Project proposal
For
Internet of Things
Lab 2015

Smart Home-User Integration with a Feedback Interface

NIT Trichy

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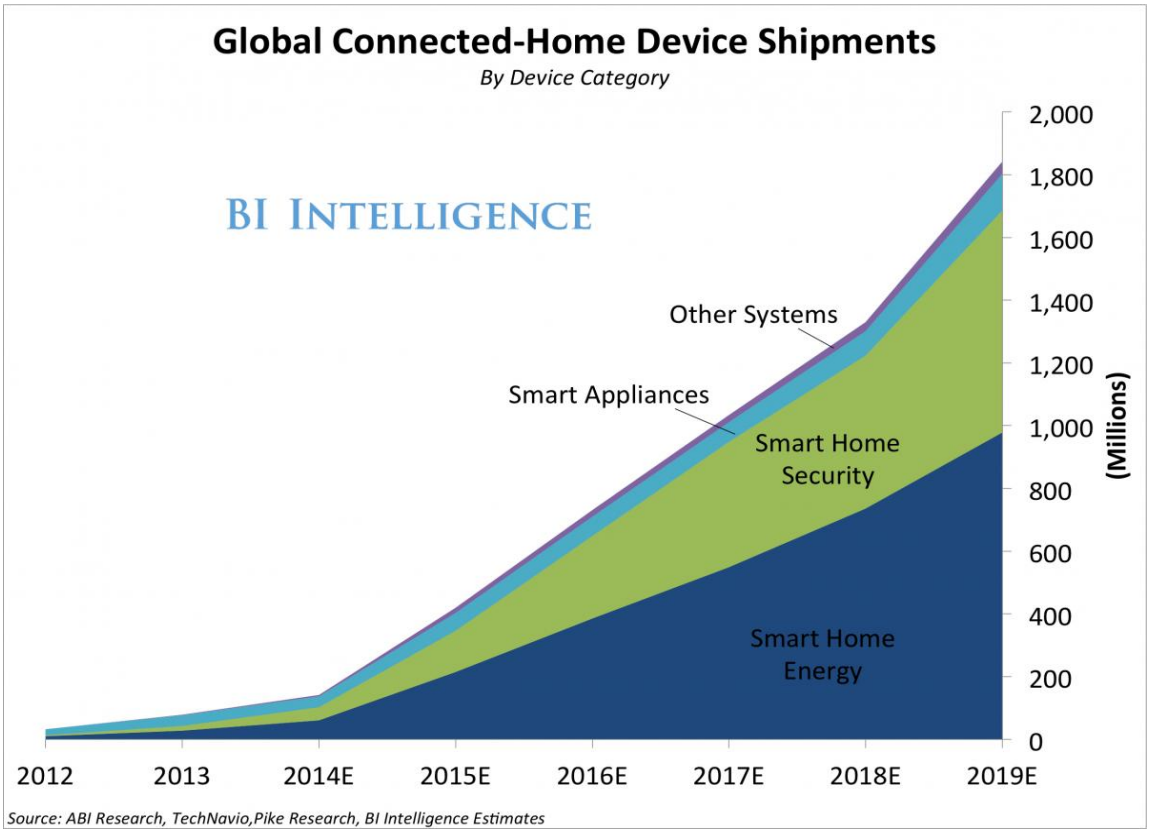
Abstract:

The project aims to build a real-time feedback interface between the user and his/her house, to make the house more intelligent and to cater to the needs of the user. Also, it makes the user aware of the changes in various systems in the house and notifies him to take actions/automatically takes the necessary action. The feedback from the user is primarily based on Facial Tracking. Using his facial expressions and based on a few sophisticated algorithms (including machine learning), we can categorize his emotion as happiness, sadness, fear, exhaustion, anger or excitement with some accuracy percentage. All this is processed and stored in a background app that runs in the mobile and the results are relayed to the house. Using this optical feedback from the user, the devices in his house such as AC/thermostat, lights, music player and television are controlled. The feedback from the house is using sensors (such as ultrasonic sensor, temperature and humidity sensor) and the results are sent as notifications to the user so that he becomes aware of the systems in his house (like garbage level, water level, security of the house etc.) through a mobile application.

