Self-learning Intelligent Human-Home Interaction through End-user Programming and Crowdsourcing

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Abstract
UPDATED—16 February 2016. This paper introduces a new method of designing and building intelligent home. We apply end-user programming, crowdsourcing, trial-and-error model of reinforcement learning and combine them to guarantee the efficiency and effect of the whole system. A set of scenes are presented to describe the advantages of our intelligent human-home interaction. Privacy and security are also taken into concern. The system is designed to improve user experience and life quality meanwhile minimizing resource cost and pollution.

Author Keywords
intelligent; human-home interaction; end-user programming; crowdsourcing; self-learning, sensor.

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H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous; See http://acm.org/about/class/1998 for the full list of ACM classifiers. This section is required.

Introduction
Intelligent home has been a popular topic in both industry and academia for years. Traditional methods

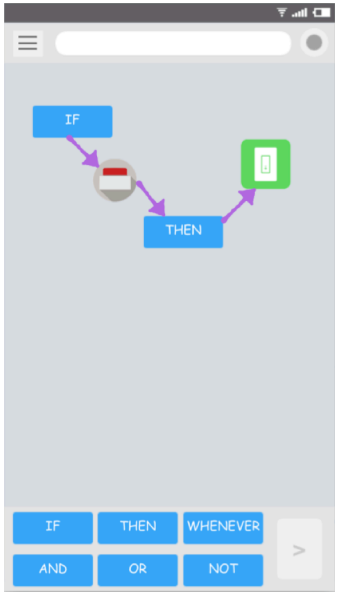

Figure 1. Two-dimension TAP through multi-touch control

focus more on intelligent devices and control systems. Modern technology has provided more possibilities of interaction between human and house. The platform of "IF-THIS-THEN-THAT" (IFTTT), for example, makes it possible for users to use simple programs to control devices. In this paper, we introduce a new way of human-home interaction: Self-learning intelligent human-home interaction through end-user programming and crowdsourcing. We treat "home" as an "N+1" member of a family by enabling its ability of learning.

End-user Programming

One of the main problems of designing intelligent home is how to interact with "home", which means the devices and services in life. Light bulbs, for example, traditional way of controlling them was using physical triggers; modern methods include central control system; remote controller; Application on mobile phone; voice controller; body gesture controller, and so on. With the development of Trigger-Action Programming (TAP), we can now write programs to send orders to light bulbs. Users can write simple TAP receipt like "IF time turns to 7:00 pm – THEN – turn the light bulb on" through IFTTT.

However, advanced method also brings more complicated problems: Ur. et al, and Huang. Et al have discovered in their publications that the final TAP and original user intent may be different sometime due to ambiguity. [1, 2] Moreover, the oversimplification of IFTTT user interface only allows very simple receipt with basic logic "IF-trigger-THEN-action".

In this paper, we introduce an enhanced method of end-user programming: Two-dimension TAP through multi-touch control. Users could use fingers to click, drag, and link between different icons on the screen. Research shown that touch-control contributes to better user experience than the traditional windows, icons, menus, pointers model (WIMP). [3]

As shown in Figure 1, each icon represents a different trigger, event, action, or logic operator. With the help of multi-touch devices, every member of the home could interact with the home through writing and editing commands easily.

Another way of end-user programming through the intelligent devices is to "talk" directly to the home and teach it what to do. End-users use verbal commands to program instead of coding. This can be built on the basis of the two-dimension TAP, which teaches the home what the users have done in the past and helps the home to understand verbal languages better. Many intelligent devices offer APIs, thus we can send requests directly, or through platforms like Smartthings. For example, we can now talk directly to Amazon Echo to let it turn on or turn off the light bulbs that we want.

Talking to home directly will make end-user programming easier and more friendly. Home will behave much more like a real member if it can understand your words: "Turn off the air conditioner if nobody is at home after 7 pm", and provide feedback: "I got it, do you want me to also turn off the heaters at the same time?" In this case situation, the home notices that the user usually gave two TAPs together to control air conditioner and heater in the past. It understands that these two TAPs are both related to the indoor temperature, thus it can ask that question to save energy.

The goal of end-user programming is not only interacting with the home, but also an important method of teaching the home about the behavior of each family member. The home will store all the TAPs in its database, and keeps learning from it. From different TAPs given by unique user, the home can come up with personalized model for every member, and even pets and visitors.

Crowdsourcing

Once the home starts learning from the database of end-user programming, it may meet a number of problems of understanding human intent. For example, if the home receives a TAP "IF – puppy Mcqueen is hungry – THEN – feed him". There will be several questions for the home:

- Who's puppy Mcqueen
- How to tell whether Mcqueen is hungry
- What does it mean by "feed him"

The user who gave this TAP will be able to answer the first question and the third one, however, it is extremely hard to answer the second question. Crowdsourcing has been proved to be a good way in solving this kind of problems[4]:

Put a sensor on puppy Mcqueen, or near its crate, or next to its bowl. Send the pic to crowdsourcing platform, i.e. Amazon Mechanical Turk (AMT), asking professional people what the pic tells us. Use the result to train a machine learning model. Whenever the sensor detects anything that the machine learning model can not understand, send the new pic to AMT again, collect answers from professionals. After several loops, the model will be able to understand all the photos taken by the sensor. In this way, a unique model designed specifically for puppy Mcqueen is finished.

