PathPass: Opening Doors for People with Disabilities

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Abstract **Conventional "push a button" door openers introduce significant difficulty for disabled persons using canes or wheelchairs. This paper presents a new design for creating easy and safe accessibility conditions through the establishment of an advanced interaction between the person and the accessibility control of the building. Based on this concept, an integrated architecture for door openers, called PathPass, is proposed that introduces easy to use equipment by the person and to the door's control unit allowing the performance of a wide range of operational modes. Finally a prototype implementation of PathPass is presented.**

Keywords- door opener; pressure pad; smart cane; smart wheelchair;

I. Introduction

For people with disabilities standard door openers at the entrance of a building, offices, restrooms, classrooms, etc. utilize on-wall buttons to open the doors (Figure 1). The way the on-wall buttons operate is by pressing them and they open the door for a certain amount of time. Despite the obvious advantages of these openers for helping disabled people and their companions, many drawbacks exist due to the fact that it is based on a static operational mode providing low level of interaction between the user and the opener.

Figure 1. On-wall button

There are three main drawbacks of the conventional openers. The first one concerns the time period the door remains open after the push of the button; at the end of this period the door closes automatically. In many cases, this constant time period is not matched with the time period the user needs to cross the door. This fact is a potential risk to the injured, disabled or elderly people who may move slowly, or to the people in wheelchairs who operate the wheelchair by themselves. Actually, it is potentially very dangerous for a door to close while there is one person in range.

The second drawback is that the on-wall buttons are often broken or located in place unreachable by the user.

The last drawback is that the cost to install conventional openers to the doors is high. Therefore, the installation of such openers is limited to a few doors, and mainly to exterior doors of the buildings, but not to all the doors a disabled person needs to cross until he/she reaches his destination.

In this paper, we propose a new door opener design called PathPass. This design introduces dynamic interactions between the user and the door's control mechanisms that eliminate the inefficiencies from the above drawbacks. The on-wall button is replaced by two control modules, one installed in the door ("door opening mechanism") and the other carried by the user ("portable device"). These modules exchange data, notifications and instructions between the user and the door that allows the user to keep control of door's operation.

The PathPass design is the result of an Interprofessional Project (IPRO) 497-351 [1] sponsored by Illinois Institute of Technology (IIT) that takes place within the educational framework of IIT.

The paper is organized as follows: Section II includes the primitives and the design of PathPass. In Section III, a pilot implementation of PathPass is presented. Discussion and performance evaluation of PathPass are presented in Section IV. Section V concludes the present work.

II. PathPass Primitives and Design

The basic concept behind the PathPass project is the establishment of communication between the door opening mechanism and the user. PathPass targets the following groups as potential users:

- *individuals* with disabilities as well as injured people who face mobility difficulties. This group includes people who utilize canes, wheelchairs or walkers and are able to control their motion without any external assistance.
- *caretakers* who accompany and aid disabled or injured persons with mobility disabilities. Caretakers provide services such as pushing, driving, or maneuvering a wheelchair, carrying equipment, etc.

Moreover, PathPass introduces an integrated door control system that is composed of the following four subsystems:

- *Door Opening Mechanism (DOM)*: It consists of an electromechanical system located on the door frame and a controller. The DOM is actuated by remote "*triggers*" that it receives from the Portable Control Device (PCD). The trigger is a formatted communication message that contains commands (open, close), time duration of the door opening and user's authentication codes. The DOM also transfers "*annotations*" to any commands reaching the PCD including information related to the door's operational capabilities and building's facilities (floor plans, accessible restrooms, etc.).

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- *Portable Control Device (PCD)*: It is located in the mobile device, cane, wheelchair, or walker (user context). The PCD is the generator of DOM's triggers and the receiver of DOM's annotations. According to the user's context, PathPass distinguishes two user interfaces, a pressure pad and a smartphone application.