Keywords—Image processing, Wireless Networks, Home Automation, Feedback Interface

Market Analysis

- Indian automation industry is growing at an annual rate of 20 to 25 percent. Renowned Brands in INDIA like L&T has grown 41% of the revenue in 2010-2011 for automation solutions.
- **Home Automation Market** was valued at USD 3.6 billion in 2012 and is expected to reach USD 16.4 billion by 2019, growing at a CAGR of 24.6% from 2013 to 2019.
- Standing at the point of inflection, home automation market is estimated to see North America retain its position as the largest market. Revival of construction activities, especially on new residential buildings and renovations, is expected to support market growth in the region.
- Of all the applications of home automation systems, growing consumer preference for safety and security solutions is expected to result in 'safety and security segment' dominate market growth across all these regions.
- While luxury segment remains the main revenue generator, the ubiquity of tablet computers and smartphones will radically change the market landscape. The price reductions and simple user interface are expected to gradually tilt the market's balance in favour of the mass market.
- The integration of tablet computers and smartphones with home automation solutions are likely to appeal to the mass segment. Additionally, the current purchasing forces in the market are more technically savvy and willing to embrace new technologies. Hence, a higher number of end users are likely to install home automation systems.
- According to Allied Market Research, the home automation market globally is growing at a compound annual growth rate (CAGR) of 29.5% from 2013 to 2020, with Asia Pacific the fastest growing market with nearly 38% CAGR.



- **Connected-home device shipments will grow at a compound annual rate of 67% over the next five years, much faster than smartphone or tablet device growth, and hit 1.8 billion units shipped in 2019, according to BI Intelligence estimates.** Connected-home devices include all smart appliances (washers, dryers, refrigerators, etc.), safety and security systems (internet-connected sensors, monitors, cameras, and alarm systems), and energy equipment like smart thermostats and smart lighting.
- **The connected-home category will make up about 25% of shipments within the broader Internet of Things category this year**, but that share will increase gradually to roughly 27% in 2019 based on our forecast, as growth in other IoT areas picks up.
- **Connected-home device sales will drive over $61 billion in revenue this year.** That number will climb at a 52% compound annual growth rate to reach $490 billion in 2019**.**

Project Description

Objective in relation with the Market Study:

We wish to improve the current Home Automation market with our product which is based on an Intelligent Feedback Interface. Human Facial Tracking that we are implementing here (using the mobile application to be discussed later), is a potential market for E-commerce and Gaming firms to optimize the user experience with the game/e-commerce firm. Our product as such is cost-effective as it uses already available sensors in the phone such as Camera and the Accelerometer. As the project heavily relies on software, the prototype is very close to the end-product. Making the trash can smart and securing the house and providing notifications to the user are some of the features that we have added as of now as the feedback from the house to the user. More such systems could be integrated into this Feedback network.

Other Extended uses:

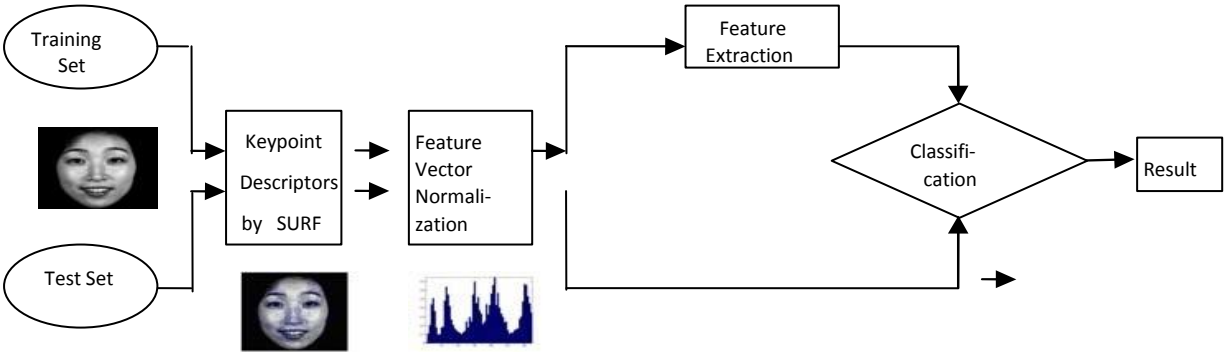
The best part is that the project can be extended to various devices easily and hence very versatile in nature. We can use this system not only in the house but maybe even in a car, where stress levels of the driver can be monitored. This project can also help the user know about his EQ (Emotional Quotient) and hence helps him in his daily life.

