Social Networks of Things for Smart Homes Using Fuzzy Logic

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Abstract
This study presents the IoT for smart home solution that allows users to specify and centrally controlled smart objects. Unlike most existing systems it uses fuzzy logic for control of smart objects. Social Network and IoT enabled sensors work with environment to automate operations of a home to make it smart and automated regarding comfort, health, security and safety. Sensor used interface for interaction with smart objects to perform operations needed automatically. Decisions to automate operations of smart objects based on sensors input associated with expert opinion according to need of environment. Fuzzy logic used to make all decisions live in the form of true or false against the given inputs. Sensors of different types like hygrometer (Humidity Sensor), Thermostat (Temperature Sensor), Photo-Voltaic Sensor (light intensity Sensor), Anemometer (Wind Speed Sensor), camera etc. used for inputs from environment. Other than sensors weather forecasting from weather station also included as input that make system performance better and more accurate. All the information for controlling environment shared to other smart home nearby to control their operations accordingly. The proposed model suggest to install sensors in only one of the homes nearby and the information after
fuzzy implementation will be shared with all other homes. This system is also useful for monitoring the communication among Smart Homes within Smart Homes Network as well.

Key words:
Internet of Things (IoT), Social Network of Things (SNoT), Smart Home, Fuzzy Logic, Sensors, Smart Objects.

1. Introduction

Worldwide network of smart objects and "things" is called IoT [4, 5]. While being remotely accessed by users or autonomous applications these objects shares their sensory information over the network [4]. The concept of IoT was proposed by the MIT Auto-ID labs, their researchers suggest the use of wireless sensor network WSN and Radio Frequency Identification (RFID) technology to detect object location [6]. Afterwards, the International Telecommunication Union (ITU) in 2005 defined the IoT as set of all objects communicating over the networks [7]. The major applications of IoT are smart cities, smart traffic control, smart homes (home automation) and elderly / child care, Smart industrial units, smart energy management, etc. [8]. The term smart home refers the management of environmental systems, such as temperature

control and lighting, monitor and control of smart objects in the home environment. Achievement of smart home is to provide comfort of living, health care services, energy management services, security and safety services to user [9, 10].

Smart objects (SO's) are main items of Internet of Things (IoT). Most of the objects in a home are not smart. To implement smart objects in the Internet of Things, we need to use sensors and a physical network connection with smart objects. Such parameters would increase a level of smartness to smart objects by allowing them to communicate with each other. Smart Objects would be accessed remotely by using network components.

Nowadays for controlling smart objects in a smart home environment programming logic is used that are not accessible by users due to different platform and architectural issues. Recent perforation of high tech gadgets in our routine life had compelled users, including technical and non-technical users, for there active role in development of smart homes. This allows users to analyze, develop, and upgrade technologies that are better implemented according to their needs. This dilemma has dubbed in the as End-User Development (EUD). EUD debates on set of techniques, activities, processes, models and tools which enables users to analyze, develop, upgrade, software and hardware technologies [11-13]. These technologies would be completely based on "plug and play" architecture [13]. The proposed system will enables End-User Development for smart homes. Individuals after all customization regarding all parameters of their home, and is required to obtain them with the tools which are necessary to customize, change, and access the smart home.

Simple IoT Enabler (SITE), is a mature system model which consists of both hardware and software subsystems which enables users to develop and modify smart home

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systems that react regarding to their requirements. The proposed system will be designed and develop to support both technical and non-technical users. To support non-technical users, we propose Simple Control Language (SCL) for the central control of smart objects (sensors) in a smart home. We will use fuzzy logic to implement Simple Control Language.

2. Literature Review

2.1 Internet of Things

Basic purpose of Internet of things is connectivity of different devices / things that may be any object all over the world for the sake of communication among them. There are several applications of IoT including Smart Homes, Smart Cities, and Smart Traffic Control Systems etc. IoT is used to make devices and Smart objects more intelligent to enable them as intelligent so that they can automate their operations and also make them recognizable over the network [1].

2.2 Smart Home design

Smart Home, Smart Energy Management, Smart City, Smart Traffic Control System are applications of Internet of Things (IoT). A common Smart Home is based on several smart objects that communicate with a central control unit may be software application. This software application is based on different applications of Distributed Services Oriented Middleware [14], Gateway and Integrator [18], ZigBee-based Intelligent Self-Adjusting Sensor (ZiSAS) [18], E-Servant [15], Controller [16], Home Gateway [17], etc. the basic features of such software application are identical and may be explained as, it receives dynamic inputs using smart objects (sensors) and controls the environment using commands sent to centralize application. Commands are mostly sent against sensor's data. This type of software application sometimes allows the user to visualize collected information at different levels.

