Making Smart Home Truly Smart

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Abstract— The paper analyses the present state-of-the-art in Home Automation or Smart Home technology and points to the potential shortcomings of the technology that led to the question whether a Smart Home is truly smart? Present Smart Homes are controlled by remote control devices by the Users. Thus, in reality, the devices in a Smart Home are rather controlled by intelligent peoples, and that the devices do not operate autonomously limiting the capability to the capacity of the user and opening avenue to human error to cerrp in. In this paper an idea of a true Smart Home is presented where the system will have Artificial Intelligence and shall detect human behavior and monitor the occupants remotely using sensors connected through Internet of Things (IoT) and utilizing Machine Learning techniques, to predict human action and control the devices automatically without the active intervention of the users.

Keywords— Artificial Intelligence, AI, Machine Learning, ML, Deep Learning, Smart Home, Home Automation, Internet of Things, IOT

I.   INTRODUCTION

"Automation" as a concept has been perennial. The term "Automation" means integration of machines into self-governing system to perform tasks performed by human beings or tasks which are impossible for human beings to perform. In easy words, to simplify and ease Human efforts. [1]

Smart Home began just as a concept and was only perceived as a science fiction. For many years many distinguished writers imagined about a future home where everything is done automatically. One such conception was Ray Bradbury's short story "There Will Come Soft Rains", where he depicted a Home which keeps on functioning on its own after the civilization was nearly destroyed by nuclear war. The idea of Smart Home or Home Automation commenced in early 20th century, with the invention of household machines called Home Appliances. It simply involved Control and Automation of household machines such as lightings, washing machines, heating, ventilation and air conditioning systems, security systems, gas leak and smoke detectors, to name a few. Although the early home appliances and machines were somewhat automatic, performing mostly their islanded functions. But cannot be mentioned as what can be called "Smart", as human intervention was still needed. [2] More to that individual unit or appliance can only be controlled through a dedicated control unit exclusively paired.

II.   EARLY SMART HOME

The first idea of a true Automated Home featured in the December 1950 edition of Popular Mechanics, Push-Button Manor, a house built by a mechanical wizard Emil Mathias of Jackson, Michigan, USA, where he installed numerous numbers of switches and thousands of meters of wires to create a house where almost anything could be controlled by a push of a button.[3] Until recently Home Automation was all about installing power outlets such as lightings, appliances and Infrared control units all around the house and interconnecting all such controllable devices, and controlling all these devices either with a remote control or voice command. [4] Early Home Automation system was installed based on wired communication channels such as LAN and Power Line Communication. Installing one such system would cost a hefty amount that could only be afforded by the only wealthy peoples. With the dawn of 21st century and the emergence of technologies, like The Internet & World Wide Web, Wireless communication, Smart Home has become a viable option and a feasible technology trend for the common consumer, and all this had been made possible by smartphones and tablet computers, devices that are handy and portable, which make these devices omnipresent, and Ubiquitous Computing possible. Any smartphone or a tablet computer can be configured as a controller of the connected online devices, from anywhere through the Internet, making a network of online devices otherwise known as Internet Of things. [5, 6]

The future Smart Home is something similar to the abode of George Jetson, from the popular futuristic animated series "The Jetsons" [7] or a mansion like one that Bill and Melinda Gates own, Xanadu 2.0, in Medina Washington, where a vast & sophisticated sensor system monitors a room's climate and lighting. Every individual is given a pin which acts as personalized controller and the individual feeds the system with personalized preferences, and when that particular individual move around the house with their personalized control pin, the temperature and lighting automatically changes as per their preferences. [8, 9]

III. PROBLEM STATEMENT

All these interconnection and the control over our entire home from any place any time, make our home really smart? At the end of everything, we manually have to control the devices when we require and we have to manually set and store preferences, which will be fixated until we change the settings. We have to be somewhat limited to the capability of the control sensors to the device's ability to can sense and identify an individual. All these factors and operations do not demonstrate truly, a smart home but smart users who use an interconnected system by issuing commands to the devices through control devices. Suppose the control unit or the Remote Control device gets damaged, then the entire Smart Home will come to a halt; furthermore if the control pin gets misplaced, in such case the smart home will no longer react to an individual's custom settings. Still, many users are not so technology savvy and even in this age of technology, many people have not adapted to the usage of touch screens, remote controls.[10]

Imagine if we could keep aside the Remote Control and still the devices get controlled based on our variable preferences. How convenient would it be if the Home can act really smart and make decision on when & how to control the connected devices? What if a user becomes one of the control sensors? The Home can sense our move and behaviour and take decision regarding which device to control, what is the user's preference at a particular moment and change the settings automatically and most importantly can learn our behaviour and predict immediate next behaviour or preference.[11, 12, 13]

IV. OBJECTIVE

In this paper we have tried to draw the picture of an Intelligent House, where all the instruments and gadgets of the house will serve the user according to necessity and, depending on the situations, user won't have to operate the system manually. Everything in this automated house will perform the operations smoothly by inferring appropriate action based of the input from the inhabitants face or body, behavior and/or by detecting their emotional state. The base data about the inhabitants will be fed in the system initially, and the system will have the capability to gather more and more data progressively, updating itself according to the newly gathered data.

