Computing Information for Intelligent Society. Info-Computational Approach to Decision Making

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Introduction

With the powerful development of pervasive information-based technology, especially intelligent computing, the question arises: How do we imagine future highly developed and humane (human-centered) intelligent information society? The answer will of course vary depending on time perspective. In a shorter-time perspective we can try to anticipate based on the existing trends in the development. The first step is to understand the current state of the art of intelligent technologies uses towards intelligent society. A longer-term perspective is more uncertain, as new intelligent technologies, especially in combination with biotechnologies and human augmentation and enhancement will be changing both the ways of being human as well as the structures and behaviors of human societies, as argued by (Wu & Da, 2020) under the heading "The Impact of Intelligent Society on Human Essence and the New Evolution of Humans".

Wu and Da anticipate that the development of widely used AI technologies will lead to the evolution of the "human essence" that will lead to the convergence between social and biological evolution. That is a radically optimistic view which declares equality between the increase in human freedom with the disappearance of necessity of regular human labor as a means to assure physical existence. In the future intelligent automated society, machines will secure material basis of existence for everybody. It will remain on humans how to meaningfully use this newly conquered space of freedom.

According to Wikipedia,

"Intelligent information society is a hypothetical social organization. It is defined by data created, collected and accumulated through advanced information, communication technology infrastructure and artificial intelligence (AI). (…) Data, knowledge and information hold greater value compared to traditional production factors (labor and capital) in this type of society. As technology advances and automation increases, intelligent machines eventually replace human cognitive capabilities."

(Retrieved from https://en.wikipedia.org/wiki/Intelligent_information_society)

Starting from the above view of intelligent society of the future, we will certainly continue to learn about possibilities of technologies and their societal and ethical consequences, so numerous questions arise, such as:

— Do we really want machines to *replace* human cognitive capabilities?
— What would be the role of intelligent machines and programs that process information (compute) for the *benefit* of society and individual humans?
— How does *computing* (information processing) affect the development of the envisaged "*intelligent society*"?
— How do we imagine *information, its structures and processes* in such an "intelligent society"?

The first question of the relationship between increasingly intelligent machines and their networks and humans have been addressed by Hofkirchner's in his Xi'an Senior Forum talk titled *Artificial Intelligence: "Machines of loving grace" or "Tools for conviviality"?* which addresses the relationship between highly developed artificially intelligent machines and humans. Hofkirchner expresses the hope that we will not end in a situation where machines (not even a most benevolent ones) completely decide and determine human lives. The proposed better relationship between intelligent machines and humans is "conviviality", not only coexistence, but mutually benevolent concomitance. In this respect we should distinguish two directions of the development towards increased individual and social intelligence:

- Humans enhanced ad augmented by intelligent technology that would increase human intelligence where humans in form of cyborgs increasingly approach designed artifacts (machines)
- Machines that develop towards human characteristics, including emotions, complex behaviors and capabilities subtle reasoning, thinking, dreaming and other capacities of human cognition

In the process of emergence of human-centered intelligent information society we expect information and data to be used for deducing/computing new information that we need for understanding the world, living in the world, decision making, and more. We talk about the envisaged disruptive techno-social process of the fourth industrial revolution (Floridi, 2014) that will provide material basis for the new society and fundamentally change its current structures, processes and relationships.

"In the Fourth Industrial Revolution, the convergence of artificial intelligence, robot technology, big data and software disrupts fields such as labor, welfare, employment, education and defense. This has sparked revolutionary change across society."
(Retrieved from https://en.wikipedia.org/wiki/Intelligent_information_society)

In parallel with the development of ICT, Information and computation are becoming ubiquitous and essential for human society, globally, on different levels, for different social groups and purposes. As participants in a major technological and cultural change caused by ICT, *we want to be able to understand ongoing processes and to anticipate future possibilities. When we introduce changes in the society, we want to know their consequences as much as possible.*

Programs of social change always envisage certain goals, but it is often not clear how those goals can be reached, and there is no guarantee that the measures applied indeed will help

reaching declared goals. The lack of understanding of possible outcomes of interventions in extremely complex and sensitive social fabric of relationships (Brown and Duguid, 2017) can result in decisions and other changes, that can lead to unexpected and unfavorable development as unintended consequences.