2.3 Existing Smart Home Systems

In many researches it is explained that Smart Objects accessed and view in smart home environment [14-16, 18]. Smart Home Systems are based on hardware and software provides users access either locally or remotely, to monitor the humidity, temperature, lighting, locks of entrance etc. These applications are implemented using IoT [14]. Some recent studies suggests to compute the CVC application using mobile devices through which the user control and monitor smart objects in the smart home environment [16-18]. These researches also suggests that Network Hardware like Hub to combine all the information given by Smart Objects before sending to the CVC application.

CVC applications are developed through programming to control smart objects. Nichols and Myers [20] methods for automated generation of user interfaces to map with CVC functions. For controlling the features of SOs Nicolas and Mayers developed the User Interface Descriptive Language (UIDL). Using User Interface Descriptive Language (UIDL), they proposed a method for generation of user interfaces automatically for controlling Smart Objects. For IoT they also proposed a Modality-Independent user interface generation method [21].

2.4 Smart Objects (SOs)

A Smart Object communicate with other Smart Objects or users in smart Home System. Smart Objects are used to automate the operations of smart home like temperature control, monitoring like detection of carbon level in a room to detect fire, and control like switching of lights "on" and "off" to implement smart home environment to provide safety, comfort, security, and energy management. All the objects in a home environment are not smart. Several techniques are used to make these objects smart to respond Smart Home environment. Some studies proposed sensors to attach these objects to respond the Smart Home environment. Holmquist et al. in their "smart-Its" project, used a tiny attachable computer system to attach on un-assembled furniture parts for gathering data about assembling of these parts. They use the core board that includes a processor and wireless router and the board containing sensors like sound, pressure, acceleration, light and temperature and also includes gas and camera as sensor [22]. Tapia et al. proposed a sensor named "state-change sensor" which is a tap-on sensor to detect change in an object state to measure user's activity. They attached several tap on sensors to a bed to detect movement of a person sleeping on that bed [23]. Kameas et al. also use similar approach in their research using tap on hardware boards to objects to make interaction among these objects and also user [24].

Alternate to these sensor board, many researchers work on embedding sensors and/or actuators to specific object for using in a specific application. Antifakos et al. for identification of users design and develop smart door lock. By using two accelerometers, one in the door handle and other in user's wrist. The detection of person identity is dependent on measuring the correlation among these accelerometer signals [25]. In "Mediacup" project a coffee cup was embedded with a processor, temperature and motion sensors, Wi-Fi network device to study the capture and communication of the cup's different status like hot, normal, cold and moving, stationary, full, and empty. All

these sensors and processor was embedded into a board attached at lower of the Mediacup [26].

3. Fuzzy Logic

Any Logic based on multiple values regarding truth values or any real number between "0" and "1" of a variable is called fuzzy logic that is used to perform the concept of partial truth in which truth vale may be between completely true and false [27].

Lotfi Zadeh introduced the fuzzy logic in 1965 in his research proposal of fuzzy set theory [28 29]. Some other researchers like Lukasiewicz and Tarasi also work on fuzzy by giving named it infinite valued logic [30].

4. Proposed Model

Smart homes uses different type of sensors with smart objects for controlling their environment those sensors may be hygrometer (Humidity Sensor), Thermostat (Temperature Sensor), Photo-Voltaic Sensor (light intensity Sensor), Anemometer (Wind Speed Sensor), camera etc. The proposed model suggest to install sensors in only one of the homes and the information after fuzzy implementation will be shared with all other homes to make their operations accordingly. Data provided by these sensors will be used as inputs from smart home environment. Other than sensors weather forecasting from weather station also included as input to make system performance better, accurate and economical. Proposed system will use fuzzy logic instead of a central application for controlling smart objects. All the information / fuzzy logic output for controlling environment will be shared to other smart homes nearby to control their operations according to their needs.

