Particularities of Visualisation of Medical and Wellness Data through a Digital Patient Avatar

Vadym Kramar, Markku Korhonen, Yury Sergeev
Oulu University of Applied Sciences, School of Engineering
Raahe, Finland
{vadym.kramar, markku.korhonen, yury.sergeev}@oamk.fi

***Abstract*—In this work particularities of visualisation of medical and wellness data through a digital patient avatar are given from a standpoint of a proposed approach, under which data for a visualisation may be obtained from a variety of sources through defined interfaces, while end-user interfaces of distinct complexity and level of immersion into the model may be exposed to different categories of users. A short introduction of important medical data exchange standards, specifications and models is offered. A brief overview of projects relevant to a subject of this work is given. The proposed approach is presented along with examples of use-cases.**

Keywords–health information management, human computer interaction, medical simulation, medical information systems, medical treatment, visualization.

I. Introduction

A lack of complete, detailed, multi-scaled 3D anatomical model of the human being expressed from a variety of continuously-updated data sets. 3D shape data is more accurate and thus reliable than 2D, but usually it is device/system-specific, often is reconstructed and thus is not easily-transferable into knowledge, thus multi-source, multi-set, multi-modal models are needed in order to facilitate predictive computer-aid medicine. Quantity of current data models grows faster than quality, and even though linking between certain taxonomies can be established (e.g. disease and medicine), but linking functional and anatomical descriptions to geometry as well as linking all those with environmental data is still a challenge, especially in dynamic. Increasing a use of knowledge technologies in modern medicine require methodologies allowing overcome a textual data overhead. Semantic-guided segmentation, time-effective registration, and spatially and temporally coherent modelling are three important stages to achieve in computer-aided medicine workflow [1].

The Roadmap for the Digital Patient [2] defines the Digital Patient as a technological framework that has the following properties:

- Descriptive – as providing access to any medical and wellness data, including relevant to life-style;
- Interpretive – as helping to be interpreted in order to gain knowledge out of data;
- Integrative – as combining any possible data for retrieving decision-support required information;
- Predictive – as evaluating, anticipating, and predicting the development of health aspects.

Taking into account a maturity of modern human to computer interaction and user interface technologies, the key enablers for maturity of digital patient models are data acquisition, processing and visualisation technologies.

II. Medical Data Exchange Overview

A. Standards.

HL7 is a family of standards for interoperability in healthcare and medical data exchange, developed by Health Level Seven. HL7 standards are grouped into reference categories [3]:

Section 1: Primary Standards - Primary standards are considered the most popular standards integral for system integrations, inter-operability and compliance. Our most frequently used and in-demand standards are in this category.

Section 2: Foundational Standards - Foundational standards define the fundamental tools and building blocks used to build the standards, and the technology infrastructure that implementers of HL7 standards must manage.

Section 3: Clinical and Administrative Domains - Messaging and document standards for clinical specialties and groups are found in this section. These standards are usually implemented once primary standards for the organization are in place.

Section 4: EHR Profiles - These standards provide functional models and profiles that enable the constructs for management of electronic health records.

Section 5: Implementation Guides - This section is for implementation guides and/or support documents created to be used in conjunction with an existing standard. All documents in this section serve as supplemental material for a parent standard.

Section 6: Rules and References - Technical specifications, programming structures and guidelines for software and standards development.

Section 7: Education & Awareness - Find HL7's Draft Standards for Trial Use (DSTUs) and current projects here, as well as helpful resources and tools to further supplement understanding and adoption of HL7 standards.

Digital Imaging and Communications in Medicine (DICOM) is the international standard for medical images and related information (NEMA standard PS3; ISO 12052:2006). It consists of twenty parts [4] that define the formats for medical images that can be exchanged with the data and quality necessary for clinical use.

System of *Concepts to Support Continuity of Care (ISO EN 13940, CONTSys)* [5] includes the following three standard for governance, coordination, planning, delivery and documentation in health and care:
C-08-001, Generic process model for health related services
C-09-001, SAMBA - Structured Architecture for Medical Business Activities
C-09-002, prEN ISO WD 13940-2 Health informatics - System of concepts to support Continuity of care - Part 2: Health care process and workflow.

Electronic Health Record Communication (EHRcom, EN 13606) [6] European Standard that is designed to achieve semantic interoperability in the electronic health record communication. Currently the Concurrent Use initiative has the goal of showing the sustainable value of three basic CEN/TC251 standards for semantic interoperability: ISO EN 13606 (EHRcom), ISO EN 12967 (HISA) and ISO EN 13940 (ContSys) [7].

Health Informatics - Service Architecture (ISO EN 12967, HISA) provides guidance for the description, planning and development of new systems, as well as for the integration of existing information systems, both within one enterprise and across different healthcare organizations, through an architecture integrating the common data and business logic into a specific architectural layer (i.e. the middleware), distinct from individual applications and accessible throughout the whole information system through services [8].

ISO 18308 (the most recent version is 18308:2011) defines the set of requirements for the architecture of a system that processes, manages and communicates electronic health record (EHR) information: an EHR architecture. The requirements are formulated to ensure that these EHRs are faithful to the needs of healthcare delivery, are clinically valid and reliable, are ethically sound, meet prevailing legal requirements, support good clinical practice and facilitate data analysis for a multitude of purposes [9].