  The "*pressure pad*" is a switch that offers a larger pressing surface than the common industrial buttons. It is manually pressed by the user and can be installed on the apparatus (cane, wheelchair, or walker) of the user. From the operational point of view, the pressure pad operates like the on-wall button. Whenever the user presses the pad, a trigger is generated and automatically transmitted to the DOM. This trigger includes an "open" or "close" command as well as a numerical value indicating the time duration the door has to be open. The main advantage of the pressure pad with respect to the on-wall button is the capability to set different time durations per user (safe user access through individualized PCD operation).

  The "*smartphone application (SPA)*" is a dedicated purpose application been installed on the user's smartphone. This interface provides advanced capabilities to the system developer to introduce to PathPass advanced functionality ensuring a high degree of user safety and high level of building's security. This PCD approach leads to the provision of full-individualized services to the user. The user's real needs, capabilities and contextual information can be organized in the form of a "user profile", allowing on-the-spot adaptations to the PathPass operation. For example, if the user is unable to reach the entrance door of the building due to low room lighting, this could lead PathPass to set an extra "turn on light function" that turns a light on while the user is crossing the door.

  These two PCD interfaces are proposed in order to cover as many as possible different social groups and all the kinds of needs for transportation. Figure 2 depicts the four main steps that the user must follow in order to cross the door using the pressure pad interface.

- *Wireless Communication Subsystem (WCS)*: It creates the wireless connection network between DOM and PCD. In respect to the PCD interface, WCS may have a different structure.

  In case of a pressure pad PCD interface, WCS consists of a one-way wireless communication link connecting a transmitter at the PCD side and a receiver at DOM side. WCS is used to transfer triggers, e.g., commands, from the PCD to the DOM. In case of a smart phone application PCD interface, WCS consists of a bidirectional wireless communication link and two receiver/transmitter pairs connected on both sides of the link. WCS is used to transfer triggers from PCD to DOM and annotations from DOM to PCM.

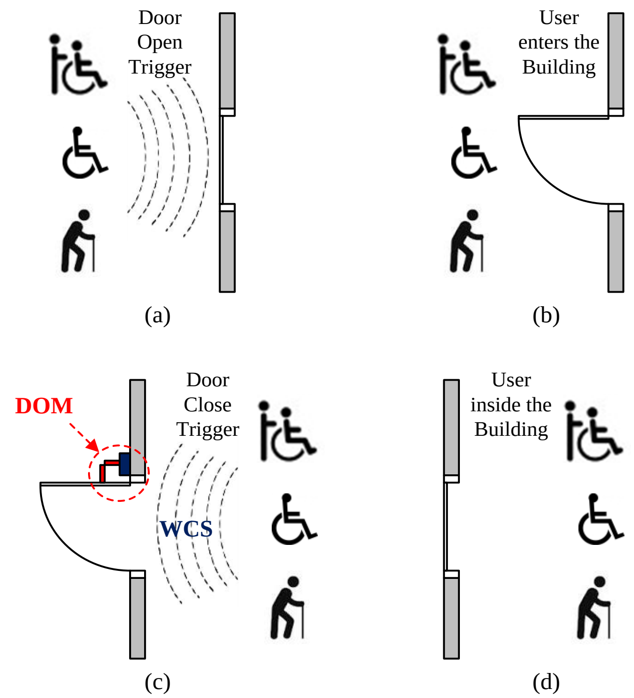

Figure 2. How to cross the door using PathPass

- *Central Control Unit (CCU)*: PathPass aims to create a homogeneous environment allowing the disabled people to circulate efficiently in a large urban area. Hence, the need arises for the existence of a central control unit (CCU) with unified rules, e.g., the use of identical trigger structures, and regulations upon the collaborative operation of all PCDs and DOMS of this urban area. This capability eliminates the required operational cost and effort for the maintenance and deployment of PCDs and DOMS. On the other hand, the CCU acts as the local authority providing authorization and authentication rights both to the users and the companies that administer the buildings of this area.

III. PathPass Prototype Implementation

This section contains the process to build a functional prototype of PathPass. The development of this prototype has been supported by IIT and by Charisma® Eldercare Services [2].

A. PCD Iplementation

Both user interfaces (pressure pad and smart phone application) of the PCD have been implemented.