Social decision making & social computing

At present, societal decisions are made based on *intuitions* (derived from previous experience) of responsible leaders. But, cognitively, as social agents, we have intuitions on the individual level, which are by necessity limited. Humans think and experience society from an individual point of view, where personal environment plays more prominent role than the other parts of society of which one does not have knowledge or experience.

Info-computational techniques can augment personal intuitions and enlarge understanding on a social level. They can provide tools to augment our everyday understanding, similar to Google earth tool (https://earth.google.com/) which is extending our intuitions about the spatial relationships on the Earth, where we can experience zooming in, and zooming out through many orders of magnitudes of scale, connecting microscopic and macroscopic worlds, which give us completely new perspectives, unlike our everyday ones. Similarly, possibility of changing perspective is given in the video presenting Ultimate Zoom in steps of Powers of Ten (https://www.youtube.com/watch?v=bhofN1xX6u0 Powers of Ten - Ultimate Zoom (micro-macro - Imax combined). Likewise, data-visualization computational tools augment human cognition helping us increase our understanding and can be used to support decision-making.
In the development towards intelligent society, we will increasingly rely on intelligent computational technology to augment our intuitions and understanding. But technology in itself is not enough, it is still only the means to supporting human judgment. We are far from intelligent machines *replacing* humans, and for a foreseeable time we are at the stage of machine intelligence supporting and enhancing human intelligence.

As an illustration, in this paper I will discuss an example of contemporary computational modelling support for the decision-making in the case of the actual Covid-19 pandemics where computing/(data)information processing and communication technologies played central role, unprecedented in human history, all over the world in supporting human decision making by intelligent forecasts.

Two aspects of social computing

One important factor in the human development of prosperous global society is grasp *of the behavior of social systems*. Computing as a tool provides means for this understanding in a form of computational models, simulations and learning technologies. Recently there are especially successful technologies of deep learning that are being developed towards increasing intelligence.
There are two different types of **social computing** (Wang et al., 2007), centered on its two different aspects:

1. **Computational aspects - mechanisms and principles of social computing** with computational modeling of groups of agents exchanging information in networks and

2. **Human aspects of social computing** (with corresponding critical theory), with social side of social web applications such as blogs, wikis, social bookmarking, instant messaging, and social networking sites and crowdsourcing.

This article will address both computational and human aspects of social computing and its relation to computational models in the coming decade.

Computers as communication devices

Computers were originally invented to **automatize calculations,** based on the Hilbert program for axiomatization of mathematics (Hilbert, 1900) and the Turing Machine model of computation (Turing, 1936). However, after the initial period of use of computes as solely computational tools, the importance of the computer as a **device for *communication* of data and information was recognized**, with its consequent shared knowledge and community building, (Licklider and Taylor, 1968). The phenomenon of the World Wide Web and Internet transformed quickly networks of computing machinery from sheer calculational devices to social space for human communication.

Having in mind that computers automatize originally human ability to process data, from the point of view of data processing, not only individuals but also human groups can be seen as information processing networks and knowledge generators. Let us have a brief look on the idea of networks of human agents exchanging (communicating) information. We will use this parallel between networks of computational agents and human social networks.

Conceptual basis for modeling of behavior of society: network models

Complexity of behavior in societies of agents can be described by networks of networks of information processing agents (nodes). Computational approaches to complex systems can be based on **descriptive** or **generative models.** Generative models are used to answer the question: How does the complexity (emergent properties) arise? Evolution of life is the most well-known generative mechanism for creating increasingly complex networked systems - evolving living organisms. (Dodig-Crnković, 2011, 2016, 2017, 2020)
" … systems that comprise many interacting parts with the ability to generate a new quality of collective behavior through self-organization, e. g. the spontaneous formation of temporal, spatial or functional structures. They are therefore adaptive as they evolve and may contain self-driving feedback loops.
Thus, complex systems are much more than a sum of their parts. Complex systems are often characterized as having extreme sensitivity to initial conditions as well as emergent behaviors that are not readily predictable or even completely deterministic." (Meyers, 2009)

Consequently, social systems being complex systems are neither readily predictable nor completely deterministic and it takes science and art of intelligent adaptive complex system management to get desired changes implemented. Intelligent computational techniques are of great help in this process.

Generative approaches. Agent-based Models (ABM)

An agent can be defined as an entity capable of acting on its own behalf (autonomously).

