An Architecture For Emotional Smartphones in Internet of Things

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***Abstract* — In the past few years, the idea of the "Internet of Things" (IoT) has been developing rapidly, with sensors and machines communicating with each other through the Internet. These new technologies can be used to support new types of Cyber-Physical Systems (CPS). Even though CPS consider humans as a part of themselves, they still treat humans as external elements, with unpredictable behavior. In fact, in order to the new IoT serves human needs better, it has to take into account all sorts of psychological and emotional states.**

Smartphones present an excellent opportunity to do so as they are a key element in IoT and they contain several sensors that allow us to collect information about user movement, location, environment, and interactions with other people. This type of mobile device usually accompanies the user anywhere he goes throughout the day.

This paper presents a work about a new paradigm that integrates human in the IoT. This paradigm is validated by the implementation of 3 applications that are detailed in this paper - HappyWalk, WeDocare and HappySpeak.

Keywords - "Human-in-the-Loop", "Ubiquitous Computing", "Behavior Inference", "Smartphone", "Cyber Physical Systems", "Behavior Change Intervention", "Emotional Sensing", "Artificial Neural Networks"

I. INTRODUCTION

The world faces many social problems such as child labor, health access or the current migrant crisis. Over the recent years, technology has been developed to mitigate these problems, providing education for children in underdeveloped countries [1], health management in underprivileged areas [2] or outreach programs to help refugees start new lives [3]. IoT and all of its devices is the path forward to solve many more of these problems. IoT is based on lowcost technologies, like wireless sensor networks, and on smartphones, and as such IoT represents an enormous potential as it can be used by all, even poor people.

In this context, we explored and developed 3 solutions based on our Happy System architecture that integrates the Human in IoT: HappyWalk, HappySPEAK and WeDoCare. These 3 projects are built upon the Happy System, an architecture that aims to use sensors to infer human emotions, and use the knowledge it gains to improve the user's life. Smartphones are the perfect tool for this, as they are becoming more widespread and possess an array of sensors that can be used to monitor the user and his environment.

We developed HappyWalk to detect one of four emotions: Euphoria, Calmness, Anxiety and Boredom. Boredom and Anxiety are considered to be negative emotions, and when detected, the systems shows the user places he may like to go to in order to improve his mood.

For the HappySPEAK and WeDoCare systems we mainly focused on two groups of people: migrants and refugees. In order to understand the needs of migrants, we exchanged knowledge and formed a partnership with Associação Fazer Avançar (AFA) and its program SPEAK.

SPEAK[4] is a cultural program designed to bring people together by promoting language learning. Its premise is simple: the main barrier that stops foreign people from bonding is language. SPEAK tries to bring down this barrier by allowing anyone from anywhere to sign up and learn or teach other languages. It goes even further by organizing social events with the purpose of creating a bond between participants.

Migrants mostly move to a new country to find better standards of living (due to financial or social needs), but sometimes can't speak the language and they travel alone. Not knowing the language makes it hard for them to socialize and meet new people. This is where HappySPEAK tries to help.

HappySPEAK replicates SPEAK's platform, allowing users to register, and view future SPEAK events in their area. Also, it collects information about the user, such as messaging and call logs, in an attempt to detect if the user feels lonely. This information is then used to suggest the user places he can visit or SPEAK events he can attend.

As we have stated before, one the main social issues in Europe is the huge influx of refugees due to the war in Syria. Millions of refugees are trying to get to Europe in order to escape war in their country. To help with these efforts many refugee camps have been created, but, due to a lack of resources and manpower, security in these places is becoming scarce. To help with this problem, we also created WeDoCare. This system aims to detect violent attacks against refugees. The app collects data from motion and sound sensors of the

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smartphone from time to time, and if an attack is detected, it sends a distress signal to nearby people and policemen.
This paper intends to describe these 3 applications in the context of integrating the Human in the future Internet - Internet of Things. Section 2 describes the theoretical work supporting the integration of the Human in the IoT. As far as we know, this topic is innovative and will have a great potential in the future Internet. Section 3 presents our Happy System model that we developed and is the base for the integration of Human in IoT. Section 4 is the proof of concept where the 3 applications that we developed are presented. Section 5 discusses future work and concludes the paper.