ASTM E2369 – 12 Standard Specification for Continuity of Care Record (CCR) is a core data set of the most relevant administrative, demographic, and clinical information facts about a patient?s healthcare, covering one or more healthcare encounters. It provides a means for one healthcare practitioner, system, or setting to aggregate all of the pertinent data about a patient and forward it to another practitioner, system, or setting to support the continuity of care [10].

B. Data Models

BRIDG [11] is a Biomedical Research Integrated Domain Group Model developed by the *Clinical Data Interchange Standards Consortium* (CDISC) [12]. *BRIDG Domain Analysis Model (DAM)* [13] is a conceptual representation of a domain of the interest, which is: “Protocol-driven research and its associated regulatory artifacts: i.e. the data, organization, resources, rules, and processes involved in the formal assessment of the utility, impact, or other pharmacological, physiological, or psychological effects of a drug, procedure, process, or device on a human, animal, or other subject or substance plus all associated regulatory artifacts required for or derived from this effort, including data specifically associated with post-marketing adverse event reporting”.

SNOMED Clinical Terms (SNOMED CT) [14] is a very comprehensive, multilingual clinical healthcare terminology that enables meaning-based operations with information from Electronic Health Records.

Logical Observation Identifiers Names and Codes (LOINC) [15] is a universal code system for identifying laboratory and clinical observations.

International Classification of Diseases (ICD) is the standard diagnostic tool for epidemiology, health management and clinical purposes [16].

openEHR is a set of specifications defining a health information reference model, a language for building 'clinical models', or archetypes, which are separate from the software, and a query language. The architecture is designed to make use of external health terminologies [17].

MedDRA is a rich and highly specific standardised medical terminology to facilitate sharing of regulatory information internationally for medical products used by humans developed by the International Conference on Harmonisation of Technical Requirements for Registration of Pharmaceuticals for Human Use (ICH) [18].

Translational Medicine Ontology (TMO) [19] is a high-level, patient-centric ontology that extends existing domain ontologies to integrate data across aspects of drug discovery and clinical practice. The ontology has been developed by participants in the World Wide Web Consortium's Semantic Web for Health Care and Life Sciences Interest Group [20] and members of the US National Center for Biomedical Ontology [21].

Foundational Model of Anatomy (FMA) is an evolving computer-based knowledge source for biomedical informatics; it is concerned with the representation of classes or types and relationships necessary for the symbolic representation of the phenotypic structure of the human body in a form that is understandable to humans and is also navigable, parseable and interpretable by machine-based systems. Specifically, the FMA is a domain ontology that represents a coherent body of explicit declarative knowledge about human anatomy. Its ontological framework can be applied and extended to all other species [22].

Health Data Ontology Trunk (HDOT) is the middle-layer ontology that provides the semantic backbone of personalised medicine, i.e. to specify how the meaning of the data relevant to the project can be managed and stored in computer format in order to have semantic standards for clinical needs [23].

III. Overview of Existing Projects

Integrated Biomedical Informatics for the Management of Cerebral Aneurysms (@neurIST) project provided an IT infrastructure for the management, integration and processing of data associated with the diagnosis by providing a seamless access to patient data using data fusion and processing of complex information spanning from the molecular to the personal level [24].

Association Studies Assisted by Inference and Semantic Technologies (ASSIST) project unified multiple patient records repositories; automates the process of evaluating medical hypotheses (association studies type); allowed researchers to combine phenotypic and genotypic data; provided an inference engine capable of statistically evaluating medical data; offered expressive, graphical tools for medical researchers to post their queries [25].

Integration of viral genomics with clinical data to predict response to anti-HIV treatment (EuResist) project integrated biomedical information from three large genotype-response correlation databases; developed and validated a number of different engines for effective prediction of the response to treatment based on the integrated biomedical information; combined the different engines into a predictive system and made it publicly available on the web, with a sponsor based exploitation schema.[26].

A Strategy for the EuroPhysiome (EuroPhysiome) project provided a roadmap [27] to the development of the Virtual Physiological Human [28].

Advancing Clinico-Genomic Trials on Cancer (ACGT) developed the Biomedical GRID infrastructure, offers supporting seamless mediation services for sharing clinical and genomic expertise, data and data-processing and supporting life science practitioners in clinical trials and bio-research [29].

Health-e-Child project developed a biomedical information platform, supported by sophisticated and robust search, optimisation, and matching techniques for heterogeneous information, empowered by the Grid and built enabling tools and services on top of it; exploited a database-guided biomedical decision support systems provisioning novel clinical practices and personalised healthcare for children; grew large-scale, cross-modality, and longitudinal information fusion and data mining for biomedical knowledge discovery [30].

The European Virtual Human Immune System (ImmunoGrid) project simulated immune processes at natural scales and provided tools for applications in clinical immunology and for the design of vaccines and immunotherapies [31].