An **agent-based model (ABM)** is a computational model for simulating the actions and interactions of autonomous individuals in a network, that enables assessing their effects on the system as a whole. They are typically used in study of **complexity** and **emergence**.
Agent-based models combine elements of game theory, complex systems, emergence, computational sociology and evolutionary programming. For simple explanation, see (http://en.wikipedia.org/wiki/Agent-based_model)

Agent-based models in general are used to model complex, dynamical adaptive systems. The interesting aspect in ABMs is the link between micro- (individual agent) and macro- (society of agents) level.

Multi-Agent Systems (MAS) models may be used for any number (in general heterogeneous) entities (agents), which can be modeled explicitly and spatially separated by the environment. Interactions between agents are in general **asynchronous** which adds to the realism of simulation. (Dodig-Crnković, Rotolo, Sartor, Simon, and Smith, 2012)

ABM simulation techniques are used to facilitate the study of society and to support decision-making policies, helping to analyze how changing policies affect social, political, and cultural behavior (Epstein, 2007).

Information, computation, cognition in agency-based hierarchies of levels
Emergence of global social computing. Towards social intelligence

With regard to the human aspect, social computing is radically changing the character of human relationships worldwide (Riedl, 2011). Instead of maximum 150 connections prior to ICT, (Dunbar, 1998), social computing easily enables individuals to maintain networks of several hundred of contacts. It remains to understand and see what type of society will emerge from such massive "long-range" distributed interactions, instead of traditional fewer and deeper short-range ones focused on the immediate physical contacts.

In this process, information load on individuals is steadily increasing, and social computing technologies are moving beyond simple social **information communication** toward **social intelligence**, (Zhang, Guo, Yu, 2011) (Lim, Stocker, Larkin, 2008) (Wang, Carley, Zeng, Mao,

2007), which brings an additional level of complexity. The question is what form of social intelligence can be beneficial for human as individuals, societies and humanity as a whole.

Computational models can be excellent tools for analysis of social phenomena as they give us an overview and possibility to study different possible scenarios in the development of social systems. They can be used for adaptive dynamical social control. However, they cannot replace good human judgment.
All simulations depend on the assumptions of the model, and on the input data. This leads to two types of errors in simulations: model-driven & data-driven. (Orbanna et al., 2017)

Social computing can be expected to develop into everyday tools for decision-making, concerning social phenomena – in economics, government, business, medicine, bioinformatics, epidemiology, politics, urban planning, etc. They should be used as tools to assist human intuitions and judgment, not to replace it.

Open theoretical questions on the path of understanding intelligence, natural and artificial

Intelligence is a capacity of agents developed through information processes, (Dodig Crnković and Stuart, 2007), and as Brenner pointed out in his Senior Forum talk, "all the complex processes necessary for the common good are multi-level and recursive." This fundamental requirement for multi-level organization can be found in Deacon's talk from this Forum titled "The hierarchic nature of the information concept emphasizing three erroneous assumptions of Information Philosophy that have been impeded the development, which supposed:
1. that information is a single level concept while it is a *nested hierarchy of concepts*
2. that language captures generic information relationships in which reference can be understood as *arbitrary mapping*
3. that only intrinsic structural information is physical and that referential and normative information relationships are "subjective" and epiphenomenal.
Deacon (2011) described in his book Incomplete nature the distinction between the following three forms of information:
1. Information 1 (Shannon) (data, pattern, signal) (data communication) [what it exhibits—syntax]
2. Information 2 (Shannon + Boltzmann) (intentionality, aboutness, reference, representation, relation to object or referent) [what it conveys—semantics]
3. Information 3 ((Shannon + Boltzmann) + Darwin) (function, interpretation, use, pragmatic consequence) [what it's for—pragmatics]
As presented by (Dodig-Crnković, 2012), in the framework of info-computationalism, all three types of information are considered as different levels of organization of information, starting from proto-information (The thing-in-itself (Kant: Ding an sich)) and through the interaction becomes the difference that makes a difference for an agent. In an agent they take the form of actual information by the process of connecting (relating) to the existing informational structures of the agent. In the next step this information will be used by the agent to act upon and thus it will exhibit meaning as Deacon's ((Shannon + Boltzmann) + Darwin) Information 3.