We begin this paper by analyzing and studying the current state of Smart Home technology, the operations and functions. After apt understanding of the system we came to the notion that Today's Smart Home is actually not "smart" in the true sense of the term. As defined by The Free Dictionary, 'smartness' is, "Having or showing intelligence." and intelligence is "capacity for learning, reasoning, and understanding; aptitude in grasping truths, relationships, facts, meanings, etc."

Furthermore, in this paper, a study of Human Activity Recognition and Prediction algorithms has been dealt with, and an idea of integrating such algorithms with the current system of Home Automation has been suggested to make an Intelligent Automated Home which will be able to detect and recognise a user and learn from the collected human behaviour patterns to be able to make intelligent decisions on its own and control the end devices as a particular user prefers to break the dependence on the user issuing explicit control commands through controlling devices or remote controls or through other invasive sensors, as stated by Emmanuel Munguia Tapia et al. [13]

V. RELATED WORKS

A. *Smart home design using wireless sensor network and biometric technologies [14]*

This paper proposes a new design for the smart home using the Wireless Biometric Smart Home (WB-SH) system. This system integrates two emerging technologies, the wireless sensor network technology and the biometric technology. WB-SH is designed to be capable of incorporating in a building automation system and it can be applied to various places like home, office and many other places. WB-SH offers a complete solution for the whole home including a number of subsystems. With the WB-SH, the home can be controlled locally or remotely through the Internet. The paper ends with a vision for the future of the smart home which employs the biometric technology in a larger and more comprehensive form.

Biometric recognition refers to the automatic recognition of individuals based on their physiological characteristics, but this method has its advantages and limitations; among them the vein recognition offers an array of advantages over the other biometric techniques including, ease of feature extraction, spoofing resistant, high accuracy, vein patterns are much less susceptible to many external factors, user friendliness, and the rapid verification against a stored reference template providing a very fast and robust biometric authentication.

B. *Modelling human behaviour from simple sensors in the home[12]*

In this paper the researcher presents a behaviour model for predicting future sensor outputs from previous data. Here "Language-As- Action" principle is introduced. The model is based on smoothened n-grams commonly used in language modelling. Here, five design goals are followed in designing the prediction system,

Probability prediction, model based vs instance-based learning, sensor location and type independence, real time performance, online learning

C. *Modelling and prediction of human behavior[11]*

In this paper, the researcher proposed that many human behaviour can be described accurately as a set of dynamic model, sequenced together by a Markov chain, where these dynamic Markov models could be used to recognize and predict human behaviour from sensory data. In this approach the human is being considered as a device with a large number of internal mental states consisting its own particular control behaviour and interstate transition probabilities. The

states of the Markov model can be hierarchically organized to describe both longer-term behaviour and shorter-term behaviours.

The authors further proposed that more improved human behavior prediction system could be made, by using such model. If there will be any system that is able to predict human behavior, it could adjust itself to serve the human's needs better. To accomplish this, the machine would need to be able to determine which of the human's control states was currently active and to predict transitions between control states. It could be then configure itself to achieve its best overall performance. Because the internal states of the human are not directly observable. This scenario requires that the human's internal state be determined through an indirect estimation process.

D. Activity Recognition in the Home Using Simple and Ubiquitous Sensors[13]

In this paper, an activity recognition system, in the home setting using a set of small, easy-to-install, and low-cost state-change sensors is introduced. The results suggest that sensing technology, which are less invasive than cameras and microphones, can be used to detect activities in real homes. Further a perception of simple, low-cost "tape on and forget" sensors those are easily taped on objects throughout an environment and used by a computing system to detect specific activities of the occupant. Computers that can automatically detect the user's behavior could provide new context-aware services in the home. If it is possible to develop computational systems that recognize daily activities, researchers may be able to automatically detect changes in patterns of behavior of people at home that indicate declines in health. The system described in this work could potentially be retrofit into existing homes to detect and monitor Activity of Daily Living ADLs.