PCD implementation based on pressure pad interface

The implemented PCD targets mainly elderly people. Hence, it is designed intentionally to offer a very straightforward interaction between the user and the PCD. Several experiments of PCD characteristics have been conducted on canes and wheelchairs.

Special attention has been given to the cane because it is a light weight apparatus (< 0.5kg) and adding on it an extra accessory (such as the PCD) affects its center of gravity. For this reason we selected a PCD configuration based on:

- a *pressure pad*: Cross Point Wireless Sensor Pad (CIVAx22, 0.0254m x 0.0762m (1in x 3in)) from Cross Point Industries Co.
- a PCD control system (CS) emitting triggers to the DOM. The CS consists of an Arduino Uno microcontroller and an XBee transmitter (Figure 3). The CS XBee transmitter and the DOM receiver communicate using LE Bluetooth triggers.
- a power supply: one AAA size battery.

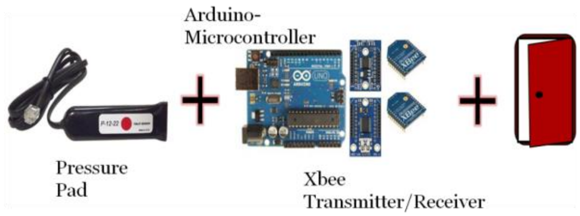

Figure 3. The PCD topology on pressure pad interface

These PCD parts support placement versatility when it came to installing them on the cane. To test the extent to which the center of gravity would be affected, several experiments were conducted. These experiments have shown that the cane simulates the motion of a pendulum when it is operated with the center of rotation at the hand-handle interface. We have concluded therefore to propose to locate the PCD as high on the cane as possible. More precisely, we propose the pressure pad to be placed underneath the handle so that the cane user can squeeze it with his/her fingers. (Figure 4) This place has been chosen because the experiments we have done have shown that the user puts a lot of pressure on the top of the handle while walking or standing.

Figure 4. The position of PCD parts on the cane

Furthermore, we also propose the CS to be placed just next to the pressure pad at a very small distance for two reasons: a) to have an as small affect as possible on the center of gravity of the cane and b) there will be a wired connection between CS and the pressure pad and longer wire leads to extra material which leads to extra weight.

On the other hand, a wheelchair offers more flexibility for PCD positioning. The pressure pad may be placed at different spots according to who is operating the wheelchair. If the wheelchair is operated by a disabled individual or an injured person who face mobility difficulties and are able to control their motion without any external assistance, the pressure pad may be placed for instance on the left/right armrest. If the wheelchair is operated by a caretaker, the pressure pad may be placed underneath one of the two handles being used to drive the wheelchair.

Operationally, the PCD placed on the cane or on the wheelchair is designed to work in two steps: a first pressing of the pressure pad activates the doors opening and a second pressing activates the doors closing. Hence, the user takes as much time as he/she needs to cross the door.

<u>PCD implementation based on SPA interface</u>

The SPA has been especially designed to offer a high level of interaction between the user and the DOM. It targets people who are familiar with smartphone technology and desire to receive integrated services rather than a simple door opening service. More precisely, the user is able to inform the DOM about his preferences, such as how long the door remains open, if a light switches on, etc. On the other hand, the DOM could return to the user information pertaining to the characteristics of the building he/she is about to enter, such as accessible restrooms, warnings if an elevator or a door is out of order, etc.

For achieving the above goals, we used as the development toolkit the Android platform [3], since our team was familiar with it and it is free for use. For the PCD code development we used the xml-based descriptors and then those are linked to the java code via event handlers.

A survey among the students of IIT proved that the SPA must fulfill the following design and operational attributes:

- be designed with large colored buttons that should be located at convenient screen locations.
- require from the user to sign in using a username and a password provided by the CCU. This attribute allows advanced secure-access polices posed by the CCU to be dynamically incorporated within the PathPass functionality, such as main door opening scheduling at different seasons or time of the day.

The above attribute led us to create the user interface of Figure 5, where Figure 5a depicts the main screen with the sign in environment. Figure 5b and 5c depict the open/close door template and the nearby buildings, respectively.

