APPLICATION OF INTERNET OF THINGS IN HEALTH CARE

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Abstract

The paper focuses on the continuously growing area of Internet of Things and its application to health care. We discuss several important aspects, namely quality, and relevance of data acquired. We illustrate IoT by a case study of diabetes mellitus personalised treatment. Modern type 1 diabetes mellitus therapy is now unimaginable without intensive glycaemia monitoring. In the last decade the possibility of real time continuous glucose monitoring (RT-CGMS) was realised along with integration to some types of insulin pump. Currently the research focuses on continuous glucose monitoring systems that have following advantages: non-invasiveness, high customer acceptance; comfort in use; ease in use; accuracy; long-term measurement up to 4 weeks; calibrating unit integrated; alerts for low or highs of glucose level; enabling higher lifestyle flexibility, e.g. physical activity, food, medication; wireless data and energy transmission; infection risk is minimised. Obviously several sensors are necessary to acquire the contextual data, in particular vital parameters, physical activity, and stress. All measured data must be collected and evaluated in parallel. The aim is to identify the mutual relations in measured parameters, the differences among patients and finally the most important parameters for development of personalised data models.

Keywords: health informatics; internet of things; data quality continuous measurement

Introduction

The rapid emergence and proliferation of connected medical devices and their application in healthcare are already part of the Healthcare Internet of Things (IoT) – as this field is now called. Their true impact on patient care and other aspects of healthcare remains to be seen and is highly dependent on the quality and relevancy of the data acquired. Furthermore key issues such as data security and privacy will be fundamental determinants of the utility of these systems in their further deployment and impact in healthcare monitoring and management. The basic definition of Internet of Things (IoT)[1] says that it is a network of physical devices and other items, embedded with electronics, software, sensors, and network connectivity, which enables these objects to collect and exchange data. Its impact on medicine will be perhaps the most important, and personal, effect. The study published by McKinsey and Company estimate that by 2020, 40% of IoT-related technology will be health-related, more than any other category, making up a $117 billion market.[2] The convergence of medicine and information technologies, such as medical informatics, will transform healthcare as we know it, curbing costs, reducing inefficiencies, and saving lives. The numbers are impressive. Nevertheless the way towards daily routine use is rather complicated since IoT use does not only mean connecting the devices, but also integrating and interpreting the collected data using additional information.

With the trend towards personalised medicine it is useful to continuously measure and evaluate patient vital parameters under everyday life conditions. This is actually the core of the concept of quantified self. The original idea of quantimetric self-tracking began in the 1970s. A major application of quantified self has been in health and wellness improvement. Many devices and services help with tracking physical activity, caloric intake, sleep quality, posture, and other factors involved in personal well-being. To get an objective picture, the measurement must be synchronised.

The trend in current medicine is towards personalised treatment because each individual is different and the interpersonal variability is very high. Therefore it is necessary to adjust the personal model (patient state) by personal parameters and compare the future development of the health state with the initial state. The most important part of the evaluation is trend evaluation.

In this paper we use a case study to illustrate the importance of continuous health data collection and evaluation, in particular in the case of chronic diseases.

Method

The standard approach to care is based on medical treatment and medication. However, it is welcomed that patients are actively involved in the treatment process. In this respect we speak about self-management of the health state. With the development of sensor systems and mobile applications it is possible to utilise these technologies for development of individualised approaches and applications, motivating for active engagement in one's own health treatment. We illustrate this approach by a case study for self-management – diabetes mellitus.

Case Study Diabetes Mellitus

Diabetes is characterised by elevated blood glucose level. The origin of this hyperglycaemia differs according to the type of diabetes. Most common types of diabetes are type 1 and 2 (T1DM and T2DM) respectively. In T2DM the leading cause of hyperglycaemia is insulin resistance. In T1DM it is insulinopaenia which is the result of an autoimmune destruction of insulin producing pancreatic beta cells. T1DM must be treated from the beginning by insulin injections. The numbers of patients suffering from the most common diabetes types is increasing dramatically so diabetes represents a serious medical problem.

Hyperglycaemia, regardless of its origin has serious metabolic consequences. Despite the most modern therapeutic methods, which are not sufficient to re-establish full normoglycaemia, both types of diabetes still lead to reducing life expectancy and worsening quality of life. For these reasons the ultimate goal in diabetes treatment is to achieve full normoglycaemia without an increased risk of serious hypoglycaemia as a result of very aggressive treatment.

Epidemiological data (based upon WHO and the International Diabetes Federation fact sheets) report that there were 415 million people worldwide with diabetes in 2015.[3,4] Type 1 diabetes causes an estimated 5–10% of all diabetes cases or 11–22 million worldwide and8.4% of adults have diabetes in the Europe Region. Diabetes caused 622,114 deaths in the Europe Region in 2012 and €138.8 billion were spent on treating diabetes in the Europe Region. The region (Europe) has the highest number of children with type 1 diabetes.