II. Related Work

A. Human-in-The-Loop

The Human-In-The-Loop (HITL) paradigm considers humans as vital part of the control loop. It can be divided in three main components: the human being, its environment and the system.

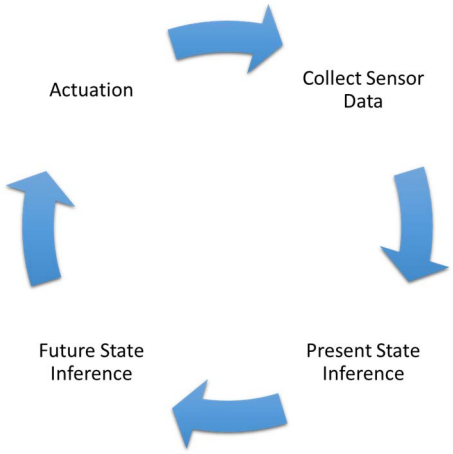

Figure 1- HITL control loop

In figure 1, we can see how the HiTL control loop works. Everything is centered on the human being:

- Data acquisition - Sensors collect information about the user and his environment.
- State inference - It infers how the user is feeling.
- Future State Inference - It uses previous information to improve its accuracy in future inferences.
- Actuation - The system tries to expose useful data to the user, in the form of information or suggestions.

There are many real-world applications that use this paradigm. Some of those are:

- Electronic Health systems that monitor patients to reduce human error. This system monitors, for instance, heartbeats and oxygen to calculate the appropriate amount of medicine that should be injected [7].
- A wheel chair with assisted driving that avoid obstacles such as stairs or drops [6].
- A memory jog system for supportive information in meetings and collaborative workspaces [5].
- A system that suggests a better path to get to a destination, in order to avoid high traffic areas [8].
- An electrical grid management system that uses information from its users to create and improve inter/intra-enterprise processes [9].

B. Behavior Change Intervention

Behavior Change Intervention (BCI) systems aim to alter human behavior in a positive way. These interventions are mainly focused on giving advice and expose information that will help the user correct negative behavior (such as a sedentary lifestyle, smoking, overeating, etc.).[10]
This type of system requires a degree of information about the user and his activities. Smartphones are extremely useful for this because they accompany the user for most of the day and have sensors that can be used to infer how he feels and the state of environment around him.
These interventions traditionally occurred in therapeutic sessions between two or more people, but are also starting to occur through the Internet and in smartphones.

C. Cyber-Physical Systems

Today's technology has evolved to a point where machines and sensors communicate with each other seamlessly, giving way to the so called "Internet of Things". This allows new types of Cyber-Physical Systems (CPS) to be developed. While CPS today are built around human interaction, many of them just consider humans as external, unpredictable element to the control loop.
Other than e-Health, there is not much scientific work done about the human context in the control loop of CPS [5]. Smartphones present an excellent opportunity to do so. They possess the processing power and the array of sensors required to develop CPSs to the next level. In short, when we start using this type of mobile devices to evaluate and monitor human nature, humans become a part of CPSs. This brings us to Human-in-The-Loop Cyber-Physical Systems (HiTLCPS).
By inferring emotional and psychological state of the user, as well as actions and behavior we can increase the accuracy of the control-loop. For instance, let's take into account cruise control systems. If the user is tired, it could suggest to him that maybe he should consider turning cruise control on.[5]Since human beings are considered to be extremely unpredictable this presents an enormous challenge.

D. Recommender Systems

Recommender Systems (also known as Recommendation Systems) have become widespread in recent years. Many well-known companies are using them to improve their services and expose new products to their customers. These include Amazon, that uses content-based recommendation to suggest items the user may want to buy, based on previous purchases; Netflix combines 107 recommendation algorithms to form a

single prediction and suggest new video content to their users. Many other companies like Facebook, Twitter, Google and LinkedIn use recommendation engines to expose interesting information to their users.[11]
These systems usually use one of two approaches: Collaborative Filtering or Content-based filtering. Hybrid approaches also exist.
Collaborative Filtering is based on user behavior, and can construct its model from it or from the collective behavior of users with similar traits. In essence, it aggregates users based on their preferences and recommends content based on it.

