**Use of Internet of Things (IoT) in Healthcare: A Survey**

## *ABSTRACT*

In today's world of connectivity, with the advancement of Internet of Things (IoT) all entities are connected to each other by some communication means. The Internet of Things for the medical equipment will produce data that can go a long way in not only increasing equipment efficiency, but also patient health. The Internet of Things (IoT) is increasingly being recognized by industry and different services mainly in healthcare. This paper describes the various Internet of Things (IoT) enable devices and its practices in the area of healthcare for toddler, children, chronic care, monitoring of critical patients, operation theaters and medicine dispenser.

# Internet of Things for Medication Control: E-Health Architecture and Service Implementation

## *Abstract*

The use of Radio Frequency IDentification technology RFID in the medical context enables drug identification but also a rapid and, of course, precise identification of patients, physicians, nurses or any other health caregiver. Combining RFID tag identification with structured and secure Internet of Things IoT solutions, one can establish a ubiquitous and quick access to any type of medical related records, as long as one can control and adequately secure all the Internet mediated interactions. This paper presents an e-Health service architecture, along with the corresponding Internet of Things prototype implementation that makes use of RFID tags and Electronic Product Codes EPC standards, in order to easily establish in a ubiquitous manner a medication control system. The system, presented and tested, has a web interface and allowed for a first evaluation of the e-health proposed service. As the service is mainly focused on elderly Ambient Assisted Living AAL solutions, all these technologies-RFID, EPC, Object Naming Service ONS and IoT-have been integrated into a suitable system, able to promote better patient/physician, patient/nurse and, generally, any patient/health caregiver, interactions. The whole prototype service, entitled "RFID-based IoT for Medication Control", and its web interface are presented and evaluated.

# A Low-Cost Flexible IoT System Supporting Elderly's Healthcare in Rural Villages

## *ABSTRACT*

We propose to create a system that, by exploiting the possibilities provided by the Internet of Things (IoT), offers a cheap and affordable solution to prevent and control health problems of people, especially elderly, living in rural villages, where assessing good health facilities is a major concern. The system consists of a heterogeneous combination of apps and Arduino-based devices that connect patients and healthcare service providers remotely located. An important feature from the interaction point of view is that the system is easily configurable by non-technical people, e.g., caregivers.

# Drug Identification and Interaction Checker Based on IoT to Minimize Adverse Drug Reactions and Improve Drug Compliance

## *Abstract*

Drug compliance and adverse drug reactions (ADR) are two of the most important issues regarding patient safety throughout the worldwide healthcare sector. ADR prevalence is 6.7 % throughout hospitals worldwide, with an international death rate of 0.32 % of the total of the patients. This rate is even higher in Ambient Assisted Living environments, where 15 % of the patients suffer clinically significant interactions due to patient non-compliance to drug dosage and schedule of intake in addition to suffering from polypharmacy. These instances increase with age and cause risks of drug interactions, adverse effects, and toxicity. However, with a tight follow-up of the drug treatment, complications of incorrect drug use can be reduced. For that purpose, we propose an innovative system based on the Internet of Things (IoT) for the drug identification and the monitoring of medication. IoT is applied to examine drugs in order to fulfill treatment, to detect harmful side effects of pharmaceutical excipients, allergies, liver/renal contradictions, and harmful side effects during pregnancy. The IoT design acknowledges that the aforementioned problems are worldwide so the solution supports several IoT identification technologies: barcode, Radio Frequency Identification, Near Field Communication, and a new solution developed for low-income countries based on IrDA in collaboration with the World Health Organization. These technologies are integrated in personal devices such as smart-phones, PDAs, PCs, and in our IoT-based personal healthcare device called Movital.

