Institution:
University of Bedfordshire

Unit of Assessment:
11

Title of case study:
Building digital platforms for patient and citizen empowerment in healthcare

Period when the underpinning research was undertaken:
Since 2013 to date

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Professor Feng Dong	Professor of visual computing	Sep. 2007 to Sep. 2019
Dr Enjie Liu	Reader in network applications	Sep. 2003 to date
Dr Vitaly Schetinin	Senior lecturer in computing and information systems	Sep. 2005 to date
Dr Sijing Zhang	Senior lecturer in computing and information systems	Oct. 2004 to date
Dr Ingo Frommholz	Senior lecturer in computing and information systems	Feb. 2011 to Nov. 2020
Dr Hong Qing Yu	Lecturer in data science	Aug. 2011 to Dec. 2020
Dr Haiming Liu	Senior lecturer in computer science and technology	Feb. 2013 to date

Period when the claimed impact occurred:
Since 2016

Is this case study continued from a case study submitted in 2014? Y/N
N

1. Summary of the impact (indicative maximum 100 words)

Our pioneering, digital platform empowers patients by offering detailed information about their condition and guidance to boost their health and quality of life. Our successful pilots, involving patients with diabetes, cancer, heart failure, renal disease and metabolic syndrome, showed a notable improvement in chronic disease control, health literacy and patient health engagement. For example:

- Reductions of 1.2% in body fat and 2.3 mmHg in diastolic blood pressure for patients with Type 2 diabetes taking part in a study using our platform.
- For patients at risk of heart failure and renal disease taking part in our study, up to 24.3% increase in 'empowerment' to manage their own condition.
- As many as 81.5% participants in our cancer care study saw the added value of ICT-aided healthcare on top of existing information management currently operating in their hospital.

Our platform has undergone a real-world 'assessment of value' by the NHS, with Moorfield Eye Hospital using it to measure the efficacy of surgical interventions on patients' lifestyle and freedoms. We are in discussions with Briteyellow Ltd about integrating our platform into their product for the private healthcare market.

2. Underpinning research (indicative maximum 500 words)

Our research has the objectives of collecting comprehensive data from patients, real-time information sharing and the provision of meaningful information to patients. The objectives are achieved through:

- Research on the Internet of Things (IoT), led by Prof Feng Dong, Dr Enjie Liu and Dr Hong-Qing Yu since 2014, that helps our platforms to collect a wide-range of health-related data, both indoor and outdoor:
    - Protocols between the platform and Big Data for sensing data transmission
    - Interactive visual data analytics, such as visualisation, which identifies the topic of retrievals and selects the most relevant information from metadata to return to the user, integrated visual data analysis from heterogeneous data sources
    - Semantic temporal-spatial data mining, and significant event mining. (**3.1, 3.2**)
- Research in Machine Learning (ML)-based predictive modelling, led by Dr Vitaly Schetinin since 2010, that enables more accurate predictions of how health conditions will behave in the population, based on current and historic health data. For example, this research discovered ineffective adaptation of learning strategies to training data that contain uncertainties. This was found to lead to inaccuracies in estimating the influence of uncertainties on a particular model's efficacy. This finding has enabled learning strategies to efficiently reduce factors that generate redundant sub models during the learning process, which significantly improves the performance and accuracy of uncertainty estimation in modelling outputs (**3.3**).
- Research in information retrieval undertaken by Dr Ingo Frommholz and Dr Haiming Liu since 2014 focuses on the overall effectiveness of search engines under dynamic user-machine interaction, which is expected to support the provision of more relevant health-related items to patients. The emphasis is on the utilisation and generalisation of classical geometrical probability and logic spaces to model different forms of user search behaviour with Quantum Information Access theory. The exploration of direct integration into search engines is carried out, along with its underlying theory. (**3.4**)
- Dr Enjie Liu and Dr Sijing Zhang have led research in network/communication protocols to meet the possible challenges of real-time, low-power consumption, high-reliability and security requirements in IoT-based digital healthcare in the future. The achievements on Media Access Control (MAC) layers include enhancement of real-time communication and energy saving MAC protocols (**3.6**). The research tackles technical issues involved in the network for multi-media services, typically used in healthcare platforms. These include remote diagnosis, patient education and services that demand timely data transmission and low power consumption for terminals to operate optimally. The physical layer research (**3.5**) investigated outdoor-indoor, indoor-outdoor, and indoor-outdoor-indoor signal propagation for dual-polarised MIMO channels in small cell environments, which are a typical scenario in IoT-based healthcare. A reliable signal quality is essential. Their research also developed a new approach to the detection of malicious attacks at the physical layer in the Gaussian relay system, allowing the system to work effectively in the presence of unreliable channel state information.

