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Autonomous Systems and Artificial Intelligence in Healthcare Transformation to 5P Medicine – Ethical Challenges

Bernd BLOBEL[a,b,c,1], Pekka RUOTSALAINEN[d], Mathias BROCHHAUSEN[e], Frank OEMIG[f], Gustavo A. URIBE[g,h,i]

[a] *Medical Faculty, University of Regensburg, Germany*
[b] *eHealth Competence Center Bavaria, Deggendorf Institute of Technology, Germany*
[c] *First Medical Faculty, Charles University of Prague, Czech Republic*
[d] *Tampere University, Tampere, Finland*
[e] *College of Medicine, University of Florida, Gainesville, FL, USA*
[f] *Deutsche Telekom Healthcare and Security Solutions GmbH, Bonn, Germany*
[g] *The European Organization for Nuclear Research, Geneva, Switzerland*
[i] *Telematics Engineering Research Group, University of Cauca, Popayán, Colombia*

Abstract. The paper introduces a structured approach to transforming healthcare towards personalized, preventive, predictive, participative precision (P5) medicine and the related organizational, methodological and technological requirements. Thereby, the deployment of autonomous systems and artificial intelligence is inevitably. The paper discusses opportunities and challenges of those technologies from a humanistic and ethical perspective. It shortly introduces the essential concepts and principles, and critically discusses some relevant projects. Finally, it offers ways for correctly representing, specifying, implementing and deploying autonomous and intelligent systems under an ethical perspective.

Keywords. pHealth, P5 medicine, autonomous systems, artificial intelligence, ethical principles

1. Introduction

In many countries, specific initiatives and strategic programs are established and continuously updated, aiming at improving care quality, patient safety, and care process efficiency and efficacy, thereby moving from volume to value based care to respond to the challenges health systems face. Those challenges are, e.g., ongoing demographic changes towards aging, multi-diseased societies, the related development of human resources, a health and social services consumerism, medical and biomedical progress, and exploding costs for health-related R&D as well as health services delivery. Organizational, but especially by disruptive methodological and technological paradigm changes enable this move. The paper shortly introduces in those paradigm changes and the accompanying organizational and ethical challenges and proposes

[1] Corresponding Author. Bernd Blobel, PhD, FAACMI, FACHI, FHL7, FEFMI, FIAHSI, Professor, University of Regensburg, Medical Faculty; Regensburg, Germany; Email: bernd.blobel@klinik.uni-regensburg.de

principles and methodologies for mitigating them, thereby critically discussing some ongoing solutions and projects.

2. Methodological, Technological and Organizational Paradigm Changes

Methodologically, phenomenological and evidence-based medicine, both relying on population-based diagnostic models based on retrospective data sets, slowly evolve towards personalized, preventive, predictive and participative precision (5P) medicine. It considers individual health state, conditions and social, environmental, occupational and further contexts at bedside in relation to the community, fully understanding the specific pathology of the health problem [1]. This requires the multidisciplinary approach of systems medicine, deploying the explicit and enhanced knowledge of all stakeholders from the different domains to be involved including the subject of care in the center, replacing the observational and analytical medicine approach [1]. Christensen et al. described healthcare transformation as move from intuitive through empirical to precision medicine [2]. Involved disciplines/domains include medicine and public health, natural sciences, engineering, administration, but also social and legal sciences and the entire systems sciences world (systems medicine, systems biology, systems pathology, etc.). Organizationally, health systems transform from an organization-centric through a cross-organizational, pre-defined and process-controlled to a context-sensitive, individually tailored, highly dynamic, fully distributed personalized care paradigm. The latter is sometimes also called ubiquitous care or care anywhere at any time. With a stronger focus on the information and communication technology (ICT) support, thereby referring to pervasive computing technology, another term frequently used is pervasive care. Both described paradigm changes are supported, impacted or even enabled by related technological paradigm changes. Here have to be mentioned: Mobile, nano-, bio- and molecular technologies; artificial intelligence (AI); robotics; bioinformatics; big data and prescriptive (based on current data) as well as predictive (includes future outcome) analytics; natural language processing (NLP) and understanding (NLU); cloud computing; cognitive computing and social business; but also the Internet of Things (IoT) [3]. A more detailed description of health systems transformation is provided in [1].