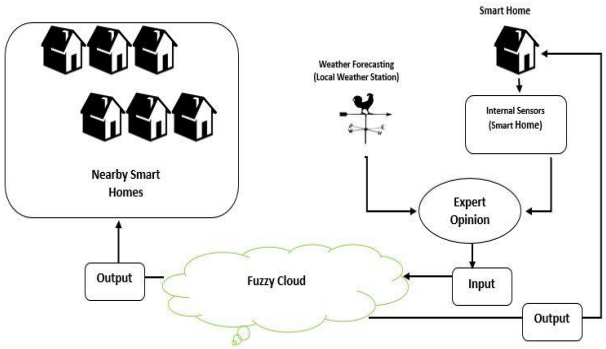

Fig. I System Diagram

4.1 Fuzzy Cloud

Data provided by smart home over the network is very sensitive and needs to secure it from unauthorized access. We proposed a fuzzy cloud for this security concern and fuzzy logic for implementation. Instead of using a central application that might be unsecure and costly, fuzzy cloud will perform the operations of fuzzy logic and is better in the sense of Security and platform independency. By using the cloud services we never need to install any additional hardware and software within the smart home network environment. All the information gained by Smart Objects within Smart home and local weather station is sent to Fuzzy cloud that will process this information using fuzzy logic accordingly and produces outputs against the given inputs to share with other Smart Homes for control of Smart Objects Within those smart Homes. Fuzzy Cloud uses the Fuzzy Rule base model for processing of the inputs to achieve required outputs.

4.2 Fuzzy Rule Base System

This system receives sensory inputs within Fuzzy cloud and on the basis of knowledge base including Scaling Function, Fuzzy Rules and Membership functions fuzzy rule base system process it to produce output after fuzzification and defuzzification using inference engine. The system diagram of Fuzzy Rule base is given in figure II.

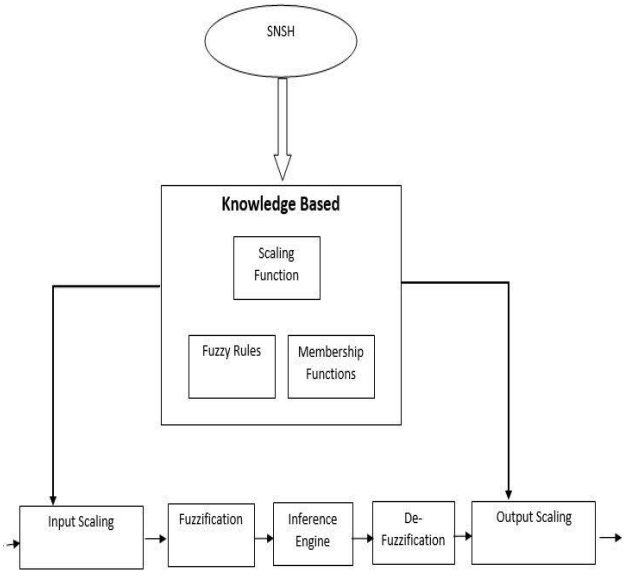

Fig. II Fuzzy Rule Base System

4.3 Inter Smart Home Communication

Inter Smart Home Communication is direct in case of network connectivity and also indirect because Smart Homes share their information using Fuzzy Cloud (Fuzzy Rule Base). Sensors are only need to install in one home of a cluster that makes the proposed model more economical. Communication among Smart homes is necessary to achieve maximum efficiency and required results from the system. Detailed Model of Inter Home Communication and its working is illustrated in figure III.

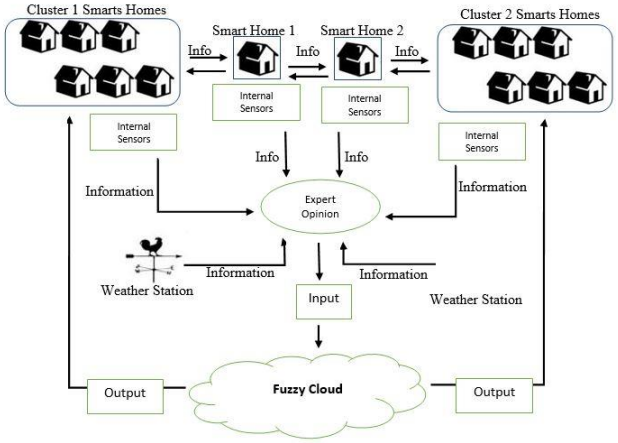

Fig. III System Diagram With Inter Smart Home Communication

4.3.1 Evaluation of Smart Home Communication Model

In the above system diagram cluster 1 and cluster 2 shows the group of homes in some different geographic locations but remotely connected to each other. Smart home 1 and smart home 2 are intermediately smart homes which are responsible for communication between cluster 1 and cluster 2. The information produced by cluster 1, cluster 2 and intermediate smart homes is collected via an internal sensors. This information is supplied to Expert opinion module which collects information of smart homes equipped with sensors and local weather stations. Then this integrated information becomes input to fuzzy cloud because all the expert opinion modules are sent to fuzzy cloud. In fuzzy cloud, Fuzzy Rule Based System are implemented. According to these rules the output and necessary information about the remote smart homes sent to the clusters. In this architecture clusters can communicate via intermediate smart homes as well as they can receive remote smart home knowledge through fuzzy cloud and make their decision according to this information. The internal model of fuzzy cloud is shown in figure II.