3. References to the research (indicative maximum of six references)

3.1. Po Yang, Danius Stankevicius, Vaidotas Marozas, Zhi kun Deng, Arunas Lukosevicius, Feng Dong, Enjie Liu, Dali Xu: Lifelogging Data Validation Model for Internet of Things enabled Healthcare System, IEEE Transactions on Systems, Man and Cybernetics: Systems, (2018), Volume: 48, Issue: 1, pp.50-64

3.2. Zhao X, Liu E, Yu H Q, Clapworthy G: A linear logic approach to the composition of RESTful web services', International Journal of Web Engineering and Technology, (2015), 10 (3), pp.245-271

3.3. V. Schetinin, L. Jakaite, and W. Krzanowski: Bayesian averaging over decision tree models: An application for estimating uncertainty in trauma severity scoring, International Journal of Medical Informatics, Elsevier, (2018), 112, pp 6-14

3.4. Muhammad Kamran Abbasi and Ingo Frommholz: Cluster-based polyrepresentation as science modelling approach for information retrieval, Scientometrics (2015), 102 (3), pp.2301–2322

3.5. T. Lv, Y. Yin, Y. Lu, S Yang, E. Liu, and G. Clapworthy: Physical Detection of Misbehavior in Relay Systems With Unreliable Channel State Information, IEEE Journal on Selected Areas in Communications, (2018), Volume: 36, Issue: 7, pp: 1517-1530

3.6. E. Liu, W. Ren: Performance Analysis of a Generalized and Autonomous DRX Scheme, IEEE Transactions on Vehicular Technology, (2014), Volume: 64, Issue: 5, pp: 2148-2153

4. Details of the impact (indicative maximum 750 words)

The trials of our digital health platforms were conducted as part of iManageCancer (**5.1**), MyHealthAvatar (**5.2**) and CARRE (**5.6**) projects.

The digital health platforms have been used to target chronic diseases, which count for a substantial share of patient care cost worldwide. For these diseases, self-management has previously proved to be an efficient approach, but patient engagement has been challenging. The platforms are designed to ease the monitoring process and provide rich analytical data in order to improve engagement. Notable impacts are:

- **Reducing prolonged sitting time and improving glucose control in people with Type 2 diabetes**

  20 patients recently diagnosed with Type 2 diabetes were recruited through Horizon Health Choices UK. They were randomly put into either a control group who received their normal care or the intervention group. The intervention group used the MyHealthAvatar (MHA) Diabetes app, which is the front end of the digital platform, for eight weeks, allowing the patients to enter and track their health and lifestyle information.

  The app collects patients' health-related information from mobile devices, such as mobile phone and wrist watches. The data is then sent to a server to be analysed. Suggestions on exercises and diet, and warnings or reminders are generated from the analysis and sent to patients. Findings included the following:

  - Daily sitting was reduced by an average of 1.4% per day. While this may seem only a small change, it means that **intervention patients took an additional nine breaks from sitting each day. This is a significant outcome as** taking more breaks from sitting has been shown to reduce glucose levels over the day and night in people with Type 2 diabetes.

  - Fasting glucose was reduced by 0.28 mmol/L and the **glucose level following a 75g carbohydrate drink was reduced by 0.65mmol/L**, which is clinically important. It shows that the patients improved their ability to control glucose levels after consuming the carbohydrate.

  - **Body fat was reduced by 1.2%,** while diastolic blood pressure was reduced by 2.3mmHg.

- **Increasing health literacy among patients suffering from heart failure, chronic kidney diseases and metabolic syndrome**

  40 patients at risk of heart failure and renal disease were recruited in two hospitals in Greece and Lithuania for a five-month trial. The patients were directed to the CARRE platform, which visually presents knowledge and risk factors of chronic cardiorenal

disease. Two visits to the patients were arranged in month two and month four of the pilot study defined by, and carried out by, the two hospitals. The comparison of the feedback from the patients showed (with the formula improvement (%) = (E2 – E1)/E1*100%):

- An overall increase in health literacy (defined as the patient's capability to obtain, process and understand health information): 9.8%

- An overall increase in empowerment (defined as the process in which patients are encouraged to construct self-regulation, self-management and self-efficacy in order to achieve maximum health and wellbeing): 8.0%, with 12.4% among metabolic syndrome patients and 24.3% among heart failure and renal disease patients.

