Internet of Things (IoT) Leading to Internet of Trees (IoT)

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Keynote Speech

(Extended Abstract)

In this talk a review of the state of the art of smart homes using sensor technologies and Internet of Things (IoT) will be presented. At first a look in to the research work related to smart homes from various viewpoints will be discussed. This includes looking from the view point of specific techniques such as smart homes that utilize computer vision based techniques, smart homes that utilize audio-based techniques and then smart homes that utilize multimodal techniques. Then I will look at it from the view point of specific applications of smart homes such as eldercare and childcare applications, energy efficiency applications and then in the research directions of multimedia retrieval for ubiquitous environments. Using a survey we found out that some well-known smart home applications like video based security applications has seen the maturity in terms of new research directions while some topics like smart homes for energy efficiency and video summarization are gaining momentum. Finally I will present some of our recent attempts to apply IoT into connected forests leading to coining the phrase "IoT - Internet of Trees".

Humans interact with the environment that surrounds them, in numerous ways. They perceive the environmental conditions and act, react or adjust accordingly. If the environment can be made to reciprocate this behavior and respond to human behavior, it can produce some useful outcomes. Such behavior can automate various tasks that humans have to perform manually, and also provide novel services and facilities. A smart home is a home- like environment that possesses ambient intelligence and automatic control, which allow it to respond to the behaviors of residents and provide them with various facilities.

The standard approach for building smart homes is to *computerize* them. A set of sensors gather different types of data, regarding the residents and utility consumption of the home. Computers or devices with computing power (e.g.: micro-controllers) analyze these data to identify *actions* of residents or *events*. They then respond to these actions and events by *controlling* certain mechanisms that are built in to the home. A simple example for such smart behavior is turning the lights on when a person enters a room. However, more complicated tasks such as detecting if an elderly resident is alone and not feeling well are also desired.

Smart homes have been researched for nearly a couple of decades. The pioneering work in this area is the Smart Room implemented by the MIT Media Lab by Alex Pentland's group. Thereafter, several researches have investigated this topic with a wide range of prospective applications. At the current state, there are many types of smart homes with three major application categories.

The first category aims at providing services to the residents by detecting and recognizing their actions or by detecting their health conditions. Such smart homes act as information collection test beds to support the wellbeing of the residents of the home. These smart homes can be further divided into three types; smart homes that provide eldercare, smart homes that provide healthcare and smart homes that provide childcare.

The second category of smart homes aims at storing and retrieving of multi-media captured within the smart home, in different levels from photos to experiences. One might argue that the

issue of privacy of such type of information collection, but it will be a matter of acceptance in to once lifestyle with time.

The third category is surveillance, where the data captured in the environment are processed to obtain information that can help to raise alarms, in order to protect the home and the residents from burglaries, theft and natural disasters like flood etc. A few researches attempted to combine these functions into one smart home.

Apart from the 3 types of smart homes we have discussed there is an emerging trend of a special type of smart homes which can help the occupants to reduce the energy consumption of the house by monitoring and controlling of the devices and rescheduling their operating time according to the energy demand and supply.

With recent advances in electronics and computing, sensing technologies and computing power; smart home controllers can be built in small size, low price and they can be energy efficient. However, providing the ambient intelligence that is required to make decisions for smart behavior is still a challenging task. Human behavior at home is highly unstructured. Multiple sensory modalities are required to sense such behavior. Advance pattern recognition techniques are required to recognize the behavior of multiple residents. Privacy becomes an important issue once the systems store the data. Due to such challenges, smart room technologies at the current state are far from being matured.

In this talk I will present the state of the art of smart home technologies from several perspectives. The talk organizes the related researches as follows. Before going into specific application categories I will first look at different techniques used in smart homes namely; video based techniques, audio based techniques and multimodal techniques. Then I will outline video based techniques for human activity detection in smart environments followed by audio-based techniques. Subsequently I will investigate how to combine multiple sensory modalities to recognize actions and events that take place in a smart home. Thereafter I will look at specific applications of smart homes such as for eldercare and childcare followed by an investigation of smart home applications that make homes energy efficient.