# Introducing IoT Competencies to First-Year University Students with the Tiles Toolkit

## *ABSTRACT*

Advances in the field of Internet of Things (IoT) are introducing innovations in multiple domains including smart cities, healthcare and transportation. An increasing number of jobs today require IoT competences that university courses need to be prepared to deliver. Yet, teaching IoT topics is a challenging task due to complexity and unstructured nature of the IoT. It requires to deliver skills in multiple domains including design, hardware and software engineering and it is often hard to find an entry point to the field. In this paper we explore using the Tiles ideation toolkit as a way to teach bachelor students in IT topics IoT fundamentals. Tiles is composed by a set of 150 cards and a workshop procedure for collaborative ideation. We performed a user study with 60 computer science students to investigate how Tiles can be used as an experiential learning tool to develop basic knowledge in IoT and to train design thinking skills. Results show the tool was accepted as useful and fun to play with. Nearly all students managed to develop a simple IoT idea during the three-hours workshop. Learning outcomes were observed in about half of participants, although time constraints and high stress levels impacted the participants' experience.

# An Integral Medicine Taking Solution for Mild and Moderate Alzheimer Patients

## *ABSTRACT*

A comprehensive solution is proposed to enhance adherence for the mild and moderate Alzheimer patients, involving not only the patient but also other participants, such as the nurse and/or relative, the drugstore, the physician and the hospital. The solution includes the development of an automatic medication dispenser and the corresponding software applications. In this article a general schema of the solution is presented, and a brief description of the first hardware and software prototypes is also included.

# Smart Wearable Device for Health Monitoring in the Internet of Things (IoT) Domain

## *ABSTRACT*

In the last few years even more devices have been developed to monitor people health status. Commonly, these devices are designed for medical tasks like monitoring severe diseases or for diagnostic purposes; moreover, a remarkable interest is growing in the field of amateur sport activities such as jogging, running, climbing and so on. Another field of interest is represented by those people that want to monitor their health status using low cost devices. In this work we propose a low cost wearable device in the IoT domain, which has the main goal to monitor, learn and fit customer habits in order to discover some outliers signals that may represent a warning. The proposed device works by performing two main steps: the first one is to monitor normal activities of the user in order to build a reference of his condition; the second one is a real-time monitoring and analysis of the acquired data that are gathered from body sensors. Health status is carried out using a Fuzzy Logic based network that is able to summarize user health status in terms of heart rate.

# Connected Resources: A Novel Approach in Designing Technologies for Older People

## *ABSTRACT*

In this paper, we describe three interactive prototypes of connected objects conceived as resources. Our aim with these prototypes is to demonstrate a new approach in designing connected technologies for elderly. This approach moves away from the stereotype of older people as frail and passive and addresses them as resourceful individuals. After presenting the design process and the prototypes, we discuss how to shift from the design of scripted products to the design of resources. This entails conceiving tools that can be used in various ways to support elderly's existing competences of resourcefulness in activities they value.

# Following or Leading?: The HCI Community and New Interaction Technologies

## *Abstract*

Envisioning, designing, and implementing the user interface require a comprehensive understanding of interaction technologies. In this forum we scout trends and discuss new technologies with the potential to influence interaction design.

# Hardware-Enabled Pharmaceutical Supply Chain Security

## *Abstract*

The pharmaceutical supply chain is the pathway through which prescription and over-the-counter (OTC) drugs are delivered from manufacturing sites to patients. Technological innovations, price fluctuations of raw materials, as well as tax, regulatory, and market demands are driving change and making the pharmaceutical supply chain more complex. Traditional supply chain management methods struggle to protect the pharmaceutical supply chain, maintain its integrity, enhance customer confidence, and aid regulators in tracking medicines. To develop effective measures that secure the pharmaceutical supply chain, it is important that the community is aware of the state-of-the-art capabilities available to the supply chain owners and participants. In this article, we will be presenting a survey of existing hardware-enabled pharmaceutical supply chain security schemes and their limitations. We also highlight the current challenges and point out future research directions. This survey should be of interest to government agencies, pharmaceutical companies, hospitals and pharmacies, and all others involved in the provenance and authenticity of medicines and the integrity of the pharmaceutical supply chain.