In T1DM treatment only intensified insulin regimes should be used, which means a multiple daily insulin injections regime (MDI) or insulin pump therapy (continuous subcutaneous insulin infusion CSII). Both regimes are built upon the basal-bolus concept. In the case of CSII treatment the pump continually doses small predefined "basal doses" of rapidly acting insulin from the reservoir. Prandial insulin needs are covered by the patient's instruction to the pump as an insulin bolus. CSII is an expensive but still more physiological way to mimic normal insulin production and is superior to MDI mainly in the reduction of serious hypoglycaemia. However, the patient must always wear a machine, which is connected by a catheter to a small needle placed into the subcutaneous tissue. Modern insulin pumps have advanced safety control mechanisms to minimise technical problems (system occlusion) and offer additional functions: to choose different prandial bolus kinetics, bolus calculator which works with predefined information on insulin sensitivity and with the knowledge on active insulin (called "insulin on board" - IOB) etc.[5]

Modern T1DM therapy is now unimaginable without intensive glycaemia monitoring. In the last decade the possibility of real time continuous glucose monitoring (RT-CGMS) was realised along with integration to some types of insulin pump.

Currently the research focuses on continuous glucose monitoring systems that have the following advantages: non-invasiveness, high user acceptance; comfort in use; ease of use; accuracy; long-term measurement up to four weeks; integrated calibrating unit; alerts for low or highs of glucose concentration; enabling higher lifestyle flexibility, e.g. physical activity, food, medication; wireless data and energy transmission; infection risk is minimised. Obviously several sensors are necessary to acquire the contextual data, in particular vital parameters, physical activity, and stress. One of the methods that is a focus of attention is the photoplethysmography (PPG) since it is a source of several parameters. PPG sensors can be placed in a bracelet or as in-ear element. Both types have their advantages and disadvantages.

In-ear PPG is a modern way of the photoplethysmography (PPG) method that monitorsdermal blood volume changes in a reflective way with a single-sided miniaturised sensor that is placed non-invasively in the person's ear channel. The sensor will be embedded into a customised ear mould to measure from the inside at the tragus. From the user's point of view, this sensor concept offers the possibility of absolutely unobtrusive vital activity monitoring without the need for an additional, wearable device when it is combined with headphones. With PPG, diverse vital signs can be detected that indicate the current physiological parameters like heart rate, respiratory rate and blood pressure variations. An additional a three axis accelerometer is used for the identification of PPG signal periods that are invalidated due to movement artefacts, balistography and an estimation of the body movement. The absolute value of the current physical work can be calculated in real-time based on a personal model assumption and the patient's current PPG and the accelerometer data.

All measured data must be collected and evaluated in parallel. The aim is to identify the mutual relations in measured parameters, the differences between patients and finally the most important parameters for development of personalised data models. There are measured additional data (basal metabolism, weight, individual fitness, psychological evaluation – not continuously but only during medical examination) that serve for more precise personalised model adjustment. These personalised data models serve for future predictions under the assumption that the patient inserts the information that cannot be measured, e.g. type and amount of food (photo and textual information) or medication. Based on the processed data and medical background knowledge a decision support system (DSS) can serve as an intelligent advisor to the patient. The DSS combines its general knowledge with the personalised patient model and recent and current measured data and recommend the patient insulin dosage.

Conclusion

Technology may be advantageous when continuously monitoring persons' health state and activities during everyday life in their homes and at work because it helps adjust a personalised health state model, in particular for a person with chronic disease. Current technology (IoT) relies on permanent connectivity and access to data storages. However, we have to develop a backup solution in case we lose connectivity or storage (usually a cloud) is inaccessible. There must be a minimalistic solution that is able to deliver such information that is relevant and satisfactory for a given task. To be able to send such aggregated information, we need corresponding computing resources at the patient place.

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References

1. Zanella A, Bui N, Castellani A, Vangelista L, Zorzi M. Internet of things for smart cities. i 2014;1(1):22–32.
2. Bauer H, Patel M, Veira J. The Internet of Things: sizing up the opportunity New York (NY): McKinsey & Company; c2016. Available at: http://www.mckinsey.com/industries/high-tech/our-insights/the-internet-of-things-sizing-up-the-opportunity accessed 21March 2017.
3. WHO. Diabetes fact sheet. (2016). Available at: http://www.who.int/mediacentre/factsheets/fs312/en/ accessed 21 March 2017.
4. International Diabetes Federation. Diabetes facts and figures. (2015).Available at: http://www.idf.org/about-diabetes/facts-figures accessed 21 March 2017.
5. Pickup JC. Insulin-pump therapy for type 1 diabetes mellitus. *N Engl J Med* 2012;366(17):1616-1624.