III. The Happy Sysyem

For a system of this nature to work properly we primarily need a sensor array that allows us to measure human behavior and his environment, and optionally, a server to save and process information. Fortunately for us, today's smartphones come equipped with many sensors, such as:

- Accelerometers - Provides information about user movement.
- Microphone - Can measure the amount of activity around the user.
- GPS - Allows us to see where the user is, at what time and consequently at what speed he is moving.
- Temperature - Measure ambient temperature.
- Ambient Light – Measures the amount of light around the smartphone.

A. Happy System Architecture

The Happy System is an architecture designed for smartphones that allows users to select a set of features and use them for emotion inference using a neural network. Its architecture can be described by the following figure:

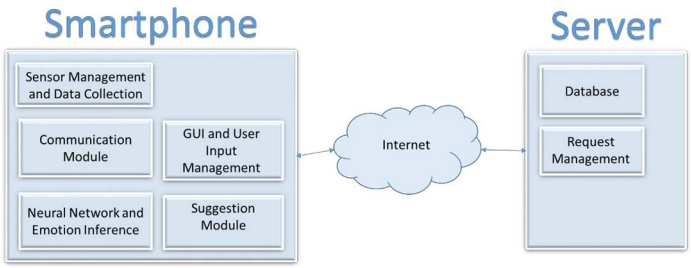

Figure 2-Happy System Architecture

In the smartphone system, we have four different components:
The **Sensor Management and Data Collection module** manages what sensors must be activated and what data must be collected. It also processes the data and saves it into the appropriate data structures.
The **Communication module** establishes connection with the server and handles all incoming/outgoing requests.
In the **Neural Network and Emotion Inference module** a neural network is "fed" with sensor data and infers how the user is feeling. This module also takes feedback for the user in order to increase its accuracy over time. Even though the base system uses a Neural Network, the model used for emotion classification can easily be switched by another one.
GUI and User Input management present the several user interfaces and handles all of the user input.
The **Suggestion Module** generates a suggestion for the user to improve his behavior.
A server-side application can be connected to the smartphone in order to save data or do processing in the cloud. In the server component we have two different components:

- **Database**- Saves incoming data from the user and saves it for future analysis.
- **Request Management**- Handles all incoming/outgoing requests from the user.

IV. Proof-Of-Concept

In this section we will describe how we implemented several systems that derive from the Happy System architecture.

A. HappyWalk

HappyWalk is a Behavior Change Intervention system that estimates the users' current mood and tries to improve their physical and mental well-being. It does this by monitoring user activity, using smartphone sensors, and inferring the users' mood. If the system detects that the user is in a bad mood, it will suggest that he takes a walk by displaying several points of interest in a map.
This app employs a full closed HiTL control- loop:

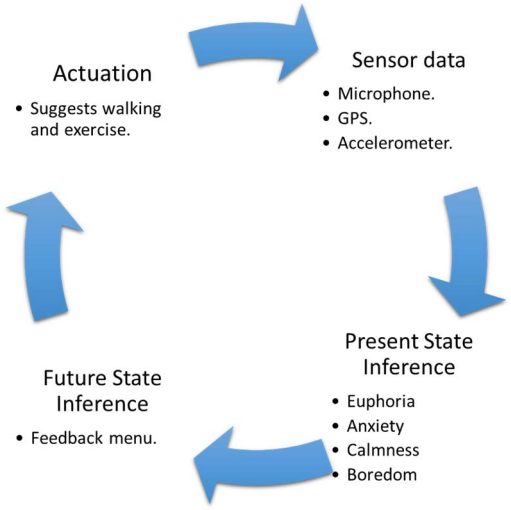

Figure 3-HappyWalk HITL implementation

HappyWalk uses data from the smartphone's microphone, accelerometer and GPS sensors as inputs in a neural network. The output will be one of four emotions: Euphoria, Boredom, Calmness and Anxiety. This system considers euphoria and calmness as positive emotions so it only gives the user suggestions if it detects Boredom and Anxiety.