- **Improving Patient Health Engagement with ICT-aided healthcare**

  A total of 37 cancer patients (22 breast cancer and eight prostate cancer patients recruited initially and a further seven later) provided their feedback at the end of the trial in iManageCancer project in Pancretan Health Medical Centre, Greece. Results are below:

	Breast cancer patients	Prostate cancer patients
Confident using the app	55%	75%
Found the various features of the platform useful	65%	63%
Would like to use this system frequently	45%	50%
Other patients would like to use the platform	60%	38%
The platform is an added value for the hospital	100%	63%

The survey results clearly showed that more than half of all patients agree that ICT-aided healthcare is useful and acceptable for patient health engagement. More importantly, as many as 81.5% of participants saw the added value of ICT-aided healthcare on top of the existing information management currently operating in their hospital.

The EC's Innovation Radar, which identifies high potential in EU-funded research and innovation projects, recognises the 'noteworthy' market creation potential for the platform (**5.3**). Bolstered by this positive feedback, we are in commercial discussion with Briteyellow Ltd about integrating our platform into its digital healthcare products. A non-disclosure agreement (NDA) has been signed between the university and the company (**5.7**).

Moorfields Eye Hospital in Bedford is undertaking a further assessment to explore the impacts (**5.4**). The aim of the study is to assess the impact of interventions (e.g. eye surgery) on the quality of life (QoL) of visually impaired patients. Levels of physical activity before and after the interventions are tracked by analysing data collected from sensors connected to MHA

In addition to our digital health platforms, our innovation of predictive modelling - using ML developed in collaboration with Fusion Radiology (UK) and Stavropol regional hospital (Russia) in the EU-funded Innovation Bridge project (**5.5**) - has also had positive health impacts by **improving the accuracy of early detection of osteoarthritis.** Predictive models have been tested on high resolution X-Ray images of knees in the early stages of the condition when the pathological changes in patients' bones cannot be reliably quantified through standard radiologic tests at Stavropol regional hospital. Trials

on 160 patients recruited for the study showed an improvement in accuracy between 7% and 9%. The algorithm will be used in the digital health platform to reinforce the modelling and prediction of patients' health conditions.

5. Sources to corroborate the impact (indicative maximum of 10 references)

5.1 iManageCancer D9 v1.0, https://cordis.europa.eu/project/id/643529, funded by EU-H2020-ICT-

5.2 MyHealthAvatar funded by EU FP7-ICT-2012-9, collaborated with Foundation for Research and Technology Hellas (Greece), Universitaet des Saarlandes (Germany) Institute of Communication and Computer Systems (Greece) Gottfried Wilhelm Leibniz Universitaet Hannover (Germany), Astried Research Kutatasfgejlesztesikft (Hungary), Ansmart Ltd (UK), Technological Education Institute of Crete (Greece) and University of Lincoln (UK), https://ec.europa.eu/digital-single-market/en/news/myhealthavatar-your-digital-health-status-through-app

5.3 Innovation Reader, https://www.innoradar.eu/resultbymaturity/1

5.4 Support letter from Moorfields Eye Hospital. *Provided as PDF*

5.5 Quantitative Imaging for Early Detection of Osteoarthritis, Innovation Bridge project, https://uobrep.openrepository.com/handle/10547/624190

5.6 CARRE project funded by FP7-ICT-2013-10, Grant No. 611140, Nov 2013 – Oct 2016, collaborated with healthcare partners Democritus University of Thrace (Greece) and Viesoji Istaiga Vilniaus Vniversiteto Ligonines Santariskiuklinikos (Lithuania), and ICT partners Open university (UK), Kauno Technologijos Universitetas (Lithuania) and Przemyslowy Instytut Automatyki i Pomiarow (Poland), https://www.carre-project.eu/

5.7 Confidentiality and Non-Disclosure Agreement with Briteyellow Ltd. *Provided as PDF*