We cannot place health and care specialists, educators, lawyers, etc., next to every person to be comprehensively served. Ubiquitous 5P medicine requires the deployment of robotics and artificial intelligence, or more generally autonomous and intelligent systems (AIS), aiming at [3, 4, 5, 6]:

a) capability and engagement augmentation for care provider and subject of care including education, access to information and services, thereby advancing accuracy, precision, location independency [7];
b) enabling cooperation;
c) improved staff and patient experience;
d) process improvement including clinical workflow and scheduling, but also business efficiency, productivity and cost containment as well as risk analysis;
e) facilitating faster and more precise decision at administration, direct and indirect caregiver, and patient level including prognosis;
f) collaborative business intelligence as self-service.

More details on types of artificial intelligence, services and related challenges especially in the health and social care context are provided, e.g., in [8].

Any action and relationship in enlightened democratic societies, but especially the health, care and welfare system have to accommodate legal, moral and ethical principles. In the next chapters, we will consider the different levels of AIS, reference moral and ethical principles, discuss initiatives and projects tackling the ethical challenges, and finally propose a sound approach for addressing this problem.

3. The Ethical Challenge of AIS

Social contracts and law define and enforce behavior for maintaining social order, peace, and justice in society. Ethics provides code and conduct guiding to decide what is good or wrong, and how to act and behave properly, thereby establishing as well as defending rules of morality and frequently going beyond the law [9]. With the evolution of societies including sciences and technologies, different approaches to, or theories on, ethics have been developed in the framework of meta-ethics, normative ethics and applied ethics. Here, Aristotle's and Plato's virtue ethics, Kant's deontological ethics, Mill's utilitarian ethics, and Rawls' justice as fairness ethics have to be mentioned [9]. Ethical values are strongly impacted by culture, social norms and geographic locations. Having the evolutionary characteristics of ethics and the terrific social and technological developments in mind, there is no chance for one global comprehensive standard of ethics. Instead, basic social ethical principles such as dignity, freedom, autonomy, privacy equality and solidarity, or the more technological categories like fairness, robustness, explainability, and lineage have been established. For bridging the gaps (at least partially), trust through transparency is discussed as solution [10]. Societal and policy guidelines help to remain human-centric by supporting humanity's values and those ethical principles [11]. There are many organizations and initiatives proposing ethical frameworks and design methodologies for AIS, such as the EU Council of Europe with its "Guidelines on Artificial Intelligence and Data Protection", the Future of Life Institute with the "Asilomar AI Principles", IEEE with "The IEEE Global Initiative on Autonomous Systems", the U.S. Congress Resolution "Supporting the Development of Guidelines for the Ethical Development of Artificial Intelligence", the OECD "Principles for AI Research and Development" proposed by the Conference Toward AI Network Society, April 2015, in Japan, The World Economic Forum "Top Ethical Issues in Artificial Intelligence", and many others. An overview about those initiatives, some content details and references are provided in [8]. Table 1 summarizes the common principles of some of them.