PROPOSED SOLUTION

PART ONE – IMAGE PROCESSING AND MOBILE APPLICATION

- The detection of facial expressions will be carried out with the help of an android app which runs the phone's front camera in the background. The rationale behind using a background mobile app is the fact that these days, human beings look a lot at their mobile phones for various purposes, such as messaging, social media, reading the newspaper, playing games and so on. In fact, a major part of their mood is determined by the notifications they receive each day. Moreover, mobile phones are portable, and this makes them a much better option than a desktop app, or an electronic circuit. Running the app in the background ensures that they can focus on other tasks, while the app does the processing.
- Firstly, as image processing is generally a processor-intensive operation, it would be helpful if the app can determine whether a person is facing the camera, or the phone is just lying around with the camera turned on. In the latter case, the app can just decide to skip the image processing until a face is detected. Android provides a face detection library under the Media package. This is the library which helps any app draw a rectangular border around a person's face in a photograph.

- Once a face has been detected, the Speeded-Up Robust Features (SURF) algorithm is carried out (implemented using OpenCV for Android). SURF works by finding various keypoints in an image, that is, those distinct features of the face that help one distinguish between a smile and a frown. This algorithm has two parts – detection and description. The detector locates the keypoints in an image, and the descriptor describes their features, and constructs their feature vectors. The keypoint descriptor is normalized to a Probability Density function descriptor.
- Once this is done, a technique called KL Divergence is used to calculate the distance between two PDF descriptors to determine the two nearest PDF descriptors from two images. The recognition tally is calculated from PDF descriptors and used for initial classification.
- Finally, Weighted Majority Voting (WMV) is used for final classification.



Initially, 3-4 sample images of each emotion of the person should be taken, so that the app is personalized for the particular person, and a more accurate analysis of the person's mood is carried out.

PART TWO – HUMAN GESTURE TRACKING

- The app is best suited for sensing natural expressions, some emotions and engagement. Facial hair and glasses could make the detection harder. It supports the detection of the six primary emotions - **Anger, Disgust, Fear, Joy, Sadness and Surprise.** Apart from this we can extend our reach to tracking gestures and movements associated with the person.
- **Static or Intrinsic Traits:**
  Commonly include tracking of **weight** and **shape**. Weight can be measured through piezo-resistive sensors while shape detectors operate by intersecting a person's shape with geometric lines which are actively produced by the sensor or passively appropriated from the environment (e.g. cameras). Another trait is the involuntary motion of the internal organs. A wireless signal is sent and is reflected from the human body. As a result any abnormalities can be detected based on the response pattern.
- **Dynamic Traits:**These are the ones due to the human activity. They can be divided into **external motion** and **vibrations**. External motion is defined as the change in a person's pose or in the position of their Body centre of mass. As for vibrations, these are the pressure waves that people produce either involuntarily (in the form of sounds and vibrations from footsteps) or voluntarily (in the form of speech), which can be measured with accelerometers and microphone.

Another elaborate method of detecting facial expressions is through **lip contour determination**
This can be divided into five subparts:

- Human face detection using skin colour identification and face feature comparison
- Mouth extraction from the detected human face
- Lip forming contour determination using edge detection
- Filling of lip contour to generate binary image of lip