A Virtual Laboratory for Decision Support in Viral Disease Treatment (ViroLab) project integrated the biomedical information from viruses (proteins and mutations), patients (e.g. viral load) and literature (drug resistance experiments) resulting in a rule-based distributed decision support system for drug ranking and developed advanced tools for (bio) statistical analysis, visualization, modelling and simulation, enabling prediction of the temporal virological and immunological response of viruses with complex mutation patterns for drug therapy [32].

A Semantic Grid Browser for the Life Sciences Applied to the Study of Infectious Diseases (Sealife) project developed Semantic Grid browsers for the Life Sciences which allow users to automatically link a host of Web servers and Web/Grid services to the Web content they are visiting, allowing for further processing [33].

Integrating Information from Molecule to Man: Knowledge Discovery Accelerates Drug Development and Personalized Treatment in Acute Stroke (I-Know) project developed a simulation model that provides automated image analysis and expert diagnostic support across infrastructural boundaries, supporting acute treatment of acute stroke [34].

Patient specific image-based computational modelling for improvement of short- and long-term outcome of vascular access in patient on hemodialysis therapy (ARCH) project developed image-based patient-specific computational modelling tools to simulate hemodynamic changes induced by AVF surgery and long-term vascular and cardiac adaptation; the tool is provided to clinical end users by a distributed IT infrastructure [35].

Integrated cardiac care using patient specific cardiovascular modelling (euHeart) project developed methods for the patient-specific modelling of the heart and its major diseases for improving the understanding of cardiovascular disease (CVD) and demonstrating the potential of biophysical models for significantly improving healthcare [36].

ICT enabled prediction of cancer reoccurrence (NeoMARK) project developed a framework to VPH representation of human cancer; it is the first attempt to develop a multifactor prediction system and methodology, based on gene expression from circulating cells [37].

Patient specific simulation and preoperative realistic training for liver surgery (PASSPORT) project developed patient-specific models of the liver which integrates anatomical, functional, mechanical, appearance, and biological modelling; those models integrated in the Open Source framework SOFA, culminate in generating the first multi-level and dynamic "Virtual patient-specific liver" allowing not only to accurately predict feasibility, results and the success rate of a surgical intervention, but also to improve surgeons' training via a fully realistic simulator, thus directly impacting upon definitive patient recovery suffering from liver diseases [38].

Computational prediction of drug cardiac toxicity (PreDICT) project developed mathematical models of individual ion channels, which control the electrical activation of each heart cell; tissue models, which encapsulate chemical processes and physical relationships between millions of individual muscle cells in the heart; and the computer code, which must compute these relationships as a series of complex equations, to enable faster than real-time simulation of a beating heart. [39].

From patient data to personalised healthcare in Alzheimer's Disease (PredictAD) project designed the decision support system, developed in close collaboration with clinicians, compares patient measurements with measurements of other patients in large databases and provides an index and graphical representation reflecting the state of the patient [40].

Road mapping technology for enhancing security to protect medical and genetic data (RADICAL) project used knowledge in quantum physics, biochemistry, nuclear physics, biology and computer science to develop the AI-enhanced virtual physiological human model that can be used in medicine, pharmaceutics, communication, sport, and education [41].

ACTION-Grid is the first European initiative on Grid Computing, Biomedical Informatics and Nanoinformatics [42]. Under the initiative the Linking Biomedical Informatics, Grid Computing and Nanomedicine white paper [43] was developed where five grand challenges for nanoinformatics are introduced: data and knowledge storage and management; nano-ontologies and semantic search and interoperability; extension of the European Virtual Physiological Human scope, including modelling and simulation at the nano level - like the activity of nanoparticles in the human body; the creation of a new area, that has been labelled as "Translational Nanoinformatics", establishing new links between basic scientific research at the nano level and future clinical applications; and extending traditional Electronic Health Records to include nano-related information, which can be used for diagnosis, therapy and the analysis of potential toxic effects of nanoparticles.

Clinically Oriented Translational Cancer Multilevel Modelling (Contra Cancrum) project developed and validated the composite multilevel simulation model of malignant tumour growth and tumour and normal tissue response to therapeutic modalities and treatment schedules by integrating molecular, cellular, tissue and higher level modelling concepts into a single technological entity that simulates therapy outcome based on the individual patient information [44].

Highly Accurate Breast Cancer Diagnosis (HAMAM) project proposed to condense all relevant information and knowledge in a common database and prototypical platform for multi-modal breast diagnosis that utilise sound statistical and mathematical framework to integrate and combine the whole spectrum of patient information [45].

Image-based Multi-scale Physiological Planning for Ablation Cancer Treatment (IMPPACT) project developed and tested data acquisitions procedures, image-analysing algorithms and 3D models as well as rendering and visualization approaches for visualization of the 3D model of liver structures, tumour, and results of numerical simulation of the Radiofrequency Ablation (RFA) procedures [46].

The Osteoporotic Virtual Physiological Human (VPHOP) project developed a multi-scale modelling technology based on conventional diagnostic imaging methods that makes it possible, in a clinical setting, to predict for each patient the strength of his/her bones, how this strength is likely to change over time, and the probability that the he/she will overload his/her bones during daily life [47].

