Process Automation in Smart Environments: Intelligent Closet Prototype

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Introduction

The educational efforts of the Engineering Technology program at the UTRGV College of Engineering and Computer Sciences focus towards research-based innovation for two of the most relevant needs of the Rio Grande Valley population: manufacturing industry and healthcare assistance. The development project in the field of smart environments, addressing subjects of home automation is the design, and fabrication of a smart closet and it is proposed as a contribution to assistive healthcare settings.

The results obtained provided the faculty with a broader understanding of the effectiveness of the proposed design and the required improvements to complete project implementation. This project was focused on the need for training professionals in a multidisciplinary approach, able to answer the regional and local needs in healthcare assistance, through innovation and technology development, envisioning a sustainable approach.

Background

The worldwide changes in the life expectancy, advancement in healthcare assistance, and the increasing numbers of the elderly and disabled population have brought the right to a person-centered healthcare, requiring for technology flexible enough to meet the end-user requirements. According to the United Nations data, the actual percentage of the elderly population is 7.6% and is projected to increase to 16.2% in 2050. Therefore, home automation systems play an important role in the advantages for safety and security[1].

Today's daily tasks and problems have found different areas to provide solutions to technology and networking related tasks through the use of information and communication technologies (ICT), and the internet of things (IoT); the aforementioned areas result in a number of novel solutions that allow the user to define the preferred sequence for compiling, transferring, processing and storing the information resulting from the continuous repetition of an action.

Some of the elements that lead process automation projects to signify a substantial impact on the independent operation and self-controlling features are safe and environmentally friendly processes, efficient control systems, the decrease in energy consumption, and the flexibility to meet the user requirements. The management of energy consumption in home automation can be achieved by selecting efficient-rated appliances[2] paired with a system able to learn from the environment and answer efficiently when necessary.

The Internet of Things (IoT), results a novel and interesting approach for process automation, allowing users to define the process and select the technology to pair with, developing its personal service centered on ubiquitous associated devices, whose combinations result in advanced composite functions with high added value, modifying the overall environmental comfort while gathering contextual information, namely temperature regulation, lighting controlling or even safety issues, when the information is used to create a schedule for the home[4].

The region known as the Rio Grande Valley is one of the fastest growing metropolitan areas of the world, holding a regional population of over 3.5 million people, amongst USA and Mexico. The University of Texas Rio Grande Valley (UTRGV) is a comprehensive academic institution that serves a 150-mile region. In Brownsville, only one in ten jobs is related to personal health care assistance. According to the Labor Department and Federal Reserve Bank of Dallas, this number is the greatest concentration of home health supporters in the country, suggesting five times the average in Texas. These statistics reflect the greatest need for improvement in the healthcare assistance, opening an innovative research area in smart environments for the elderly and disabled.

The Engineering Technology (ENGT) program at The University of Texas Rio Grande Valley (UTRGV), aims to prepare students to be professionals on diverse technology applications, within a sustainable approach, in which knowledge of mathematics and natural science, gained by higher education, experience, and practice, is devoted primarily to the implementation and extension of existing technology for the benefit of humanity. Engineering Technology education at UTRGV focuses primarily on the applied aspects of science and that portion of the technological spectrum closest to product improvement, industrial practices, and engineering operational functions[3].

The Intelligent Closet: towards the improvement of residential storing and retrieving systems

Process automation has been regularly developed for industrial and manufacturing environments, due to the imminent requirement of continuous repetitive steps, reducing errors, increasing quality, safety and the interval amongst segments. For healthcare development, smart environment applications include behavior monitoring, emergency detection, physical reaction, responsive reply, etc., to offer a variety of useful services, solutions or benefits to specific patients, disabled and the elderly, in a patient-centered approach.

A general description of automation can be explained as a process following pre-determined sequential steps with almost no human interaction needed, and it is feasible due to the use of a variety of sensors for context awareness, actuators and a wide diversity of devices to interact with[4]. The use of novel technology in the process industry has developed new IoT technologies and ICT's in order to continue competitive[5], and its benefits must justify associated costs[6].

However, incorporating physical and digital technologies (technologies 4.0) into an integrated mechanism of automated storage and retrieval systems is an element for a future generation of smart health assistance environments moving towards autonomous healthcare environments.

Currently, the constant advance in technology has been devoted to the development of various solutions to problems encountered in daily tasks, and as the progress continues, it carries a wide selection of new areas of performance, where we can witness the constant flourishing of smart homes implemented projects, while interacting with active members of these systems.

The key for a successful interaction, in an ideal condition, is to develop an adequate technology-embedded environment along with a user-friendly interface. On the other hand, the most difficult situation is to come across the need to perform such implementations in a built environment; in this situation we will be facing a case of building retrofits within a residential environment, to assist daily tasks with the exclusive purpose to provide the users with a better quality of life.

Quality of Life (QOL) is an indicator that has been widely described as a collective process that results from a series of relations (network) and interruptions that elders and disabled experience throughout their daily activities[7]. This indicator is based on the individual's perception of their position in a given context, and for this particular project, we have focused our attention on the importance of the built environment and the need of advancement in the research of the users' perception within the residential living space and the use of technology to perform such daily tasks.

The Intelligent Closet project is developed as an option in the design and construction of automated storage and retrieval systems, primarily for garment organization, within a residential setting. Emphasis is placed to create a system where the user preserves inventory information stored in a database and be able to access the garment selection through a graphical user interface (GUI), establishing as an ultimate goal to cause a positive influence in the user QOL. As a first stage in the smart environment laboratory development, this project is intended to confirm the hardware and software communication feasibility interaction in an enclosed typical residential setting.