E. Human behavior prediction for smart home using deep learning[4]

In this paper the researchers propose two algorithms, DBN-ANN and DBN-R, based on the deep learning framework for predicting various activities in a home. This research attempts to extract the relationship between past and future action using deep learning, because 'intention' and 'prediction' are deeply interrelated, and in order to predict human behavior accurately, understanding of inherent intention is needed. In this paper the researcher uses five different algorithms, k-means, a nonlinear SVM, DBN-ANN, and DBN-R, for making predictions. For implementing a nonlinear SVM.

DBN-SVM is a hybrid model which combines a DBN and a nonlinear support vector machine (SVM). The input data is connected to the visible layer of a DBN, and the uppermost hidden layer is connected to input of a SVM. A radial basis function is used as a kernel for the SVM.

DBN-ANN is a similar hybrid model, where an artificial neural network (ANN) is used instead of SVM. The back propagation algorithm minimize the mean square error (MSE) using the scaled conjugate gradient (SCG) method is used to train the ANN. The number of hidden layers can be freely selected.

DBN-R is a new formulation of the deep learning architecture for prediction. The DBN model is inspired by the ability of reconstructing missing data in an RBM.

F. BodyBeat: A Mobile System for Sensing Non-Speech Body Sounds[15]

In this paper, a mobile sensing system for capturing and recognizing non-speech body sounds in real-life scenarios, BodyBeat is proposed. Non-speech body sounds, human sounds of eating, breath, laughing, and coughing contain invaluable information about our dietary behavior, respiratory physiology, and affect. The BodyBeat mobile sensing system consists of a custom-built piezoelectric microphone and a distributed computational framework that utilizes an ARM microcontroller and an Android smartphone. The custom-built microphone is designed to capture subtle body vibrations directly from the body surface without being perturbed by external sounds. The microphone is attached to a 3D printed neckpiece with a suspension mechanism. The ARM embedded system and the Android smartphone process the acoustic signal from the microphone and identify non-speech body sounds. A substantial evaluation of the BodyBeat mobile sensing system is done. The results show that BodyBeat outperforms other existing solutions in capturing and recognizing different types of important non-speech body sounds.

VI. THE INTELLIGENT HOME

Every one of us, in our imaginary world since childhood, dreamt about having a 'Genie' like the one 'Aladdin' had. As we grew up the world of fairy tales faded, but somewhere in our subconscious mind, still a child is dreaming about having a 'Genie' who will create a comfortable living environment by following our physical and mental needs and look after us; watching our back and protecting us from any possible dangers. In this paper, we have tried to create a 'Genie' for our everyday life where the system will serve as the 'magic lamp'; or even better, even the need of 'making wish' is eliminated.

After hectic hours of work when we came back home, everyone wishes, if there were someone who will make the environment and ambience of the house that fits our comfort level, it would have been a boon. Other than that, in this globalized world, we all are running round the clock and we are not able to give enough time to the elderly member or other dependents of our home. But a tension is always there in our minds for our loved ones. The surveillance cameras are the story of past decade. Even though we can monitor with cameras, in the face of any adversity it is not able to help them out, other than capturing the picture and videos of situation and sending the pictures to a previously set receiver for records. But the proposed system will be able to help them out by creating the proper environment for their comfort. The system will continuously monitor the inhabitants of the house, and also will monitor the outside conditions and whenever

it will sense any anomaly or any similarity, it will take relevant actions. Moreover, the system would also be able to monitor the exterior and perimeter of the house and detect or predict a threat.

A. The Convenience

The system will be intelligent enough to recognize every inhabitant and to learn the behavior, emotion and preference of each inhabitant of the house and manage the house as per the comfort of the inhabitant. Adding to that, the system will track the activity and monitor the condition of the inhabitant remotely as the entire system will be interconnected through Smartphones [16] and Internet Of Things, then the system will be able to control the devices in the house without the intervention of the users or in simple words 'Eliminating the use of remote control devices'. Considering a scenario where a person is extremely tired and reaches home, and finds the temperature of the house perfectly set to his comfort, the ambience of the room set to his preference and the environment of the living room to match his preference, adjusting as per the atmospheric condition, or his, relaxing music playing in the background, the bathing room is already prepared according to his preference. Here unlike the already available systems, the person will not be required to control any of the devices and no remote control device will be necessary.

Another scenario would be, suppose Mr. Krishna who is not very interested in other sports apart from cricket, but one night he wakes up at night at an odd hour, say 2'O clock at night and turns on the television and tunes in to the sports channel, for a live cricket match, but tunes to a channel where a hockey match at the Rio Olympics is being telecasted, and he started enjoying the match, and got very happy with the performance of Indian Hockey Team. Then again the next night when he wakes up, the System will be intelligent enough to take in consideration of the odd night hours, and will not turn on the television automatically but instead will wait for the television to be turned on, now if the television is powered on then the system will compare the present state of Mr. Krishna and will compare with the state of last night further will check for the programs those are being telecasted currently, and if any other Olympic Indian match is showing the system will automatically switch to that channel, or switch to channel where a cricket match is telecasted.