The proposed system is providing an economical solution to create an intelligent and smart environment of Smart Homes. In the proposed system it is not necessary by every node (house) to equip with sensor devices, rather every smart home is required to be a part of the Smart home network for smart data sharing.

4.4 Fuzzy Logic Implementation for Smart Home System

Smart Homes are based on different modules / subsystems and those subsystems are independent to each other and are totally different on the basis of sensors used by them and logic for implementation of these sub-systems to automate the operations of home to make it smart/ automated. Some of these sub-systems are temperature control system, energy management systems, health care systems, security systems, fire detection and control systems etc. These systems uses different sensors for input data and smart objects for performing output operations. For example temperature control system uses some sensors like temperature sensor and humidity sensor and smart objects like Air Conditioner and Exhaust is used for controlling the temperature as well according to given inputs by sensors on the basis of fuzzy logic. So that these system needs separate control logic for their proper working according to user comfort. Fuzzy cloud will manage this issue by using different fuzzy logic rule for different subsystems. So it is needed to develop different fuzzy logic rules for these subsystem for implementation over the fuzzy cloud.

Temperature control system is basic need of a smart home to provide users comfort of living. A proposed smart temperature control system using fuzzy logic is given below.

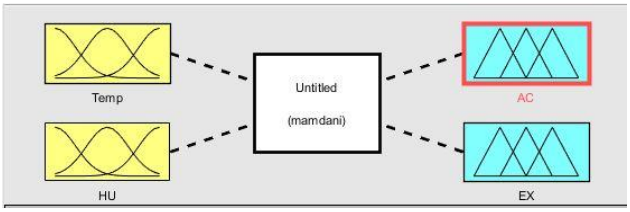

Fig. IV Fuzzy logic System for Temperature Control based on Mamdani model.

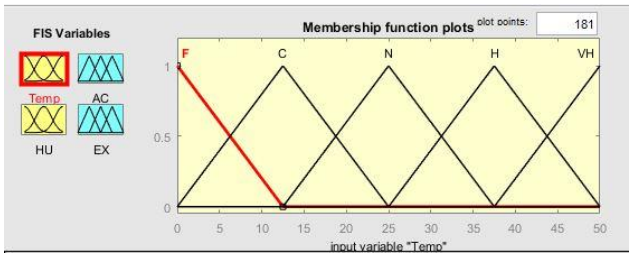

Fig. V Plot of membership function for input variable Temperature.

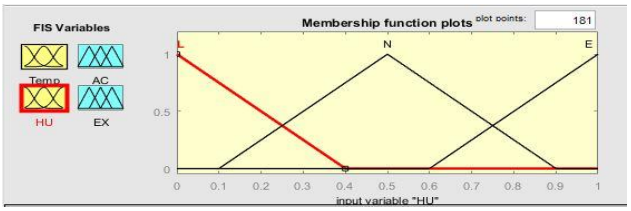

Fig. VI Plot of membership function for input variable Humidity.

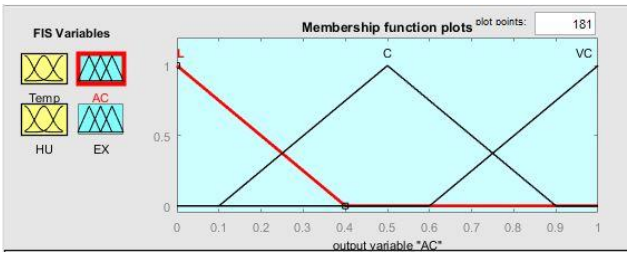

Fig. VII Plot of membership function for output variable for Air Conditioner.

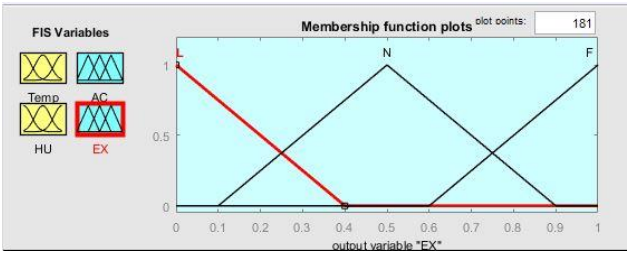

Fig. VIII Plot of membership function for output variable for Exhaust System.