However, it is worth noticing that all three Deacon's information types only differ in structure, and not in fundamental constituents, which are basic data or Bateson's differences. Deacon's three types of information parallel his three levels of emergent dynamics, which in Salthe's notation looks like:
[1. thermo- [2. morpho- [3. teleo-dynamics]]]
with corresponding mechanisms
[1. mass-energetic [2. self-organization [3. self-preservation (semiotic)]]]
and corresponding Aristotle's causes
[1. efficient cause [2. formal cause [3. final cause]]]

Deacon shows in his Senior Forum talk how much work still remains for us in the field of the foundations of information that will clear the conceptual confusions and provide basis for understanding of intelligence, meaning and values.

In the search for the new common ground, Marijuán addresses the "Common Mission of Information Science and Information Philosophy" the important insight shared with (Wu, 2016) and (Wu and Brenner, 2017).
According to Marijuán talk, the goal is "achieving balance and collective wisdom upon human needs and nature and addressing the planetary challenges of sustainability."

Even with the convergence between Information Philosophy and Information Science, which is a major step, there are still questions to be addressed within both Information Philosophy and Information Sciences – they both as a rule are still interested in single-level phenomena studied in isolation.

Zhong talk in the Forum, "Great Challenges to The Studies of Information" presents yet another field for development - Information ecology. In a way Multi-level hierarchy of information (Burgin and Dodig Crnković, 2020) and may be seen as an aspect of information ecology. Zhong sees the root cause in the methodology of "Divide & Conquer" which is dominant in contemporary thinking and proposes a paradigm shift from the "Pure Formalism" toward the methodology of Holism – connecting Form with Value and Meaning. In this new scheme, the important role of emotion for intelligence is acknowledged.
The way towards this envisaged future goes through processes of changes that require transcending our current ideas, way of thinking and methodologies.
So, the understanding of the process of change is central, as presented by Brenner at this Forum. However, there is a problem and necessity of changed thinking and methodology even here:
"Western theories of change, however, have focused on making it mathematically, computationally and logically tractable, within the framework of standard logic. In fact, change is contradictory: it is regular and irregular; consistent and inconsistent; continuous and discontinuous. Since the only logics available have been propositional bivalent logics, incapable of accepting real contradictions, they have been incapable of describing change." (from the talk

by Brenner, "Philosophy, Information, Intelligence, Society; A Complex Cognitive Ontolon") Here, "Ontolon" is unit of existence.
This topic is even further developed in (Brenner and Igamberdiev, 2021). Both study of information (structure) and computation (information processes) are necessary for achieving a new understanding of change, as argued in (Dodig-Crnković, 2012), "Physical Computation as Dynamics of Form that Glues Everything Together".

The above are some of ideas about the necessary theoretical and methodological developments paving the way towards intelligent society.

An actual example. Managing a Covid-19 pandemic

As an illustration of the power of info-computational models in intelligent support of well-informed decision-making let us have a look at the current example of Covid-19 pandemic. In the beginning of the pandemic, several computational models have been proposed, illustrating the influence of various factors on the spread of epidemic such as "The hammer and the dance model" providing assessment of different interventions (see Covid-19 links) However, not many decision-makers were ready to use those info-computational AI- based tools in decision making.

One of the most important aspects is humanistic approach to the use of digital technologies in Covid-19 management (Digital Humanism & Covid-19 simulations) addressed by The Digital Humanism movement, originating at the TU Vienna, based on the scientific approach in the tradition of the enlightenment, transdisciplinarity, interdisciplinarity, and multidisciplinarity.

Digital humanism is a global, international issue. People are in the focus, as individuals and societies. Technology is for people and not the other way round. Humankind is at the focus, building just and democratic society with humans at the center of technological progress.

Emerging AI technology has been used in variety of ways to help adequate response to the pandemic. They include the search for a cure, with AI-generated predictions of the virus structure, and 3D model visualizations, as well as a support to the authorities by big AI tech companies with computing power for processing of huge amounts of data in epidemiology, bioinformatics and molecular modelling. AI was a driving force for knowledge discovery, generation and sharing through analysis of enormous amounts of papers published globally on the pandemic. Artificial intelligence was also used for observation and prediction of the evolution of the pandemic, for the early detection of the virus and to track the spread of the coronavirus. For example, Google Maps have a Covid-19 overlay, based on the data from Johns Hopkins, *The New York Times*, and Wikipedia, presenting the weekly average of confirmed cases in an area. Instagram has a site which presents the speed of Covid-19 at the state level.