Figure 1. 3D Model Intelligent Closet design

An important section of the conceptual design was to avoid major alterations within the built environment, in order to preserve the user's daily life routine, taking in consideration the possible displacement problems to the elderly and disabled, caused by minor changes within the residential interior floor plan layout. During the project planning, students worked within the defined goals and required assignment functionality. During this phase, the students and faculty had to determine the scope of the project, towards the future concept development. Subsequently, during the design phase, students and faculty created the concepts based on the functionality defined in the planning, creating a 3d model to fit within a typical residential setting (as shown in Figure 1).

The mechanical components were fabricated by the students, based on the original design, to be paired with the electronic components. Finally, the built prototype was tested to evaluate the working conditions of the prototype (as shown in Figure 2). The project was iteratively developed on a component by component integration, due to modifications in the design, based on the project needs. Upon completion of the development stage, the prototype was tested, creating the smart environments to analyze.

Figure 2. Intelligent Closet 3D Assembly, gear fabrication process and finished the first prototype.

Lessons learned in home automation for clothing management and storing

The analysis and development of scenarios for automated storage and retrieval systems in the residential environment is an area of slow development. The composition of the Intelligent Closet Prototype aims to become an essential part of assisting smart environments within the area of clothing management and storing.

The purpose of the Intelligent Closet is to provide an automated system to shorten the time spent in the process of storing and choosing an outfit within a conventional closet environment while improving its storage capabilities. This process is intended to allow the elderly and disabled to continue having a sense of self-sufficiency within their living space, during the execution of simple daily tasks.

The users often encounter problems during their daily routines such making the selection and management of different items from a large variety within a reduced space. Moreover, the effort involved in putting together an outfit makes it very complex to make a choice for the elderly and disabled when even routine tasks can be perceived as hazardous, due to the reduced area assigned to a particular duty.

Based on the objectives previously described, the Intelligent Closet delivers a glimpse of interesting benefits in the adoption of technologies to better manage residential storage spaces. One of the benefits is the saving of misused space in homes, the reduction in hazardous tasks such as lifting for storing or retrieving. An additional benefit is the opportunity to create an inventory of the items stored, with the advantage of specifying the system requirements with the creation of a user-friendly interface.

However, one of the restrictions of working in a residential setting is to develop a project within the space designated as a closet in the built environment. Nevertheless, the advantage of novel technology applications and faster networking systems opens an opportunity gap to new interaction amongst domestic devices, facing towards the development of automation systems proficient enough of solving complex tasks, with the capability of continuous adaptation, in accordance to the user wants and needs.

Process automation in smart healthcare assistance environments can significantly decrease the extent of interaction required by the users, as well as reduce the energy consumption and other potential excesses, related to technology adoption. These abilities can also offer significant features such as the recognition of unusual conducts on health monitoring[8], and is with the inclusion of nonintrusive sensors, hat we can be able to create an environmental aware system, to perform beyond the interaction with the user towards a context learning environment, in order to increase the safety of the users.

From a broader perspective, there are numerous residential devices and appliances that result easy to operate by the elderly and disabled. Whereas some of the operations of these common use devices involve similar processes, those who drastically changes a process are the ones that represent a drastic variation and are the ones who challenge new users[9].

Through the inclusion of continuous adaptation capabilities, the Intelligent Closet aims to widen the benefits of a network system, to ease daily tasks and to extend the user self-sufficiency, only to a point where it does not represent a danger to the user's health.

Advancement in technologies in the field of home automation is opening a wide range of opportunities for building retrofitting never seen before. While the innovation in technology creates new demands and new industries[10] and with the fast growth of internet-enabled devices used in homes, we can find an additional potential for the improvement of residential smart environments.

Future work in home automation for storing and retrieving systems

Based on the objectives initially set as the project’s primary goal, several benefits follow as outcomes, and as opportunities for future projects and research, for the QOL improvement for the elderly and disabled:

- The reduction of misused space in the residential built environment (ongoing and future projects have been registered for the analysis of unconditioned spaces: garage, attic, crawling space, and basement).
- The technology-based aid provided to the elderly and disabled users to organize and select stored items through an automated retrieval system.
- The importance of preserving track of inventory and the possibility of a wider remote access through personal devices.
- The use of novel technology to assist in storage inventory (GUI, a database for clothing inventory).
- The reduction of time spent during the processes of selecting a stored item.

- The use of cost-effective technology for home automation (microcomputers, sensors, personal devices, network, and energy-saving equipment and appliances).
- The analysis and proposal to overcome potential challenges on the use of new technology (testing diverse interaction methods to identify the adequate system according to the user restraint or disability)

Conclusions

The advancement in storage and retrieval systems is an area in which home automation systems have been improving at a slower pace than other automation areas. Since the management and choice of clothing are not considered a vital activity, the efforts in technological development are concentrating on the preservation of life in the face of imminent danger. Monitoring of vital signs and basic safety and functionality are planned to be included in the subsequent phases of the Intelligent Closet project.

However, the proposed intelligent closet system aims to go further: envisioning smart environments that analyze the user preferences, process the information to translate it into user-patterns, and autonomously suggests the garments in accordance to the user needs. This is one of the main advantages of the project: to have a customizable system to assist in routine tasks, with the ability to be integrated to the home network in the built environment, reducing the associated costs of a stand-alone system, by using existing devices.

For this reason, this technology changes the perception of a luxury item for a system that improves the QOL by automating the process of storing, selecting and retrieving of clothing in a simplified manner within a typical closet. Nevertheless, extending the time the elderly and disabled can freely move into their own homes represents an advantage in self-esteem and it would be interesting to analyze the positive effects of having the ability to resume simple daily tasks during their daily life, with the use of user-friendly technology. Thus, even the first stage of the project can be defined as concluded, the replication of built environments towards smart environment solutions is an ongoing project by the Engineering Technology program at UTRGV.

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