Feedback from devices

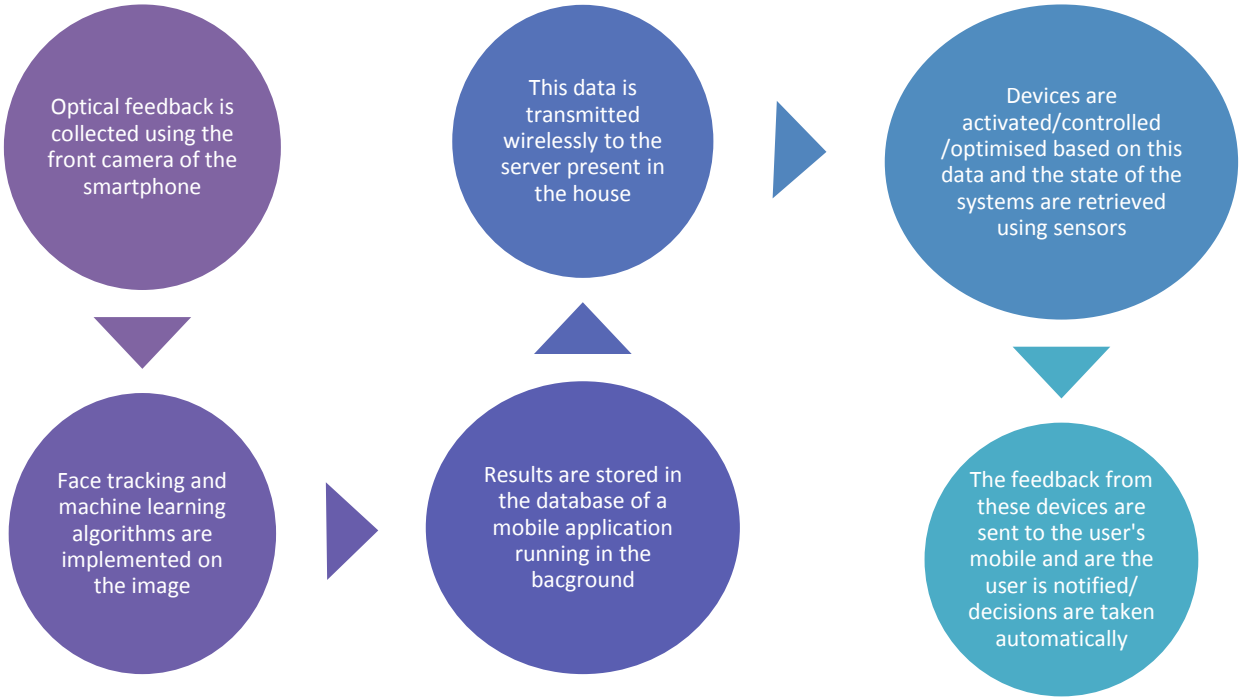
The communication between the user's mobile phone and the devices in the house is done through wifi. The app on the phone sends data to a web server in the house which is communicated to the devices via a wifi module. These devices, in turn, use their wifi modules to send their data to the server which can be received by the mobile app (feedback).

Examples of feedback systems:

1. **Smart trash can**: An ultrasonic sensor is placed above the trash can to determine the extent to which the can is filled. Whenever the can is filled, this information is sent to the garbage truck drivers via wifi so that they could empty it.
2. **Security system:** A system that alerts the user when the house is unlocked.

   Similarly, the feedback used in this project is as follows: If the app reports that a user is sad, the device like, say the audio player gets this information from the server, and then makes a decision to play an energetic song to lift the person's mood. On the other hand, if the app reports that a person is agitated, the air conditioner turns on, and the audio player plays a soothing song.

- **BLOCK DIAGRAM**



PROJECT EXECUTION PLAN

1. **Proposal to Prototype:**

   The primary system that we are trying to build is a MOBILE APPLICATION that runs in the background. This app uses the 'Camera' service to get the images of the user using the smartphone.
   First, we plan to research about face detection, recognition and tracking of facial features. Then, we'll go ahead and implement the same using platforms such as OpenCV/Matlab on a computer. We'll try to optimize the application and then using App Development using the OpenCV API for Android, we plan to convert all this work into a mobile application. We would also like to integrate machine learning algorithms so as to customize the product to the end user.
   This mobile application will also have a database storing critical data about the user over time. Using Wi-Fi, we wish to route this data to the server in the house.
   In the house we plan to control a plethora of devices all of which will be connected to the central server. For prototyping, we wish to implement the same using lighting, music player and AC. For feedback from the systems in the house, we wish to implement the smart trash can and a security system for the house. These systems will relay information about their state to the user through another mobile application. This will be the second part of our prototype.

2. **Prototype to Product:**

   - The prototype is very close to the product (in terms of software) as the mobile applications that we build are extremely close to those which can be put to use in real-time.
   - We plan to use Wi-Fi as our communication protocol. It is robust and is simply the most used in the current scenario.
   - This is better than home automation products available today due to the feedback interface.