AI was used as a source of information for policy makers, in planning of Covid-19 measures. It was used as a reliable information source for the media and the public and it enabled observation of emerging trends in the pandemics.

In healthcare, AI was used to assist healthcare personnel with coronavirus diagnostic software and real time simulation-based decision support in health care systems. It was also a useful tool in logistic and prediction of needs of healthcare. Data about available healthcare and other resources and their dynamical (real-time) allocation, maintenance and adaptation. Intelligence was used in planning, optimization, prediction, information to involved stakeholders.

One of the examples where there is still a lot of controversy is AI as a tool for population control, with mass surveillance policies and corona contact tracing (Morley, Cowls, Taddeo, Floridi, 2020) (Vinuesa, Theodorou, Battaglini, Dignum, 2020)(Taddeo, Floridi, 2018) A socio-technical framework for digital contact tracing. Results in Engineering Vol. 8, December 2020, 100163). Singapore and China were examples of efficient use of those techniques in Covid-19 crisis, while many countries could not find consensus in application of radical lock down or population control measures.

The role of governments and tech giants is central, and it must be assessed as "lessons learned" and cost-benefit analyzes, that will enable better preparedness globally for the threat of new pandemic. (COE, 2020)

Pandemics is a complex dynamic system and strategies have been developed to control it info-computationally.
Data-based and evidence-based decision-making and control have been proven essential for adequate policies. In order to control a pandemic in an efficient way, successful policies are needed based on reliable information, which in turn is based on reliable and extensive (big) data. As we have seen, computational resources have been heavily engaged in epidemic control: data collection about individuals and their behavior (including testing and contact tracing) in order to contain infections. This has been made possible by moving, among others: work, schools, cultural events, research, shopping, governmental and healthcare functions online – all of which is based on info-computational technologies.

Central property of intelligence is ability to learn and learn to learn. Covid-19 pandemic is the prime example of the global opportunity for humanity to learn, solving common, global problem.

Conclusions and future work

Science, research, innovation and technology are essential for the development of humane intelligent society. Currently people are mostly focusing on the advances of Artificial Intelligence and particularly Deep Learning technologies, which are rapidly developing and have manifold of problems to solve in the future. One of those is meaning (semantics) of information that artificially

intelligent machines process. The others are emotions, values, imagination, and similar aspects still missing in intelligent artifacts. In this paper, as well as in the Xi'an Forum talks, challenges for methodological and theoretical developments in Information Philosophy, and Information Sciences, with manifold of related fields, have been addressed. We emphasize necessity of new understanding of informational phenomena taking into account multi-layer recursive nature of information (Burgin and Dodig Crnković, 2020), as well as its ecology, logic capable of dealing with change, and adequate computational models.

Our civilization relies heavily on technology, and the prospect of knowledge-based intelligent society is connected to variety of data-/information- processing (computation) technologies. We should keep in mind that existing technologies present embodiment of present understanding of information and intelligence, and that new suggested developments will results in new and more powerful technologies.

It is also good to remember that changing ways of learning, communication, processing and memorizing information changes human nature, "human essence" (Wu & Da, 2020 that is constantly evolving, which results in change of values and priorities.

Technologies provide tools and their role is to support the development of the new ethical and good, humane intelligent society (Floridi et al., 2018)(Cath, et al., 2018) Intelligent technologies require resources to develop, design, produce, adopt by users, maintain and finally decommission/recycle their products. They are costly both in terms of invested time and materials (environment) and should be used wisely. Our trust in future intelligent society depends essentially on our assessments of its benefits and costs.

In this context, it is worth mentioning the importance of development of a new culture of learning (Thomas and Brown, 2011) where the emphasis is on cultivating the imagination for a world in transformation, also known as a „white-water world", undergoing constant and dramatic changes.

What we can say already now, at this stage of the development of intelligent society, intelligent technologies based on scientific approaches in combination with natural human intelligence have shown decisive in such an unprecedented global crisis caused by Covid-19 pandemic. This is only an example of situation where societies globally were faced with the necessity of quick and informed intelligent decision making, which is only one expression of the capabilities of intelligent societies. Lessons learned from this crisis with respect to the use of intelligent decision-making technologies will be valuable in filling the notion "intelligent society" with a concrete real-world content.