Multi-level patient-specific artery and atherogenesis model for outcome prediction, decision support treatment, and virtual hand-on training (ARTreat) project developed the CT Plaque Characterization and Reconstruction tool, DICOM datasets and 3D models for Interventional and Treatment Decision Support [48].

Development of an Open-Source Software Library for the Interactive Visualisation of Multiscale Biomedical Data (MSV) project [49] proposed the MSVTK infrastructure and open-source library for Visualization Toolkit (VTK) that enable a multiscale spatiotemporal visualisation [50].

Personalised models of the neuromusculoskeletal system (NMS Physiome) project developed the NMSBuilder providing a complete modelling toolkit for the pre-processing of musculoskeletal models and simulation of movement from patient-specific biomedical data, by integrating the multimodal data fusion functionalities of the Multimod Application Framework as well as PMM module performing probabilistic simulations of motion with multibody musculoskeletal models [51].

A grid-enabled pan-Atlantic platform for large scale simulations in paediatric cardiology (Sim-e-Child) project started work on developing a grid-enabled platform for large scale simulations in paediatric cardiology, by integrating the Health-e-Child's Gateway and CaseReasoner (Health-e-Child's application for grid powered knowledge discovery and decision support) with tools for simulation workflow composition and sharing of scientific experiments; the models in development will allow the simulation of interventions on morphology, dynamics, and hemodynamics of the aorta to make personalized predictions of optimal therapy [52].

Interoperable Anatomy and Physiology Project (RICORDO) aims to develop a VPH annotation vocabulary and a technical infrastructure that will result in a multiscale ontological framework in support of the Virtual Physiological Human community to improve the interoperability amongst its Data and Modelling resources [53].

Transatlantic Tumour Model Repositories (TUMOR) project aims to define/develop a European clinically oriented, semantic layered cancer multi-scale digital model/data repository with interoperable interfaces; to develop and/or provide specific tools and methods for collection, curation, validation and customization of existing models and clinical data; and implement/demonstrate an integrated, interoperable transatlantic 'predictive oncology' workflow environment prototype [54].

Future and Emerging Technologies for the Virtual Physiological Human (VPH-FET) [55] developed the Advanced Technologies for the Future of the Virtual Physiological Human roadmap [56].

Patient specific modelling and simulation of focused ultrasound in moving organs (FUSIMO) project will develop will develop, implement and validate a multi-level model for moving abdominal organs for use with High-Intensity Focused Ultrasound (FUS) and Magnetic resonance-guided focused ultrasound surgery [57].

A Social Collaborative Working Space Semantically Interlinking Biomedical Researchers, Knowledge And Data For The Design And Execution Of In-Silico Models And Experiments In Cancer Chemoprevention (GRANATUM) innovative social collaboration platform for chemoprevention researchers for building and executing collaboratively complex biomedical studies and in-silico experiments on largely available and high-quality data repositories will facilitate the social sharing and collective analysis of biomedical experts knowledge and experience, as well as the joint conceptualization and design of scalable chemoprevention models and simulators, towards the enablement of collaborative biomedical research activities beyond geographical [58].

Promoting and Monitoring Biomedical Informatics in Europe (INBIOMEDvision) Coordination and Support Action [59] has published the Prospective Analysis on Biomedical Informatics Enabling Personalised Medicine report, gives an overview of biomedical information with respect to health-related genomics, network-based decision support for systems medicine, integration of HER data and population-based clinical information, and proves that the integration of population health data with individual genomic measurements will enable the practice of personalised medicine [60].

Integrative Cancer Research Through Innovative Biomedical Infrastructures (INTEGRATE) project developed the INTEGRATE prototype platform and proposed the semantic interoperability layer including the core dataset and the Common Data Model (CDM) in order to provide homogeneous access to different data sources [61].

From data sharing and integration via VPH models to personalised medicine (p-medicine) project developed ObTiMA, the ontology-based clinical trial management system for personalised medicine, intended to support clinicians in both designing and conducting clinical trials [62].

Evidence-based Diagnostic and Treatment Planning Solution for Traumatic Brain Injuries (TBIcare) develops a methodology for finding efficient combinations of multi-modal biomarkers used in statistical models to objectively diagnose and assess an individual Traumatic Brain Injury (TBI) patient, and a simulation model for objectively predicting the outcome of the planned treatment of an individual TBI patient [63].

A quantitative model of thrombosis in intracranial aneurysms (THROMBUS) project develops a multiscale computational modelling and simulation framework for the thrombosis – to conjugate the need for feasible and reliable patient specific models with the timing of clinical decision making [64].

Virtual Gastrointestinal Tract (VIGOR++) project develops the personalised virtual gastrointestinal (GI) tract model and ICT tools for image analysis, modelling and classification and interactive visualisation and simulation of human physiology and disease processes [65].

Airway Disease Predicting Outcomes through Patient Specific Computational Modelling (AirPROM) project aims to produce computer and physical models run by an expert centre - of the whole airway system for people with asthma and chronic obstructive pulmonary disease (COPD) [66].

