	63	1.0%
monobit_long	203	1	0.5%
monobit_general	46020	565	1.2%

The results meet our expectations: the failure rate is around 1% and the speed loss caused by the extractor is also apparent, as the monobit and monobit_general tests have the same sequence length, effectively showing the reduced bit rate as a difference in total runs. (Since the main goal is to test the operation of the system, a rather "safe" extraction method is used, not prioritizing extraction efficiency)

We also investigated the computational need of each test by measuring execution time inside the processes. These results are not hardware-independent but can be used to roughly compare the tests to each other. Results using a virtual machine utilizing 4 threads of a 5-year-old Intel i7-4710HQ laptop processor can be seen in Table IV. This benchmark can serve

TABLE IV
EXECUTION TIME OF TESTS AND CORRESPONDING PROCESSING SPEEDS.

Test	avg. time	min. time	avg. kbit/s	max. kbit/s
approxentropy	3737ns	3482ns	2140	2297
cusums	958ns	240ns	8348	33000
dft	838ns	507ns	9543	15770
excursions	562ns	527ns	14220	15770
linearcomplex	122433ns	121778ns	65	65
longest_runblock	406ns	173ns	19667	46022
matrix	1183ns	1119ns	6758	7143
mauer	1140ns	1052ns	7016	7599
monobit	107ns	18ns	74147	442810
monobit_long	135ns	18ns	58982	442810
monobitblock	948ns	384ns	8431	20791
runs	315ns	55ns	25378	143091
serial	4111ns	1978ns	1945	4043
template	88539	87741	90	91

as a starting point when choosing tests we want to run in real-time, as our limited computational resources may not be able to run certain tests at the necessary speeds to keep up with the incoming data stream. Simpler tests tend to run faster, potentially reaching speeds up to 400 Mbits/second even in this suboptimal environment, while for other, more complicated ones it can be said with high confidence that we won't be able to run them real-time with a decent entropy source.

VII. CONCLUSION

In this paper, we presented a system capable of realizing output based real-time monitoring for random number generators while providing possibilities for analyzing long term behavior too. In the absence of the planned entropy sources, we utilized readily available pseudo-random number generators to simulate probable situations the system needs to be able to handle, validating our design. While doing so, we also examined the future applicability of the tools available in this framework.

The next logical step is to pair the system with the proposed hardware as construction reaches a prototype state and optimize the monitoring tools used for this specific use case. Although the main goal was adequately supporting particular architectures, since the input of the system is only the raw data stream, it can be paired with other generators too. The flexible modular nature allows for the analysis of the tools within given a known, etalon generator. To effectively realize this potential in the future, however, some additional development aimed at easier usability for potential users not yet familiar with the code might still be needed.

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