# The Adventures of Older Authors: Exploring Futures through Co-Design Fictions

## *ABSTRACT*

This paper presents co-design fiction as an approach to engaging users in imagining, envisioning and speculating not just on future technology but future life through co-created fictional works. Design fiction in research is often created or written by researchers. There is relatively little critical discussion of how to co-create design fictions with end-users, with the concomitant opportunities and challenges this poses. To fill this gap in knowledge, we conducted co-design fiction workshops with nine older creative writers, utilising prompts to inspire discussion and engage their imaginative writing about the trend towards tracking and monitoring older people. Their stories revealed futures of neither dystopia nor utopia but of social and moral dilemmas narrating their wish not just to "maintain their independence", but a palpable desire for adventure and very nuanced senses of how they wish to take control. We discuss inherent tensions in the control of the co-design fiction process; balancing the author's need for freedom and creativity with the researcher's desire to guide the process toward the design investigation at hand.

# Situated Agents and Humans in Social Interaction for Elderly Healthcare: From Coaalas to AVICENA

## *Abstract*

Assistive Technologies (AT) are an application area where several Artificial Intelligence techniques and tools have been successfully applied to support elderly or impeded people on their daily activities. However, approaches to AT tend to center in the user-tool interaction, neglecting the user's connection with its social environment (such as caretakers, relatives and health professionals) and the possibility to monitor undesired behaviour providing both adaptation to a dynamic environment and early response to potentially dangerous situations. In previous work we have presented Coaalas, an intelligent social and norm-aware device for elderly people that is able to autonomously organize, reorganize and interact with the different actors involved in elderly-care, either human actors or other devices. In this paper we put our work into context, by first examining what are the desirable properties of such a system, analysing the state-of-the-art on the relevant topics, and verifying the validity of our proposal in a larger context that we call AVICENA. AVICENA's aim is develop a semi-autonomous (collaborative) tool to promote monitored, intensive, extended and personalized therapeutic regime adherence at home based on adaptation techniques.

# Classification and Suitability of Sensing Technologies for Activity Recognition

## *Abstract*

Wider availability of sensors and sensing systems has pushed research in the direction of automatic activity recognition (AR) either for medical or other personal benefits e.g. wellness or fitness monitoring. Researchers apply different AR techniques/algorithms and use a wide range of sensors to discover home activities. However, it seems that the AR algorithms are purely technology-driven rather than informing studies on the type and quality of input required. There is an expectation to over-instrument the environment or the subjects and then develop AR algorithms, where instead the problem should be approached from a different angle i.e. what sensors (type, quality and quantity) a given algorithm requires to infer particular activities with a certain confidence? This paper introduces the concept of activity recognition, its taxonomy and familiarises the reader with sub-classes of sensor-based AR. Furthermore, it presents an overview of existing health services Telecare and Telehealth solutions, and introduces the hierarchical taxonomy of human behaviour analysis tasks. This work is a result of a systematic literature review and it presents the reader with a comprehensive set of home-based activities of daily living (ADL) and sensors proven to recognise these activities. Apart from reviewing usefulness of various sensing technologies for home-based AR algorithms, it highlights the problem of technology-driven cycle of development in this area.

# Combining Emerging Patterns with Random Forest for Complex Activity Recognition in Smart Homes

## *Abstract*

New healthcare technologies are emerging with the increasing age of the society, where the development of smart homes for monitoring the elders' activities is in the center of them. Identifying the resident's activities in an apartment is an important module in such systems. Dense sensing approach aims to embed sensors in the environment to report the detected events continuously. The events are segmented and analyzed via classifiers to identify the corresponding activity. Although several methods were introduced in recent years for detecting simple activities, the recognition of complex ones requires more effort. Due to the different time duration and event density of each activity, finding the best size of the segments is one of the challenges in detecting the activity. Also, using appropriate classifiers that are capable of detecting simple and interleaved activities is the other issue. In this paper, we devised a two-phase approach called CARER (Complex Activity Recognition using Emerging patterns and Random forest). In the first phase, the emerging patterns are mined, and various features of the activities are extracted to build a model using the Random Forest technique. In the second phase, the sequences of events are segmented dynamically by considering their recency and sensor correlation. Then, the segments are analyzed by the generated model from the previous phase to recognize both simple and complex activities. We examined the performance of the devised approach using the CASAS dataset. To do this, first we investigated several classifiers. The outcome showed that the combination of emerging patterns and the random forest provide a higher degree of accuracy. Then, we compared CARER with the static window approach, which used Hidden Markov Model. To have a fair comparison, we replaced the dynamic segmentation module of CARER with the static one. The results showed more than 12% improvement in f-measure. Finally, we compared our work with Dynamic sensor segmentation for real-time activity recognition, which used dynamic segmentation. The f-measure metric demonstrated up to 12.73% improvement.