Patient-specific spinal treatment simulation (MySpine) project develops a simulation platform, able to help the diagnosis and the prognosis of lumbar spine back pain, using a cell-to-tissue-to-structure model integration, clinical software interface for treatment prognosis, simulation result probabilistic analysis, and informative and scientific databases. [67].

Virtual Physiological Human: Sharing for Healthcare - A Research Environment (VPH-Share) aims to develop and deploy the VPH infostructure, the computing infrastructure through which the VPH community will be able to store, share, reuse and integrate data, information, knowledge and wisdom on the physiopathology of the human body; introduces a process by which models are formulated, analysed and annotated for integration into workflows; and develops the concept of a patient avatar as the information representation at the centre of a personalised simulation [68]. For that purpose the VPH-Share portal has been launched as an online environment for the development, construction and storage of biomedical workflows [69].

Digitally Integrated Scientific Data for Patients and Populations in User-Specific Simulations Research Area (DISCIPULUS) [70] project and initiative defines a roadmap for the Digital Patient and promotes incorporation of physiological processes modelling in a systematic way into the clinical decision-making process. The Roadmap for the Digital Patient [2] has been developed by the effort of this project.

Modelling and simulation environment for systems medicine (Chronic obstructive pulmonary disease -COPD- as a use case) (Synergy-COPD) project develops a platform based on a complex mathematical model developed from epidemiological data, clinical trials and interviews, which will help predict the evolution of chronic obstructive pulmonary disease in people and allow specialists make better treatment decisions [71].

Digital Patient (DIPACT) project researches and develops 2D and 3D systems, which can be used to create new practical visualization tools and optimize health care quality and efficiency [72].

Models and simulation techniques for discovering diabetes influence factors (MOSAIC) will address two very specific aspects linked to the prediction of risk of developing diabetes (type 2 and gestational) and complications associated to diabetes with models of the human metabolic response that can be enhanced with elements incorporating socio-economic aspects, geographic localization, cultural background, nutrition, etc. [73].

Semantic Infostructure interlinking an open source Finite Element tool and libraries with a model repository for the multi-scale Modelling and 3d visualization of the inner-ear (SIFEM) project's vision is to develop an Infostructure to semantically interlink a Finite Element (FE) tool and open-source supportive tools and libraries with the clinical knowledge, the available clinical and experimental data and a Model Repository in order to obtain more elaborate and reusable multi-scale models of the inner-ear [74].

The Digital Radiation Therapy Patient (DR-THERAPAT) project aims to create the Digital Radiation Therapy Patient platform that will integrate available knowledge on tumor imaging, image analysis and interpretation, radiobiological models and radiation therapy planning into a coherent, reusable, multi-scale digital representation [75].

Model-Driven Paediatric European Digital Repository (MD-Paedigree) project's goals are to integrate and share highly heterogeneous biomedical information, data and knowledge, using best practices from the biomedical semantic Web; develop holistic search strategies to seamlessly navigate through and manage the integrative model-driven infostructure and digital repository jointly develop reusable, adaptable and composable multi-scale VPH workflow models, support evidence-based translational medicine at the point of care; and ultimately facilitate collaborations within the VPH community [76].

Multiscale Immune System SImulator for the Onset of Type 2 Diabetes integrating genetic, metabolic and nutritional data (MISSION-T2D) project aims at developing and validating an integrated, multilevel patient-specific model for the simulation and prediction of metabolic and inflammatory processes in the onset and progress of the type 2 diabetes (T2D) [77].

A Demonstration of 4D Digital Avatar Infrastructure for Access of Complete Patient Information (MyHealthAvatar) proposes the avatar to be the digital representation of patient health status that is designed as a lifetime companion for individual citizens that facilitates the collection of, and access to, long-term health-status information [78].

Virtual Physiological Human: Personalised Predictive Breast Cancer Therapy Through Integrated Tissue Micro-Structure Modelling (VPH-PRISM) project proposes personalised integrated multidisciplinary, multi-scale ICT modeling of breast tissue microstructure in the context of environmental, genetic, and clinical factors [79].

Generic Open-end Simulation Environment for Minimally Invasive Cancer Treatment (GOSMART) project will develop a generic, reusable, robust simulation environment with the relevant physics and physiology needed to correctly predict the result of each Minimally Invasive Cancer Treatment (MICT) in terms of lesion size and shape using a multi-scale physiological model computing the treatment response of a full organ, its anatomical structures and tissue properties going down to the cellular level. [80].

Virtual Physiological Human: DementiA Research Enabled by IT (VPH-DARE@IT) project aims to provide a systematic, multifactorial and multiscale modelling approach to understanding dementia onset and progression; it will explore the lifestyle and environmental factors that predispose to its development, and will deliver more objective and accurate differential diagnosis than what is available thus far in Europe, by shortening the current average 20-month time lapse between the onset of cognitive and memory deficits and its specific clinical diagnosis [81].

IV. The Approach

An avatar is considered to be a digital representative of a human being that is expressed by a visualisation of a set of human-specific data models [82]. The patient avatar involves a more global integration of data collected at the point of care and at the 'point of life', as well as a broader range of simulations of pathophysiological processes, not necessarily related to the specific disease in question. The result is truly integrative medicine, capable of coping with patients with poly-disease and complex cases more effectively; the goal is the full realisation of the Digital Patient vision [2].