Tools and Components

PARTS	USAGE/ADVANTAGE
Wifi module (ESP8266)	Used for communicating the sensor data to the server
Wifi router	Connects the devices in the house with the user's mobile
Ultrasonic Sensor	Used to sense the percentage of volume filled in the trash can
Webcam	Used for Human Facial Tracking
Temperature Sensor	Used to monitor the temperature of the house
Humidity sensor	Used to monitor the humidity parameter in the house
Accelerometer (for motion capturing)	Used to capture the pattern of movement of the user

Bill of Materials

PART	FUNCTION	ESTIMATED QUANTITY	ESTIMATED COST
Wi-Fi module(esp8266)	Used to communicate wirelessly with the server in the house	4	1400
Wi-Fi router	Sends the wireless signals to be captured by the mobile device	1	1300
Ultrasonic Sensor	Detects the conditions where ultrasound is generated	2	240
Webcam	Captures the gestures	1	550
Temperature Sensor	Keeps the temp to moderate levels	1	120
Humidity sensor	Senses the presence of relative humidity in the atmosphere	1	100
Accelerometer	Used for motion capturing on the web cam	1	220

Links for components and tool samples to purchase

1. Wi-Fi Module (esp8266)
   http://www.ebay.in/itm/ESP8266-Serial-WIFI-Wireless-TransceiveR-Module-Send-Receive-LWIP-AP-STA-/181520772825

2. Wi-Fi Router
   http://www.flipkart.com/tenda-wireless-n150-easy-setup-router/p/itmdzsejyawe3hax?pid=RTRDZSEG8ZZMEXMH&ref=L%3A3034481926956167 87&srno=p_5&query=wifi&otracker=from-search

3. Ultrasonic Sensor
   http://www.flipkart.com/robomart-ultrasonic-sensor-module-hc-sr-04/p/itme2zrvgz2hqznz?pid=ETYE2ZRVHW7WGHEF&otracker=from-search&srno=t_1&query=ultrasonic+sensor&ref=3d28d1ae-64e0-4999-9b17-4c7d59306f5d

4. Webcam
   http://www.flipkart.com/super-it-netra-webcam/p/itme25rvgfgrgxf6?pid=ACCE25RVZAE6MGDD&otracker=from-search&srno=t_6&query=webcam&ref=f8591d06-90e6-43a5-a3e9-83a5e3690bbf

5. Temperature Sensor
   http://www.flipkart.com/robomart-temperature-sensor-module/p/itme2zrvgfacy5bk?pid=ETYE2ZRV7STGWFWW&otracker=from-search&srno=t_2&query=Temperature+sensor&ref=6d395433-d5c6-427f-b7f5-310b2fb0ec42

6. Accelerometer
   http://www.amazon.in/Simple-Labs-Triple-Axis-Accelerometer/dp/B00K2Z3140

7. Humidity Sensor
   http://www.ebay.in/itm/DHT11-Temperature-and-Humidity-Sensor-Arduino-ARM-and-other-MCU-/121635562440?pt=LH_DefaultDomain_203&hash=item1c520b63c8

Conclusion

Home automation is a flourishing, rather exploding market. The numbers reveal that this sector is very promising in terms of IoT and its applications in the years to come. This project delves into this popular field and attempts to implement some non-conventional strategies of smart homes and intelligence including face recognition and feedback based on the identified mood and emotion. This would redefine the concept of "smart homes" by not only relying on external environmental factors and adapting to it, but also taking extra efforts to make human life more comfortable by relying on feedback from humans themselves, without any explicit human exertion. Thus, this project is a humble attempt at improving the quality of living of any person by adjusting his environment to suit his requirements by making use of Artificial Intelligence and Image Processing concepts.

List of References

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  Andreas Savvides Yale University
- *Measuring emotions through a mobile device across borders, ages, genders and more*
  Rolfe Swinton and Rana El Kaliouby
- *Facial Gesture Identification using lip contours*
  Council of Scientific and Industrial Research
- *Face and head tracking using the Intel Realsense SDK*
  https://software.intel.com/en-us/blogs/2015/01/19/face-tracking-using-the-intel-realsense-sdk-bkms
- *Home Automation prospects*
  https://www.linkedin.com/pulse/20140523072725-339157087-home-automation-market-an-overview-of-growth-factors-and-future-prospects-2013-2019
- http://www.businessinsider.in/

Project Timeline

Tentative Timeline for completion of the project.

Phases	Progress
Week 1	Research on Image Processing and Machine Language algorithms to be implemented

Week 2	Implementation of face detection and face recognition algorithms
Week 3	Implementation of tracking of facial features
Week 4	Implementation of machine learning followed by testing
Week 5	Integration of developed application with the mobile
Week 6	Piloting and checking for performance improvement spots
Week 7	Demonstration to mentor and receiving suggestions and inputs
Week 8-11	Implementation of the hardware section with sensors and the Wi-fi module
Week 12	Final Submission