# A Cognitive Robotic Ecology Approach to Self-Configuring and Evolving AAL Systems

## *Abstract*

Robotic ecologies are systems made out of several robotic devices, including mobile robots, wireless sensors and effectors embedded in everyday environments, where they cooperate to achieve complex tasks. This paper demonstrates how endowing robotic ecologies with information processing algorithms such as perception, learning, planning, and novelty detection can make these systems able to deliver modular, flexible, manageable and dependable Ambient Assisted Living (AAL) solutions. Specifically, we show how the integrated and self-organising cognitive solutions implemented within the EU project RUBICON (Robotic UBIquitous Cognitive Network) can reduce the need of costly pre-programming and maintenance of robotic ecologies. We illustrate how these solutions can be harnessed to (i) deliver a range of assistive services by coordinating the sensing & acting capabilities of heterogeneous devices, (ii) adapt and tune the overall behaviour of the ecology to the preferences and behaviour of its inhabitants, and also (iii) deal with novel events, due to the occurrence of new user's activities and changing user's habits.

# Ontology-Driven Semantic Unified Modelling for Concurrent Activity Recognition (Oscar)

## *Abstract*

Activity recognition has a vital role in smart home operations. One of the major challenges in object-sensor-based activity recognition is to learn the complete activity model derived from a generic activity model for sequential and parallel activities. Such challenge exists due to erratic degrees of dissimilar activities in which inhabitants perform activities in sequential and interleaved fashion while interacting with different objects. The proposed work focuses on recognizing a complete set of actions (of activity) by exploiting different knowledge engineering techniques, ontology-based temporal formalisms and data driven techniques. Semantic Segmentation has been employed to establish the generic activity model. The spurious semantic segmentation produced by sensor noise or erratic behaviour is removed by Allen's temporal formalism. Moreover, Tversky's feature-based similarity has been used to remove the highly similar spurious activities produced as a result of mistaken interactions with wrong home objects. The duration to perform activities varies among inhabitants; such duration intervals are identified dynamically using the proposed model in order to have a complete activity model. A comprehensive set of experiments has been carried out for evaluating the proposed model where the results based upon different metrics assert its effectiveness especially when compared with other contemporary techniques.

# Recognizing Activities at Home: Digital and Human Sensors

## *ABSTRACT*

What activities take place at home? When do they occur, for how long do they last and who is involved? Asking such questions is important in social research on households, e.g., to study energy-related practices, assisted living arrangements and various aspects of family and home life. Common ways of seeking the answers rest on self-reporting which is provoked by researchers (interviews, questionnaires, surveys) or non-provoked (time use diaries). Longitudinal observations are also common, but all of these methods are expensive and time-consuming for both the participants and the researchers. The advances of digital sensors may provide an alternative. For example, temperature, humidity and light sensors report on the physical environment where activities occur, while energy monitors report information on the electrical devices that are used to assist the activities. Using sensor-generated data for the purposes of activity recognition is potentially a very powerful means to study activities at home. However, how can we quantify the agreement between what we detect in sensor-generated data and what we know from self-reported data, especially non-provoked data? To give a partial answer, we conduct a trial in a household in which we collect data from a suite of sensors, as well as from a time use diary completed by one of the two occupants. For activity recognition using sensor-generated data, we investigate the application of mean shift clustering and change points detection for constructing features that are used to train a Hidden Markov Model. Furthermore, we propose a method for agreement evaluation between the activities detected in the sensor data and that reported by the participants based on the Levenshtein distance. Finally, we analyse the use of different features for recognising different types of activities.