Acquisition of data is performed from variety of sources, including national and commercially available Electronic Health Record (EHR) databases as well as a variety of medical and wellness systems and applications that imply a use of generic medical data models (e.g. such home care supporting systems as HoviMestari [83]), variety of personal (remote, wearable, implanted) and environmental (devices/gadgets, home environment, city/municipal) sensors using existing and novel approaches [82]. In [2] the novel approaches of acquisition methods are observed as following:

Secondary care: The most sophisticated data acquisition systems for morphological as well as functional information will be available and will need to be exploited optimally: IT-based systems that advance effective usage and data transfer; multi-modal image analysis and physiological modelling for model-based diagnosis and selection of intervention; lab-on-a-chip based techniques including automated optical- or sensor-based data acquisition systems.

Primary care: Due to advances in technology, automation of data acquisition, and miniaturisation of devices the primary care system will take over part of the diagnosis currently performed in the hospitals: variety of handheld devices and near-patient sensor technologies.

Home Care: Part of the shift of data acquisition will be extended to the home-care environment: high fidelity measurement and monitoring systems to measure patient behaviour and well-being in the home situation connected to personal as well as shared database systems; data from regular checkups or from continuous monitoring can be performed in a home environment under the condition that this is guided and validated by high-end technological systems taking care of automated data acquisition and transfer managed by secondary or primary care providers.

Mobile: new developments in portable and wearable sensors will enable the monitoring of physiological function at activity level as well as the collection of life-style data: sensors based on flexible and stretchable chips (e.g. printed bio-sensors); systems that reduce measurement inaccuracies due to motion artefacts either by using sensors that are not sensitive to un-targeted motion influences or by involvement of data analysis systems that can identify and eliminate motion artefacts from the raw or processed data; wireless connection with servers at home, or at sites of primary- and secondary-care providers, as well as local storage systems that can be read-out at these sites can be used to permanently store information for later use.

Semantic annotation is performed in accordance to a selected set of data models and enhanced with the other models that may contextually supplement the main model to improve a quality of data, a visualisation and a decision-making process [82].

Automated applying of semantic similarities and cross-domain querying for retrieving and analysing supplementary/complementary knowledge (e.g. details on disease, cure, environmental particularities, prognoses, etc.) as well as semi-automated semantic-guided segmentation utilising a-priori knowledge about the anatomical particularities with all the relevant details (including topological constraints) obtained from a variety of knowledge technologies tools bring endless opportunities for availability of just-in-time required information [82].

Registration methodologies must take into account time factors, and a history of changes stored whenever it is appropriate; data fusion and multimodality are considered as well as traditional data manipulation and protection techniques [82].

Expressing data models in 3D (avatar itself and surrounding environment) with a proper geometric data