Crowdsourcing can also help solve questions asked directly by members of the home. For example, a user can ask "What sofa should I choose for my living room", the home can send this question to a certain group of people who have authority and knowledge to this question, and provide answers back to the user.

Research has shown that crowdsourcing has significant strong power in some problems that are hard for computers or artificial intelligence (AI). We would like to let people work on what they are best at, and let AI deal with what requires its advantages of computing and modeling.

Self-learning

With the help of end-user programming and crowdsourcing, the home gains the ability of updating its database and model over time. We think house itself should be the additional member of any family. The more data it has, the better it knows and understands the family. We then enable the house to ask questions by itself to serve the family members better.

The trial-and-error model of reinforcement learning is the base of self-learning of the home. Whenever a good question is asked, the family members could give reward to the home. When a bad question appears, penalty will arrive. Reward and penalty will also work for good and bad solutions as well. For example, if the home asks "Do you need some beautiful music" but plays unwelcomed music, it will learn from the penalty that what type of music is "beautiful" to which people.

People in the house can give reward and penalty to any action of the home at anytime. The home will use the feedback it receives to train and update its model. In the end, it will have personalized model for any unique user. The home will be able to provide different feedback to the same command given by different people.

Privacy and Security

An intelligent home can not be trained without the help of sensors. However, some sensors, i.e. cameras, may be worried by people for the concern of privacy. On the other hand, security is also one of the most important aspects of intelligent home. We apply the technology of machine learning and electric field.[5]

Electric field exists almost everywhere. Research has shown that the changes of pressure on the walls, floors and ceiling will lead to changes of electric field. By building machine learning models of these changes, the home can know what happens in the house through a sensor which detects changes of electric field. The sensor will not take any vision or sound of the house, thus the privacy can be protected better.

Whenever special events are detected, the home can react correctly immediately. For example, when a baby climbs close to the window, the home can send alarm to adults; when old people fall to the floor, the home can contact medical service; when there is water leaking, the home can call the maintenance; when there is a thief breaking into the house, the home can call the police.

Scene of Intelligent Human-home Interaction

In a well-trained intelligent home, people will be able to stay away from most physical triggers:

- When a user wants to open the window, the only thing he needs to do is to wave his hand towards the window, which will open automatically to the place where the user is pointing at
- Light bulbs will be able to change angles and intensity dynamically. When a user wants to switch from movie time to dance time, the only thing she needs to do is to stand up and pose ready. The house will understand this command, and operate all the light bulbs so that they follow the user as she moves
- If a user usually comes back home at 6 pm, the home will turn on the air conditioner at 5:50 pm to make the air ready for the user
- If all users leave the house, the home will turn off all the devices that do not need to work, thus the house will save more energy, resources meanwhile produce less pollution
- At around midnight, a four-year old baby wakes up and wants to go to restroom while all the adults are asleep. The baby is too short to reach the triggers of light bulbs, and the intensity of light bulbs is too strong for her eyes. The intelligent home will know what's happening, and perform in a best way: It will open light bulbs one by one and let them produce very soft light to lead the baby to the restroom. The intensity of the light will be just enough for the baby to walk, neither too strong nor too weak for her eyes. The angles of the lights will also change

dynamically for the baby. After the baby comes back to her bed, sleep mode will start working again

Discussion

Home, instead of house, can be an "N+1" member of a family. The purposes of intelligent human-home interaction are:

- Minimize resources (water, electric energy) cost
- Minimize pollution
- Improve user experience
- Improve life quality

We believe that an intelligent home that has the ability of learning from TAP, crowdsourcing, people's behavior, and asking questions could produce personalized service for any different user. With the power of end-user programming, crowdsourcing, trial-and-error system of reinforcement learning, we can train AI in a much better, faster, and more efficient way.

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References

1. Huang, Justin, and Maya Cakmak. "Supporting mental model accuracy in trigger-action programming." *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing*. ACM, 2015.
2. Ur, B., McManus, E., Pak Yong Ho, M., and Littman, M. L. Practical trigger-action programming in the smart home. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, ACM (2014), 803–812.
3. Wang, G., Bowditch N., Kwon M., Zeleznik R., and Laviola J. *A Tablet-Based Math Tutor for Beginning Algebra.* 2015 Workshop on the Impact of Pen & Touch Technology on Education (WIPTTE 2015), Redmond, WA, April 28-30, 2015.
4. Papoutsaki, A., Guo, H., Metaxa-Kakavouli, D., Gramazio, C., Rasley, J., Xie, W., Wang, G. and Huang, J., 2015, September. Crowdsourcing from Scratch: A Pragmatic Experiment in Data Collection by Novice Requesters. In Third AAAI Conference on Human Computation and Crowdsourcing.
5. Lombardi, M., Vezzani, R. and Cucchiara, R., 2015. Detection of Human Movements with Pressure Floor Sensors. In *Image Analysis and Processing—ICIAP 2015* (pp. 620-630). Springer International Publishing.