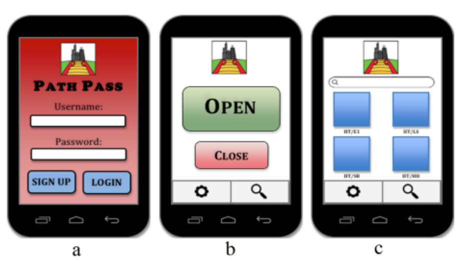

Figure 5. The application template

B. *DOM Implementation*

The Americans with Disabilities Act of 1990 (ADA) [4] requires that a door must be at least 0.9144 m (36in) wide to allow enough clearance for a wheelchair. Our initial research and experimentations proved that the typical weight of such a door is about 27.21 kg (60 lb.) that requires a torque about 0.678 Nm (6in-lb.) to open it. These requirements led us to select the following experimentation equipment:

- A door with dimensions 0.9144m x 2.032m x 0.0381m (36in x 80in x 1.5in) weighing 13.6kg (30lbs).
- A DC motor from McMaster-Carr (Figure 6a) with: a) power output of ⅓ horsepower, b) maximum 3900 rpm, c) maximum torque 0.6643Nm (5.88in-lb).
- A worm and a worm gear (Figure 6b). The worm gear is attached to the arm of the door. As the motor turns, the arm would turn simultaneously to open the door.
- An Arduino Uno microcontroller connected to an XBee receiver.

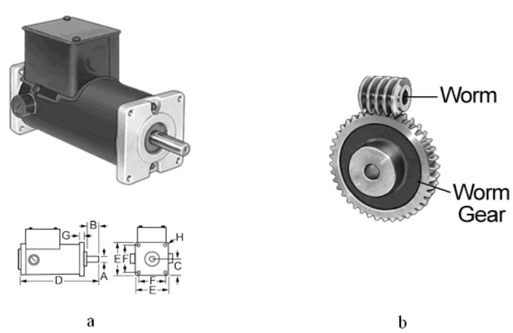

Figure 6. The DC motor of DOM and the worm gear

Figure 7 demonstrates the overall control plan of the DOM's operation. The microcontroller receives triggers from the WCS and creates the appropriate electrical control signals to the DC motor. These signals signal the motor that rotates the arm and the door opens.

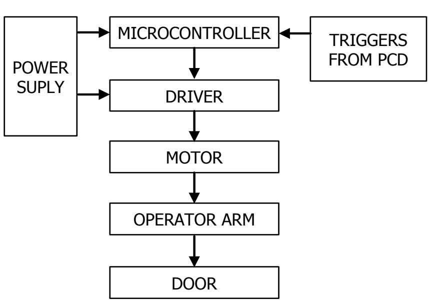

Figure 7. The control plan

C. *WCS implementation*

Both interfaces of PCD (pressure pad and SPA) use a low energy Bluetooth interface of XBee transmitter and receiver pair. However, the pressure pad PCD interface establishes a one-way communication path, while the SPA interface establishes a full duplex (bidirectional) path.

IV. Discusion - Evaluation

Before defining task-oriented groups, the authors' team sought external input to confirm their initial ideas. The primary source of feedback was M. Chizek of Chizek Charisma® Eldercare Services. This allowed the authors to consider more than one type of disability, which gave additional perspective on the potential users.

The PathPass prototype is currently under laboratory testing. But PathPass is intended to be a commercial product. Therefore, apart from the technical integration, a strategic marketing, business, distribution and installation plan need to be implemented.

V. Conclusion

This paper presents a new design for constructing integrated systems for easy and safe accessibility to buildings. PathPass establishes communication between the door opening mechanism and the user (disabled or injured people and their caretakers). Moreover, PathPass introduces an integrated door control system that is composed of the Door Opening Mechanism (DOM), the Portable Control Device (PCD), the Wireless Communication Subsystem (WCS) and the Central Control Unit (CCU). PCD implementation is based on a pressure pad interface and on a smartphone application (SPA) interface.

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