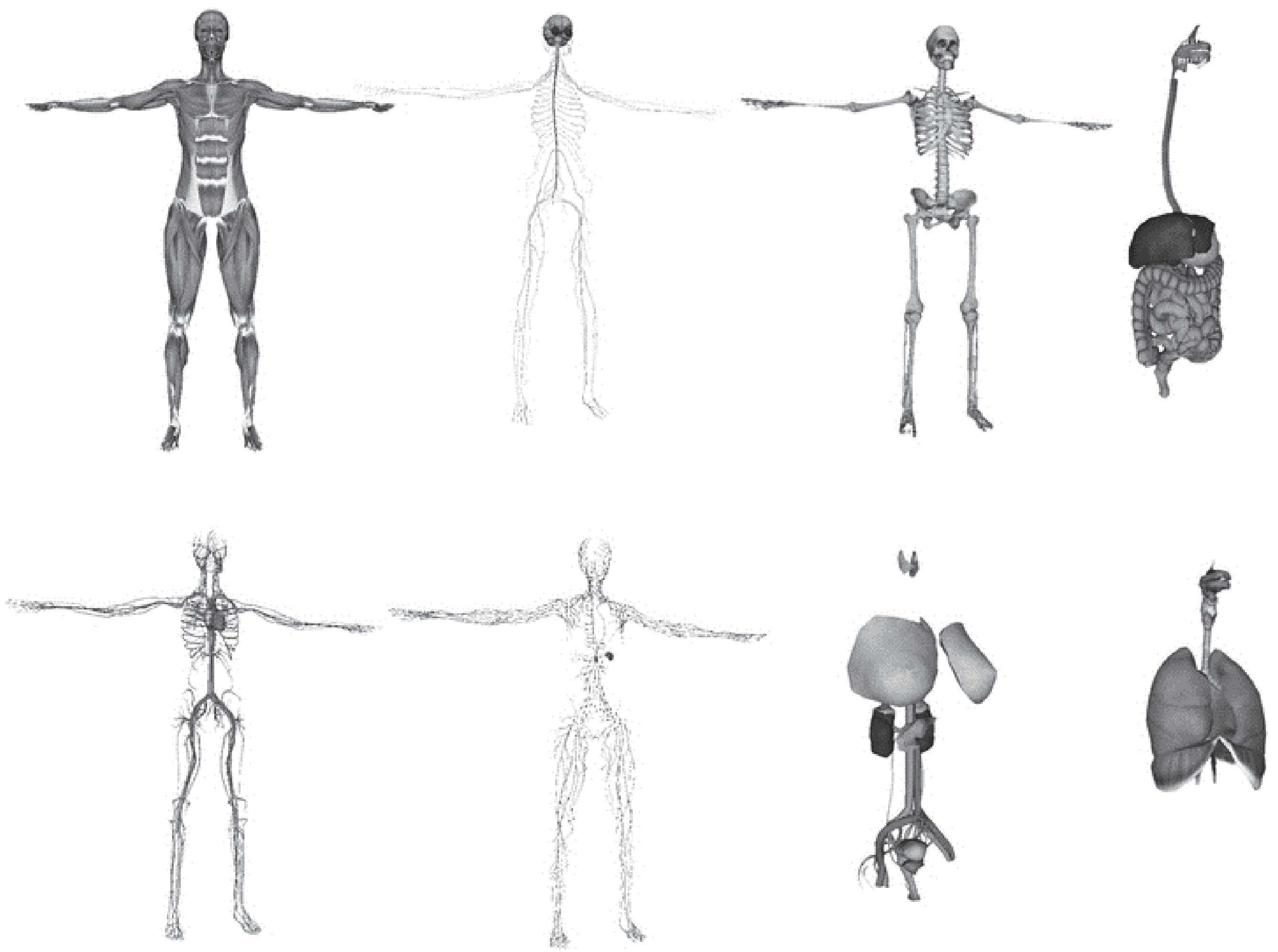

Fig. 1. Examples of 3D anatomical visualization.

where all/selected health/medical-related particularities are visualised and may be shown along with accompanying data brings an ultimate perception. The model may repeat a behaviour of the human and be shown in a virtual environment reflecting a real world [82].

Examples of 3D anatomical visualization of such biological systems like integument, muscular, respiratory, digestive, urinary, skeletal, nervous, circulatory, and lymphatic, developed by the Digital Patient project [72], are shown on Fig. 1. A user can manipulate models (e.g. zooming, rotating, and moving), browse it layer by layer, and observe a history of changes of a health status presented by the model using a timeline slider.

Simulation is performed automatically (as a result of situation awareness) or upon a request; its target is to show of how a newly-occurred factors may affect to a current situation and what could be a result of such affect [82].

Visualisation technologies are to be selected/developed with a purpose to bring the most accurate multi-scale representation of an entire human model, or an anatomical particularity, which reflect a current state of the human, or result of simulation [82].

Interaction with avatar may be performed via a variety of interfaces developed for different categories of users (e.g. medical professionals, careers, family members, users themselves); interfaces should allow different level of immersion: from a distant observation of an avatar till interacting with avatar via another avatar that is resided in the same virtual world [82].

Interactive health analytics consider the development of exploratory interfaces that enable a more holistic exploration of the data currently available at multiple points of care for each patient; here the goal is improved fusion of all existing knowledge about each patient – individualised knowledge fusion [2].

Individualised/personalised health management implies that the available clinical data are not only explored, but truly integrated into simulation-based decision support systems that guide fully-individualised treatment decisions [2].

By a condition of quality data and mature modelling technologies, 3D presentation of medical data is more accurate and reliable than textual. Visual evaluation of medical case ensure faster understanding of a problem and access to complementary data comparing to evaluation obtained in a result of reading [82].

A combination of situation awareness, simulation of environmental changes, or changes in human's body, and using of semantically-enhanced models may result in a very powerful tool for preventing and following medical, and some other human problems [82].

Detailed visualisation of medical problem allows overcoming of a language barrier in case of foreign cure (e.g. in telemedicine or travel insurance cases) while knowledge technologies make possible internationalisation schemas in complex knowledge domains [82].

V. USE-CASE EXAMPLES

A. Health Care Use-Case Example: Cardiological disease risk modelling.

As a cardiologist prepares for an appointment, he opens the patient's profile, which is a 3D model of a patient (avatar) in a specialised software system. By pointing the mouse to different areas of the avatar, the doctor sees results of the previous analysis and health-checks. Nothing indicates any problems, the patient has been healthy.

While the patient tells about his symptoms, the doctor types notes. All the nouns are analysed and pop-up messages propose the possible need for clarification or indicate associated problems. The doctor may reject or use the suggestions, and as a result the doctor has a full enough description of the patient's complaint. He observes that the patient did not sleep much recently and appears to be nervous.

The doctor notices that the heart is highlighted in the avatar. Directing the mouse pointer to the avatar's heart, the doctor moves the timeline slider and sees that years ago the patient complained of pain in his heart. It happened when the patient was a student and had a heavy examination period. He slept very little at that time and was very anxious. Based on the addition of the current symptoms, the system proposes a set of analyses to the doctor and a list of required checks.