Finally I will look into the research directions on Multimedia Retrieval for Ubiquitous Environments. A Ubiquitous Sensor Room is an environment that captures data from both wearable and ubiquitous sensors to retrieve video diaries related to experiences of each person in the room. A paper by Jaimes et al. (Jaimes, Omura et al. 2004) utilized graphical representations of important memory cues for interactive video retrieval from a ubiquitous environment. The Sensing Room is a ubiquitous sensing environment equipped with cameras, floor sensors and RFID sensors for long-term analysis of daily human behavior. Matsuoka et al. (Matsuoka and Fukushima 2004) attempted to understand and support daily activities in a house, using a single camera installed in each room and sensors attached to the floor, furniture and household appliances. In their paper de Silva et al. (de Silva, Yamasaki et al. 2008) presented their techniques for experience retrieval in a smart home. The smart home they have analysed was equipped with 19 cameras, 25 microphones and pressure-based sensors mounted on the house floor. Hierarchical clustering of pressure sensor data followed by video handover automatically created videos tracking residents as they walked to and from different rooms. Video summarization reduced these videos to sets of key frames, for faster viewing. Sound source localization followed by supervised machine learning facilitated video indexing by audio events. In the talk I will explain this in more details.

In conclusion of the talk I will summarize the research work related to smart homes from various viewpoints including application of IoT in Internet of Trees (IoT) arena. In the future we can envisage that more and more computer power given to smart sensors researchers will make use of them in home area distributed sensor networks with IoT. Each sensor will either report in real time to the host or they will keep the information in the memory for offline processing. In order to address complex situations in smart rooms, multiple agents based intelligent and distributed software/hardware frameworks have been proposed recently. Some top software companies are building application specific software targeted for smart homes so that existing infrastructure can be upgraded with added intelligence and decision making support. In the future our homes will not be the same. A simple example is our mobile phones. About 10 years ago it was just a phone that can make calls. Now the number of functions it has is countless among the calling facility. This analogy can be easily applied to our homes. One day it will be a

robot inside out. The house will look at us from many directions to protect us from potential dangers due to our forgetful ness or due to other physical disabilities. Then we will always have a friend to live in with us who will care for us and give advises and attend to routine work on behalf of us.

In the same note of using IoT in homes, use of IoT in the forests in the form of Internet of Trees (IoT) will give an added benefit to the living beings and plants in the jungle. Internet of Trees can help us to produce and equivalent of the "Facebook" in the jungle; a "Junglebook".

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Bio Data:

Professor Liyanage C De Silva received BSc Eng(Hons) degree from the University of Moratuwa Sri Lanka in 1985, MPhil degree from The Open University of Sri Lanka in 1989, MEng and PhD degrees from the University of Tokyo, Japan in 1992 and 1995 respectively. He was with the University of Tokyo, Japan, from 1989 to 1995. From April 1995 to March 1997 he pursued his postdoctoral research as a researcher at ATR (Advanced Telecommunication Research) Laboratories, Kyoto, Japan. In March 1997 he has joined The National University of Singapore as a Lecturer where he was an Assistant Professor till June 2003. He was with the Massey University, New Zealand from 2003 to 2007. Currently he is a Professor of Engineering and the Dean of the Faculty of Integrated Technologies (FIT) at the Universiti Brunei Darussalam (UBD).

Liyanage's current research interests are Internet of Things (IoT) Neural Network Applications, Image and Speech Signal Processing (in particular multi modal emotion recognition and speech emotion analysis), Digital Communication (CDMA, OFDMA etc.), Information theory (source coding), Pattern recognition and understanding (biometric identification), Multimedia signal

processing, and Smart Sensors (Smart environments for security, eldercare and energy efficiency). Liyanage has published over 170 technical papers in these areas in international conferences, journals and Japanese national conventions and holds one US, one Brunei and one Japanese national patents. The Japanese national patent was successfully sold to Sony Corporation Japan for commercial utilization. Liyanage's works have been cited as one of the pioneering work in the bimodal (audio and video signal based) emotion recognition by many researchers. His papers so far have been cited by more than 3000 times (according to scholar.google.com) with an h-index of 22.

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