REFERENCES

Brenner J.E., Igamberdiev A.U. (2021) Philosophy in Reality. Studies in Applied Philosophy, Epistemology and Rational Ethics, vol 60. Springer, Cham.

Brown, J.S., Duguid, P. (2017) The Social Life of Information. Harvard Business School Publishing Corporation, Harvard, US.

Burgin, M. and Dodig Crnković, G. (2020) A Multiscale Taxonomy of Information in the World. In: Burgin & Dodig Crnković (2020) THEORETICAL INFORMATION STUDIES: Information in the world (Book) World Scientific Series in Information Studies, Vol 11. World Scientific, Singapore. https://www.worldscientific.com/worldscibooks/10.1142/11191

Cath, C., Wachter, S., Mittelstadt, B., Taddeo, M. & Floridi, L. (2018) Artificial intelligence and the 'good society': the US, EU, and UK approach. Sci. Eng. Ethics 24, 505–528.

COE (2020) AI and control of Covid-19 coronavirus https://www.coe.int/en/web/artificial-intelligence/ai-and-control-of-covid-19-coronavirus

Deacon, T.W. (2011) *Incomplete Nature*: *How Mind Emerged* from Matter; W. W. Norton Company: New York, NY, USA.

Dodig Crnković, G. and Stuart, S. (2007) Computation, Information, Cognition. Cambridge Scholars Publishing, Cambridge, UK.

Dodig-Crnković, G. (2011) Dynamics of Information as Natural Computation, Information, 2(3), 460-477; doi:10.3390/info2030460 Special issue: Selected Papers from FIS 2010 Beijing Conference, 2011. http://www.mdpi.com/2078-2489/2/3/460/

Dodig-Crnković, G. (2012) Physical Computation as Dynamics of Form that Glues Everything Together, Information (doi:10.3390/info3020204) Special Issue on Information: Its Different Modes and Its Relation to Meaning, 3(2), 204-218

Dodig-Crnković, G. (2016) Information, Computation, Cognition. Agency-Based Hierarchies of Levels. FUNDAMENTAL ISSUES OF ARTIFICIAL INTELLIGENCE, Müller V. C. (ed.), Synthese Library 377, pp 139-159. Springer International Publishing Switzerland, DOI 10.1007/978-3-319-26485-1_10 http://arxiv.org/abs/1311.0413

Dodig-Crnković, G. (2017) Nature as a Network of Morphological Infocomputational Processes for Cognitive Agents, The European Physical Journal Special Topics, DOI: 10.1140/epjst/e2016-60362-9 Eur. Phys. J., 226, 181–195.

Dodig-Crnković, G. (2020) Morphological Computing in Cognitive Systems, Connecting Data to Intelligent Agency Proceedings 2020, 47, 41.

Dodig-Crnković, G.; Rotolo, A.; Sartor, G.; Simon, J. and Smith C. (Ed) (2012) Social Computing, Social Cognition. Social Network and Multiagent Systems. Social Turn - SNAMAS 2012 AISB/IACAP World Congress 2012. Birmingham, UK, 2-6 July 2012. ISBN 978-1-908187-18-5 http://events.cs.bham.ac.uk/turing12/proceedings/11.pdf

Dunbar R. (1998) Grooming, Gossip, and the Evolution of Language, Harvard Univ. Press.

Epstein, J. M. (2007) Generative Social Science: Studies in Agent-Based Computational Modeling. Princeton University.

Floridi, L. (2014) The fourth revolution: How the infosphere is changing human reality, Oxford University Press. Oxford, UK.

Floridi, L. et al. (2018) AI4People—an ethical framework for a good ai society: opportunities, risks, principles, and recommendations. Minds Mach. 28, 589–707

Hilbert, D. (1900) "Mathematische Probleme", Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen, Math.-Phys. Klasse, 253-297. Lecture given at the International Congress of Mathematicians, Paris.

Licklider, J.C.R. and Taylor R. W. (1968) The computer as a communication device. Science and Technology (September), 20-41.

Lim, H. C., Stocker, R., Larkin, H. (2008) Ethical Trust and Social Moral Norms Simulation: A Bio-inspired Agent-Based Modelling Approach. In: 2008 IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology, pp. 245-251.

Meyers, R.A. (Ed) (2009) Encyclopedia of Complexity and Systems Science. Springer, New York, NY.