As soon as results of all the analyses and checks are ready, doctor sees a pop-up message with a warning. EKG shows that patient has a problem with his heart. The system has simulated a development of a problem and found that such patient's hobby as power-lifting is not recommended in a given case until the problem is eliminated. By moving a slider of a simulation timeline the doctor sees that the problem may progress really fast and thus the patient must be forewarned immediately. By moving a slider of a zooming scale, the doctor observes that area of patient's heart where the problem is. Along with 3D model of a problem, he sees results of analyses and checks as well as recommended treatment.

C. Home Care Use-Case Example: Preventive and informative visualization.

An elderly woman (70-years old) lives alone in her flat. She does not want to move to a nursing house, and still prefers to go shopping herself. She used to bring heavy (as for her abilities) bags from supermarkets.

A specialised software system built-in into a living environment receives data from a heartbeat monitor worn by the woman and discovers the extra high heart-beat. At the same time built into a floor sensor reports that a weight of a woman is 10 kg higher than usually. By matching this data with information that "Visit a supermarket" event is over and comparing with other historical data, the system runs simulation and concludes that carrying relatively heavy weight is dangerous for woman's heart.

The system sends a video-message to woman's daughter. On a video a result of a simulation is shown: an avatar of the woman is carrying a plastic bag to which the following label is attached: "Supermarket, 10 kg". A heart of the avatar is blinking red, and results of heartbeat measure is shown. Then avatar falls down and result of simulation of heart's problem is displayed. The daughter calls to his mother and tries to explain her how dangerous it is to carry in hands heavy parcels from supermarkets.

In a long while, the woman does not still listen to daughter's advices and brings a heavy parcel from a supermarket. As it was anticipated by a simulation, she gets a heart attack. She does not have time to push a "Panic Button" on her wrist. Immediately based on data from a fall-detection system and the heart-beat monitor, the system causes the "Human in danger" alarm.

The woman's daughter and first-aid dispatcher receive the same multimedia message: avatar is laying down, its heart is red and shown in a larger size, and heartbeat is displayed on the virtually-attached label. The daughter has only given information, but a medical professional may access to any complementary data that may help - from all sensors around the woman. Supplementary data that is available and displayed on the avatar, and around it – at those places where data were obtained.

The same information (avatar, its position and available supplementary data) is sent to a doctor of an ambulance car (he uses a mobile version of the system). The ambulance car doctor is able to browse a medical records of the women up-to a current moment – for being better prepared to treat his new patient properly.

D. *Wellness Use-Case Example 3: Visualised self-control.*

A family couple, both at the age of 45, decide to loose some of their extra weight. Every of them launches a personal "Loosing weight" programme using a specialised software system built-in into a living environment. The system guides them both to visit a nutritionist. They apply for an appointment, and give permissions to check their nutrition data.

The nutritionist receives information about dietary habits of a family couple. This information is a result of processing data from a refrigerator, the "Cooking aid" software, movement detectors, weight sensors, and those systems that are providing wellness and social life services. The nutritionist prescribes a set of analysis and checks.

As soon as results of all the analyses and checks are ready, the software system models bodies of both family members. By observing their avatars, both family members are able to see their skin transparent in those areas where fat is. They can zoom in and see their fat structure in details.

By doing exercises and changing their dietary habits, both family members lose weight; they can observe progresses and compare those with previous states by using timeline sliders of their avatars.

When the special diet is over, and the family couple comes back to usual life, the system continues to observe nutrition habits and stile of life of the family. In case the system observes unwanted changes, it informs family members of those. The family couple may see a result of simulation showing how those unwanted changes may affect to their weigh.

VI. Conclusion and Discussion

By observing existing projects, it is clear that medical community, researches and industry are well aware of benefits of visualisation of medical and wellness data through a digital patient avatar. Consumers are behind in a perception of health and wellness visualisation – mostly due to an innovative nature of such and as result – an absence of consumer-oriented application and systems.

Historically a big effort has been given to data processing technologies, but with exponential growth of data and appearance of such phenomenon like Bog Data, a demand for efficient and interoperable data management systems is strong.

Due to a width, heterogeneity and complexity of medical domain, current visualisation processes may not be considered mature enough for a wide adoption in all areas of medicine. Nevertheless, the successful application of visualization in certain areas of medicine inspires. Visualisation systems that allow a seamless immersion into a model from the highest level of observation (an avatar in a virtual world) until the finest-graining levels (nano-biomedicine) are yet to come.

Data certification and provisioning that ensure privacy, security, and trust are the important aspects. Quality of data and efficiency of automated knowledge-retrieving systems in a course of entire data processing chain – from data acquisition until final representation – is a big challenge that require a variety of considerations in relevant fields, such as technological, medical, and legislative.

Multidisciplinary R&D projects that strongly rely on existing achievements in the field, and are able to form a consolidated effort of relevant stakeholders will gradually overcome existing technological challenges, and thus ensure a wider adoption of 3D visualising application.

Acknowledgment

This work has been partly funded by Ambient Assisted Living Joint EU Programme (ICT for Ageing Well) for Advanced Support for Independent Living; Human LifeCycle Approach in Senior Housing (LILY) project and by Tekes – the Finnish Funding Agency for Technology and Innovation, for Digital Patient (DIPACT) project.

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