In previous figures we can observe that all the inputs (Temperature and Humidity) are mapped with outputs (Air Conditioner and Exhaust) using fuzzy logic rules on the basis of Expert Opinion.

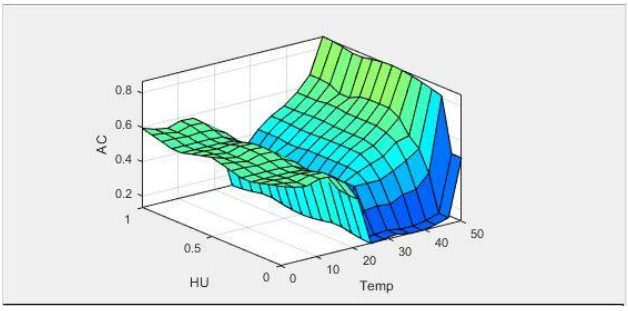

Fig. XI Plot between Humidity and Temperature representing the changing of output according to inputs.

To implement complete Smart Home it is suggested to deploy all smart subsystems using fuzzy logic and connect them to Smart Homes Network System so that they can share their information for controlling their environment accordingly.

5. Conclusion

This Paper presents a novel approach for Smart Homes using Fuzzy Logic. The proposed study provides solutions for development of smart homes and proposed a model for inter Smart home communication. This approach not only gets real time data from internal sensors rather it also includes input from local weather station for Fuzzification and Defuzzification process to produce results in real time. The aim of proposed system is to provide dynamic information and communication between nearby as well as remote smart homes. The proposed model will provide an economical solution for inter-smart home communication because in the proposed Smart Home network system it is not necessary to deploy or install sensors for input in every node (home) rather it only needs one home form a cluster to be equipped with sensors or smart objects in order to share the sensory information to its own as well as other clusters within smart home network using fuzzy cloud services.

6. Future Work

In future Social Network Analysis (SNA) can be implemented over this Smart Homes Network for monitoring and analysis of communication among Smart Homes. After deploying data repository in the proposed system, the communication and data collected from Smart Home network nodes can also be used for big data analysis in order to generate useful patterns and association rules.

References

[1] M. A Majeed and T. D Rupasinghe, "Internet of Things (IoT) Embedded Future Supply Chains for Industry 4.0: An Assessment from an ERP-based Fashion Apparel and Footwear Industry", International Journal of Supply Chain Management, vol. 6, no. 1, pp. 25-39, 2017.

[2] K. N. Truong, E. M. Huang, and G. D. Abowd, "CAMP: A magnetic poetry interface for end-user programming of capture applications for the home," in International Conference on Ubiquitous Computing, 2004, pp. 143-160: Springer.

[3] J. Coutaz, A. Demeure, S. Caffiau, and J. L. Crowley, "Early lessons from the development of SPOK, an end-user development environment for smart homes," in Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct Publication, 2014, pp. 895-902: ACM.