Morley, J., Cowls, J., Taddeo, M., Floridi, L. (2020) Ethical Guidelines for SARS-CoV-2 Digital Tracking and Tracing Systems (April 22, 2020). http://dx.doi.org/10.2139/ssrn.3582550

Orbanna C, Sattenspiel L, Miller E, Dimka J. (2017) Defining epidemics in computer simulation models: How do definitions influence conclusions? Epidemics. Vol. 19, pp. 24-32

Riedl, J. (2011) "The Promise and Peril of Social Computing", Computer, vol.44, no.1, pp. 93-95

Taddeo, M. & Floridi, L. (2018) How AI can be a force for good. Science 361, 751–752.

Thomas, D. and Brown, J.S. (2011) A New Culture of Learning: Cultivating the Imagination for a World of Constant Change 1st Edition ISBN-10: 1456458884. CreateSpace Independent Publishing Platform, US.

Turing, A.M. (1936) On Computable Numbers, with an Application to the EntscheidungsproblemÊ. Proceedings of the London Mathematical Society, series 2, 42:230-265.

Vinuesa, R., Theodorou, A., Battaglini, M. Dignum, V. (2020) A socio-technical framework for digital contact tracing. Results in Engineering Vol. 8, December 2020, 100163

Wang, F-Y., Carley, K.M., Zeng, D., and Mao, W. (2007) Social Computing: From Social Informatics to Social Intelligence. IEEE Intelligent Systems 22, 2, 79-83. DOI=10.1109/MIS.2007.41

Wu, K. (2016) The Interaction and Convergence of the Philosophy and Science of Information. Philosophies, 1, 228-244.

Wu, K., Brenner, J. (2017) Philosophy of Information: Revolution in Philosophy. Towards an Informational Metaphilosophy of Science. *Philosophies*; 2(4):22.

Wu, K., Da, K. (2020) "The Impact of Intelligent Society on Human Essence and the New Evolution of Humans" *Proceedings* 47(1):44.

Zhang D., Guo B., Yu, Z. (2011) Social and Community Intelligence, Computer, Vol. 99, No. PrePrints. doi:10.1109/MC.2011.65

TALKS

Senior Forum on The Philosophy of Information and the Development of Intelligent Society
Xi'an Jiaotong University, Shaanxi, China, September 12-13 2020

Brenner, J. – Philosophy Information, Intelligence, Society; A Complex Cognitive Ontolon

Hofkirchner, W. - "Machines of loving grace" or "Tools for conviviality"?

Zhong, Yixin – "Great Challenges to The Studies of Information"

Marijuán, Pedro C. – "The Common Mission of Information Science and Information Philosophy"

Deacon, T. – "The hierarchic nature of the information concept"

Dodig-Crnković G. "Computing Information for Intelligent Society. Info-computational Approach to Decision-making"

LINKS

Covid-19 simulations

https://www.youtube.com/watch?v=gxAaO2rsdIs&feature=youtu.be Simulating an epidemic, 3Blue1Brown (video)

https://medium.com/@tomaspueyo Tomás Pueyo, articles

https://tomaspueyo.medium.com/coronavirus-the-hammer-and-the-dance-be9337092b56 The hammer and the dance

https://www.youtube.com/watch?v=LE8uJcnvm5E (Part 1, video)

https://www.youtube.com/watch?v=5pJGQIV0CJg (Part 2, video)

https://www.youtube.com/watch?v=gyaevOeQHQA (Part 3, video)

https://www.youtube.com/watch?v=OEVDzOFj2JI Cambridge Adjutorium in the response to COVID19 - hospital-level projections of upcoming demand for ventilators and ICU beds.
https://www.vanderschaar-lab.com/covid-19/ van der Schaar Lab and COVID-19

https://engage.aps.org/communities/community-home?CommunityKey=f6e05446-ccb9-44e2-959f-4b20034f0fa5 COVID Research and Resources Group brings physicists together

Digital Humanism forum

https://www.youtube.com/results?search_query=Digital+Humanism+from+Covid-19 Digital Humanism & Covid-19

https://youtu.be/FKN2feOdGO8 Corona Contact Tracing – The Role of Governments and Tech Giants

https://www.youtube.com/watch?v=VTcAiiYnPPw&list=PLKsY-6BoMQ8Ild7x2yRWZ4nApmS2PuDAP&index=4&t=0s An example where computational simulation tools have been used

All links retrieval date: 2021 01 18.