Table 1. Common ethical principles proposed by different organizations

Guideline Originator	Transparency	Accountability	Controllability	Security	Value Orientation Ethics	Privacy	Safety	Risk	User Assistance
OECD	x	x	x	x	x	x	x		x
IEEE	x	x	x		x	x		x	x
Asilomar	x	x	x	x	x	x	x	x	
US Congress	x	x	x	x		x	x		x
World Economic Forum				x	x			x	

4. Representing/Modeling Ethical, Moral and Legal Concepts

Ethics and morality are complex humanistic domains with social, legal, religious and philosophical impact. Their concepts, relations and constraints on them can be represented but not be defined and justified in ICT viewpoints due to the context-free, highly expressive and formal languages deployed, resulting in inconsistent, indefinite and incomplete models. Instead, the concepts, relations and constraints of the domains contributing to the real-world business system must be formally represented and interrelated/harmonized using the ISO 23903 Interoperability and Integration Reference Architecture approach [12]. Its system-oriented, ontology-driven, policy-controlled formal representation of real-world business systems and the related software development process extends ISO/IEC 10746 Open Distributed Processing – Reference Model and turns it into a multi-domain model [13]. Figure 1a presents the AIS use case to be automatically transformed into corresponding ICT solutions.

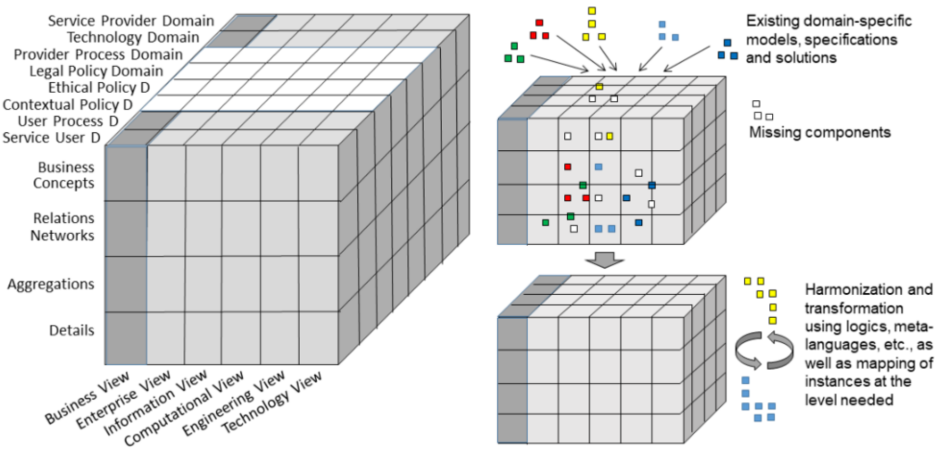

Figure 1. AIS representation, design and implementation enabling advanced interoperability and integration acc. to ISO 23903

Despite the aforementioned limitations regarding the ICT modeling of complex systems, overcome by profiling specifications and remaining at quite generic level, projects have been established to specify implementable components representing ethical and context-related behavior. Here, efforts in modelling morality with prospective logic [14], but also the IEEE P70xx project series [15] have to be named. As they just focus on the ICT representation, they must be integrated and correctly interrelated using the ISO 23903 framework as shown in Figure 1b.

5. Discussion and Conclusions

It is crucial to define objectives, constraints and limits for AIS as well as inevitable principles and not acceptable behavior, auditing their entire lifecycle. In that context, AIS can never be used as means relinquishing or displacing humans' responsibility [10]. The complexity of AIS and the multiplicity of interaction levels for ethical behavior require the consideration of all aspects of human value instead of defining and implementing a sub-set of legal and ethical principles. Modelling such AIS and their components must be performed following Good Modelling Practices [16, 17], starting with the multi-disciplinary knowledge space, its formalization and harmonization. Many of the ongoing ethics-related projects are limited to ICT perspectives, ontologies [18], and representation styles. The IEEE P7007 project "Ontological Standard for Ethically Driven Robotics and Automation Systems" for example starts with representing some ethical principles and scenarios as UML diagrams, whose elements are then axiomatized using the free and IEEE owned Suggested Upper Merged Ontology (SUMO), developed as foundation ontology for a variety of computer information processing systems. For integration with other specifications, the deployment of the ethical domain ontology represented in the domain's language [19] is inevitable. The current ISO 23903 project provides an appropriate framework also for developing ICT solutions under legal and ethical concerns. A recent formulation of those concerns is provided in [20].

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