# A Survey of Depth and Inertial Sensor Fusion for Human Action Recognition

## *Abstract*

A number of review or survey articles have previously appeared on human action recognition where either vision sensors or inertial sensors are used individually. Considering that each sensor modality has its own limitations, in a number of previously published papers, it has been shown that the fusion of vision and inertial sensor data improves the accuracy of recognition. This survey article provides an overview of the recent investigations where both vision and inertial sensors are used together and simultaneously to perform human action recognition more effectively. The thrust of this survey is on the utilization of depth cameras and inertial sensors as these two types of sensors are cost-effective, commercially available, and more significantly they both provide 3D human action data. An overview of the components necessary to achieve fusion of data from depth and inertial sensors is provided. In addition, a review of the publicly available datasets that include depth and inertial data which are simultaneously captured via depth and inertial sensors is presented.

# Designing Connected Resources for Older People

## *ABSTRACT*

In this pictorial, we illustrate steps towards a novel approach that situates connected technologies for older people as resources. In contrast to mainstream approaches in gerontechnology that consider elderly as frail and passive, we aim to complement older people's vital competences by designing technologies that can be used in less prescriptive, and broader ways. The pictorial describes our design process in which resourceful strategies were identified through thing ethnography and used as inspiration to create a series of new connected objects conceived as resources.

# Balancing Noise Sensitivity, Response Latency, and Posture Accuracy for a Computer-Assisted Canine Posture Training System

## *Abstract*

This paper describes a canine posture detection system composed of wearable sensors and instrumented devices that detect the postures sit, stand, and eat. The system consists of a customized harness outfitted with wearable Inertial Measurement Units (IMUs) and a base station for processing IMU data to classify canine postures. Research in operant conditioning, the science of behavior change, indicates that successful animal training requires consistent and accurate feedback on behavior. Properly designed computer systems excel at timeliness and accuracy, which are two characteristics most amateur trainers struggle with and professionals strive for. Therefore, in addition to the system being ergonomically designed to ensure the dog's comfort and well-being, it is engineered to provide posture detection with timing and accuracy on par with a professional trainer. We contend that providing a system with these characteristics will one day aid dogs in learning from humans by overcoming poor or ineffective timing during training. We present the initial steps in the development and validation of a computer-assisted training system designed to work outside of laboratory environments.The main contributions of this work are (a) to explore the trade-off between low-latency responses to changes in time-series IMU data representative of posture changes while maintaining accuracy and timing similar to a professional trainer, and (b) to provide a model for future ACI technologies by documenting the user-centered approach we followed to create a computer-assisted training system that met the criteria identified in (a). Accordingly, in addition to describing our system, we present the results of three experiments to characterize the performance of the system at capturing sit postures of dogs and providing timely reinforcement. These trade-offs are illustrated through the comparison of two algorithms. The first is Random Forest classification and the second is an algorithm which uses a Variance-based Threshold for classification of postures. Results indicate that with proper parameter tuning, our system can successfully capture and reinforce postures to provide computer-assisted training of dogs.

# Research Fiction and Thought Experiments in Design

## *Abstract*

Any design process involves an imaginative act, a picturing of the world as other than it is. Fiction has long played a part in design research in the form of scenarios, personas, sketches, paper-based prototypes, simulations, prototypes and speculative design. The term "design fiction" has been adopted to describe more elaborate and detailed representations of products and services that do not exist yet. Design fiction is an emerging practice and there are several competing definitions and forms. This article traces design fiction from the Italian radical design of the 1960s through British Art Schools in the late 1990s to contemporary adaptations of the practice by companies like Google, Microsoft and Facebook. Design fiction is now produced regularly by individuals launching Kickstarter campaigns, corporations selling visions of future products and governments imagining new digital services. But there is little agreement about the status of such fictions: what constitutes a good fiction\_\_ \_\_ How does fiction relate to research\_\_ \_\_ In what sense does fiction contribute to existing knowledge\_\_ \_\_ Although fiction can sometimes result in accurate prediction this is not its main value. It is rather the creation of ambiguous artefacts that help us think carefully about emerging technologies and their potential impact. Although fiction may seem to be the antithesis of empirical enquiry it is often employed in the form of "thought experiments" in Physics, Mathematics, Ethics and Philosophy. This article argues that design fiction can also be considered as a form of thought experiment. Excerpts from a fictional Wikipedia article about Valdis Ozols, a Latvian historian and author writing design fiction in the 1940s precede each section as think pieces about the nature and value of fiction. The text is illustrated with pages from a fictional design workbook written in an invented language.