B. Caring for our loved ones

Furthermore this system will be capable of monitoring the persons, especially the elderly members of the house, which will continuously keep track of their vital signs, such as heart beat, body temperature, breathing, [15, 17] and in case of any abnormality or say, illness is detected the system will not only inform the concerned persons but also will transmit the present condition to the emergency services or the medical services so that the paramedic officials will be prepared in advance to take care of the persons and provide initial treatment, which will reduce the preliminary diagnosis time and will save precious time, before the treatment could begin. According to medical experts, one of the best ways to detect exacerbating medical conditions before they become critical is to look for changes in the activities of daily living (ADLs).[13] Suppose Mr. Raman's grandmother, who is in her late 80s, lives with him and one day, when Mr. Raman is at office his grandmother had a stroke, in earlier days it would had been a nightmare because no one will be aware of the situation unless grandmother could somehow notify someone or someone else check on grandmother regularly. With the advent of the surveillance and remote home monitoring systems, Mr. Raman could know that his grandmother had collapsed and can notify the medical services to attend his grandmother, but apart from knowing that the person collapsed, the medical officers had no other information on the condition of the patient, so they will have to make an initial diagnosis to understand what the situation is before they could start any treatment. This system will supposedly eliminate these problems, as this will be able to predict that grandmother may have a stroke, and at the very first sign the system will automatically notify the medical services with all the information on the patient, so that the medical officers will be prepared to start appropriate treatment without losing valuable time and also notify Mr. Raman.

C. Security

Most importantly, the system will perform as the security shield against any threat. The system will recognize any unknown person and observe his activity and analyse the activity to determine whether the person is a threat or is friendly and will act accordingly. If threat is detected, activate defences mechanism or notify the law enforcement officers, or if a friendly then notify the occupants or if there is nobody at home, the system can notify the guest about this or even welcome the guest inside the house. To explain this with an real life situation, let's imagine a thief, who has a conviction history, is approaching the house, the system will be able to fetch the information from the available criminal database of the law enforcement agencies, and match the information with the approaching person and detect his emotion and activity and take decision on whether that person has the intention of stealing or not, and will take actions on its own, or suppose a mob is approaching towards the house, the system will be able to detect the pattern of the mob whether it's a violent mob or just another group of people coming for donation or any other peaceful purpose.

VII. LIMITATIONS & CONCERNS

To achieve the goal several limitations has to be addressed, most important limitation or problems, as described by Miguel A. Labrador and Oscar D. Lara Yejasare in the book 'Human Activity Recognition: Using Wearable Sensors and Smartphones', are Human Activity Recognition Problem (HARP). The problem is based on the assumption that a person does not perform same activity simultaneously, i.e. a person does not stand and jump at the same time, hence HARP is not feasible to solve deterministically. The number of combination of activities can be very large or infinite and finding the transition becomes very difficult as the duration of each activity is not known. To address this problem a relaxed version of HARP is introduced, Relaxed Human Activity Recognition Problem (RHARP), dividing the time series into

fixed length time windows, but this relaxation introduces some errors since a person might perform multiple activity during a time window. RHARP specifies the problem of building a learning model to recognize activities. These limitation are critical in activity recognition. [16]

Moreover, a major problem is the concern for privacy. Implementing this system will certainly mean that we are giving a lot of control of our daily lives to a machine, and empowering a machine to laterally read our minds. Will we be comfortable enough in giving this much control or our lives to a machine? As renowned physicist Stephen Hawkins said "the development of full artificial intelligence could spell the end of the human race." what if the prediction "It would take off on its own, and re-design itself at an ever-increasing rate, Humans, who are limited by slow biological evolution, couldn't compete, and would be superseded." by Stephen Hawkins proved to be true? [18] Only time will tell.

VIII. CONCLUSION

In this paper we tried to propose a home automation system or a Smart Home which will actually show Intelligence, and will be able to track and model human activity and behavior and using machine learning algorithms will be able to detect human behaviour and predict human action, and practically automate a home setup. The proposed system will act as the caretaker of the entire house which will control all the devices automatically without usage of any remote control and user input, the only input will be from the different types of sensors which will detect human behaviour and emotion. Furthermore the system will also act as a governor in the house which will not only monitor over the peoples in the house but also act for the wellness of the occupant of the house. Most importantly the system will act as a guardian of the house which will protect the inhabitants of the house.

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