[4] L. Atzori, A. Iera, and G. Morabito, "The internet of things: A survey," Computer Networks, vol. 54, no. 15, pp. 2787-2805, 2010.
[5] D. Bandyopadhyay and J. Sen, "Internet of Things: Applications and Challenges in Technology and Standardization," (in en), Wireless Personal Communications, vol. 58, no. 1, pp. 49-69, 2011/05// 2011.
[6] I. Bose and R. Pal, "Auto-ID: managing anything, anywhere, anytime in the supply chain," (in en), Communications of the ACM, vol. 48, no. 8, pp. 100-106, 2005/08/01/ 2005.
[7] I. Peña-López, "ITU Internet report 2005: the internet of things," 2005 2005.
[8] A. Zanella, N. Bui, A. Castellani, L. Vangelista, and M. Zorzi, "Internet of Things for Smart Cities," IEEE Internet of Things Journal, vol. 1, no. 1, pp. 22-32, 2014/02// 2014.
[9] G. Fortino, A. Guerrieri, and W. Russo, "Agent-oriented smart objects development," in Computer Supported Cooperative Work in Design (CSCWD), 2012 IEEE 16th International Conference on, 2012, pp. 907-912: IEEE.
[10] M. R. Alam, M. B. I. Reaz, and M. A. M. Ali, "A review of smart homes—past, present, and future," Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on, vol. 42, no. 6, pp. 1190-1203, 2012.
[11] J. A. Macías, "Development of end-user-centered EUD software," in Proceedings of the 13th International Conference on Interacción Persona-Ordenador, 2012, p. 24: ACM.
[12] H. Lieberman, F. Paternò, M. Klann, and V. Wulf, "End-user development: An emerging paradigm," in End user development: Springer, 2006, pp. 1-8.
[13] R. Dautriche, C. Lenoir, A. Demeure, C. Gérard, J. Coutaz, and P. Reignier, "End-user-development for smart homes: relevance and challenges," in Proceedings of the Workshop" EUD for Supporting Sustainability in Maker Communities", 4th International Symposium on End-user Development (IS-EUD), 2013, p. 6.
[14] A. Souza and J. R. A. Amazonas, "A Novel Smart Home Application Using an Internet of Things Middleware," in Smart Objects, Systems and Technologies (SmartSysTech), Proceedings of 2013 European Conference on, 2013, pp. 1-7: VDE.
[15] R. Blasco, Á. Marco, R. Casas, D. Cirujano, and R. Picking, "A smart kitchen for ambient assisted living," Sensors, vol. 14, no. 1, pp. 1629-1653, 2014.
[16] R. Piyare and M. Tazil, "Bluetooth based home automation system using cell phone," 2011, pp. 192-195: IEEE.
[17] R. Piyare and S. R. Lee, "Smart Home-Control and Monitoring System Using Smart Phone," in 1st International Conference on Convergence and its Application (ICCA), 2013.
[18] M. Yan and H. Shi, "Smart living using Bluetooth-based Android smartphone," International Journal of Wireless & Mobile Networks, vol. 5, no. 1, p. 65, 2013 2013.
[19] J. Byun, B. Jeon, J. Noh, Y. Kim, and S. Park, "An intelligent self-adjusting sensor for smart home services based on ZigBee communications," Consumer Electronics, IEEE Transactions on, vol. 58, no. 3, pp. 794-802, 2012.
[20] J. Nichols and B. A. Myers, "Creating a lightweight user interface description language: An overview and analysis of the personal universal controller project," ACM Transactions on Computer-Human Interaction (TOCHI), vol. 16, no. 4, p. 17, 2009.
[21] S. Mayer, A. Tschofen, A. K. Dey, and F. Mattern, "User interfaces for smart things--A generative approach with semantic interaction descriptions," ACM Transactions on Computer-Human Interaction (TOCHI), vol. 21, no. 2, p. 12, 2014.
[22] L. E. Holmquist et al., "Building intelligent environments with smart-its," Computer Graphics and Applications, IEEE, vol. 24, no. 1, pp. 56-64, 2004.
[23] E. M. Tapia, S. S. Intille, and K. Larson, "Activity recognition in the home using simple and ubiquitous sensors," in Proceedings of Pervasive, 2004, pp. 158-175: Springer.
[24] A. Kameas, I. Mavrommati, and P. Markopoulos, "Computing in tangible: using artifacts as components of ambient intelligence environments," Ambient Intelligence, pp. 121-142, 2005.
[25] S. Antifakos, B. Schiele, and L. E. Holmquist, "Grouping mechanisms for smart objects based on implicit interaction and context proximity," in Adjunct Proceedings of International Conference on Ubiquitous Computing (Ubicomp), Seattle, USA, 2003: Citeseer.
[26] M. Beigl, H.-W. Gellersen, and A. Schmidt, "Mediacups: experience with design and use of computer-augmented everyday artefacts," Computer Networks, vol. 35, no. 4, pp. 401-409, 2001.
[27] V. Novák, I. Perfilieva and J. Močkoř, Mathematical principles of fuzzy logic. Boston: Kluwer Academic, 1999.
[28] "Fuzzy Logic (Stanford Encyclopedia of Philosophy)", Plato.stanford.edu, 20018. [Online]. Available: https://plato.stanford.edu/entries/logic-fuzzy/. [Accessed: 24-Jan-2018].
[29] L. Zadeh, "Fuzzy sets", Information and Control, vol. 8, no. 3, pp. 338-353, 1965.
[30] F. Pelletier, "Hájek Petr. Metamathematics of fuzzy logic. Trends in logic, vol. 4. Kluwer Academic Publishers, Dordrecht, Boston, and London, 1998, viii + 297 pp.", Bulletin of Symbolic Logic, vol. 6, no. 03, pp. 342-346, 2000.