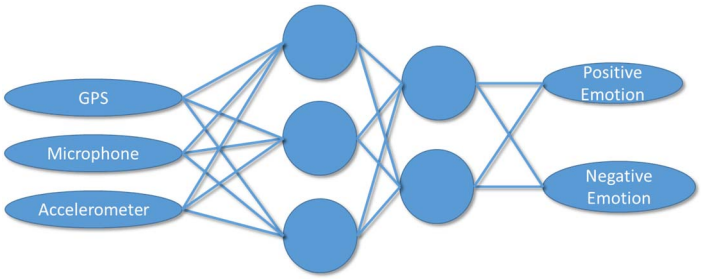

Figure 4 - HappyWalk Neural Network

This Neural Network is trained by asking the user for feedback on how he is feeling from time to time.

B. *HappySPEAK*

In the past decades the world has been witnessing a huge increase in the number of migrants, searching for better standards of life. The reasons that make people migrate are varied, and can be classified as:

- Economical
- Social
- Political
- Environmental

Moving to a different country isn't easy. Cultural differences and linguistic barriers make it harder for migrants to connect with citizens of the hosting country. This can lead to migrants feeling lonely, especially if they came to a new country alone.
This is where SPEAK tries to help. First it tries to connect them with people in the same situation, by organizing dinner parties and events that brings them together and makes them learn more about one another.
SPEAK[4] is a cultural program designed to bring people together by promoting multiculturalism and the democratization of language learning. It provides courses and encourages people from different cultures to share their interests and break any prejudices they may have about foreigners.
The neural net that is currently implemented is a Feedforward neural network with a sigmoid function.
After the data is collected the following features are extracted:

- SMS ratio: Division between received and sent text messages that show if the user is sending more messages than he receives.
- Call Ratio: Division between the number of calls the user received/made.
- SPEAK attendance: If the user is registered in SPEAK classes, we check his attendance record, in order to see if he is trying to socialize with other people.

If the network detects that the user feels lonely, it triggers the map activity which displays suggestions of SPEAK events occurring soon and places that can help him meet new people. These suggestions will help the users to socialize; thus, reducing his isolation.

C. *WeDoCare*

WeDoCare is a system built upon the Happy System that aims to prevent violent attacks on refugees. It takes advantage of the mechanisms built in HappyWalk for detecting human emotion and applies it to this kind of situations, trying to help people by warning nearby policemen and common citizens that someone is in danger.
The app periodically collects data and uses it to check if the user is in a danger situation. The data comes from three sensors: the accelerometer, GPS and microphone, and is able to work with Wi-Fi, mobile networks and Wi-Fi beacons.

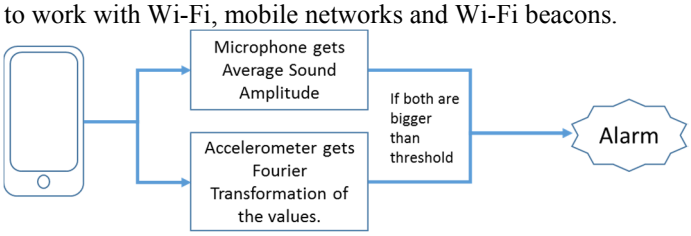

Figure 5-WeDoCare Attack classification

IV- Conclusions

The developed systems show the versatility of the Happy System Architecture, as we were able to apply it to different user classes and contexts. We can improve the architecture even further by experimenting with other classifiers such as SVM, Naive Bayes and Deep Neural Networks. The suggestion module can also be improved by using Social Network information to direct users to places they like or to services they enjoy. The architecture may also be complemented with more advanced emotion recognition techniques such as using deep learning to recognize emotions via speech, searching for specific keywords in text messages among others.

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