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AUTOMATED USER BEHAVIOR MONITORING SYSTEM FOR DYNAMIC WORK ENVIRONMENTS

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ABSTRACT

The aim of the study is to improve existing methodology for user observation to evaluate user performance in a dynamic and complex work environment. We developed a new user behavior monitoring system and used the system to analyze user behaviors in a complex and dynamic work environment. The proposed monitoring system is composed of an object tracking module using RFID tags on objects and a RFID reader on user's hands, and video cameras for recording user behavior. We also designed a smart floor with embedded pressure sensors for monitoring user movement through variation of pressure sensor signals. The system is installed in an observation room where a model take-out coffee shop was simulated for verifying the utility of the proposed observation system. The system would provide valuable insights to improve user performance and work environment redesign.

Keywords: User behavior monitoring, RFID, Smart Floor

1 INTRODUCTION

Since today's technology improvement and manufacturing advancement can affect the user-centered design, the application of new technology would give a new experience to users and provide improving products and services. Traditionally usability tests are conducted in order to obtain user needs. Most of current usability evaluating protocols currently were designed to observe only one user at a time and also got limited position as well. According to Hsu et al. (2006), they experimented using a variety of sensors to analyze the behavior of users. They monitored with combined video and RFID data in the reading room environment [1]. A 'sensing room' was created by Mori et al. (2006), and the location and lifestyle of users were analyzed in the room. Pressure sensors and RFID tags attached to the floor and the furniture were used in constructing the room.

Typical usability evaluating systems observe only one user using a specified target objects in a specially pre-set laboratory. A different monitoring system from the traditional laboratory environment that can record continuous activities of multiple users in a more real-life setting could be used to evaluate the usability of not just a product but of spaces and environmental design. This type of system can take advantage of high technologies such as wireless communication modules and various sensors. Symonds et al. (2007) used RFID tags in a house, bedroom and to identify the movement of certain goods which are easy to be lost in traditional tracking system using just cameras. They were trying to solve the problems what the elderly and disabled people are faced in real life [2]. Pulson and Hammond (2008) observed the behavior of static users who work in the same place without moving in an office environment. They attached RFID tags on the desk, phone ~~or~~ and cups, with a small RF reader attached on the user's wrist. Through RFID tag data they tracked the use of stationaries, based on the user's arm movement [3]. M. Buettner et al. (2009) observed the behavior of users using a RFID reader and antenna which were installed on the landmarks inside apartment for daily life. In their study, small_items were moved inside an apartment with attached RFID tags. The RFID tag was detected based on location and 95% of user behaviors were correctly identified from the data [4]. These systems, however, could only monitor each user's movement path and observe whether a certain product was used. They could not analyze user intention and behaviors reflecting contextual situation.

In this study, we have developed an automated user behavior monitoring system that can observe multiple users engaged in dynamic tasks and can provide detailed information regarding the individual user behavior in the working environment, using RFID tags attached on the machines and objects in a model shop and a wireless camera mounted on a cap worn by the user.

2 SYSTEM DESIGN

2.1 Hardware Development

The suggested system is composed of three modules - a video-based observation system, WPAN (Wireless Personal Area Network)-based measurement system, and a Smart floor-based measurement system. We built a typical model take-out coffee shop for applying the suggested system for the purpose of user behavior monitoring and usability evaluation of the current work setting. Each objects, tools, and machines in the model shop, including an espresso machine, a coffee grinder, a toaster, bottles of syrups, and cups are attached with RFID tags, ISO 15693 - 13.56 MHz. Some have two or more tags attached to differentiate the parts and orientation to see which side and part user grasps, while using the objects. There are approximately 150 RFID tags attached on a total of 27 different machines and objects in the model shop.

For building a video observation system, we used two types of camera to monitor user movements and user traffic in the work area. The video observation module records all the users' movements and behaviors using three cameras. Two PTZ(Pan, Tilt and Zoom) type dome cameras were positioned at the both ends of the ceiling, and a small wireless camera was attached under the brim of user's cap that user would be able to put on during the experiment, so that we can track user's eye gazes and monitor the current status of objects used.

Figure 1. (a) PTZ dome camera (b) wireless camera

A WPAN-based measurement system was also developed by using a 13.56 MHz RFID package. User puts a small wrist guards' band with RFID readers attached with a small antenna (40x20 mm) on the ring finger of both hands. Since the RFID tags are attached on all of the objects in the model shop workshop environment, the RFID reader on the wrist band recognizes the corresponding tag and leaves a log data on the server any time user grabs an object for performing tasks. The RFID reader was connected to a Bluetooth communication module to transfer the tag data to a server.

` *Figure 2. The wrist band with a RFID tag and a reader*

The smart floor-based measurement system was developed for monitoring user movement and work traffic, to complement the video-based observation system. The user location and the change of location can be identified in real-time using flexi-force pressure sensors installed underneath of the floor tiles.

For connecting all the pressure sensors to collect the data, the 1019-Phidget Interface Kit Input/Output board was used. A total of 135 pressure sensors and 20 Phidget modules were installed to build a smart floor, with a size of 5m x 1.5m. Each hardware module consists of 6 to 7 flexi-force pressure sensors connected with a regular pattern. All the flexi-force pressure sensors calibrated and checked for maintenance before every measurement. A small bump at the end of the pressure sensor was attached to amplify the pressure signals to increase the recognition rate. Each hardware module was connected to a USB communication module to transfer the pressure sensor data to a server.

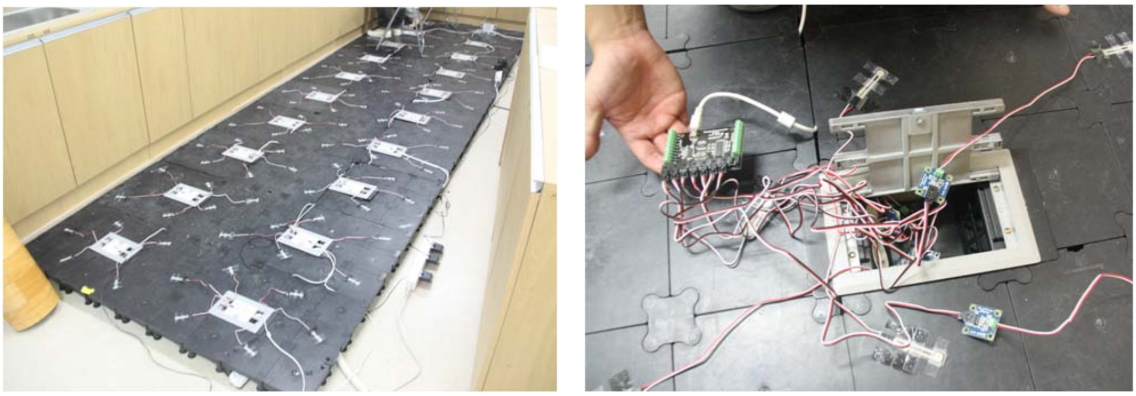

Figure 3. (a) Phidgets board (b) Smart floor development

2.2 Software Development

An observation module was developed for automated user behavior monitoring. The observation software monitors the user behaviors and analyzes all of video and RFID tag data from video cameras, RFID readers, and 135 flexi-force pressure sensors. The observation software is divided into two parts – an RFID monitoring module and a smart-floor monitoring module.

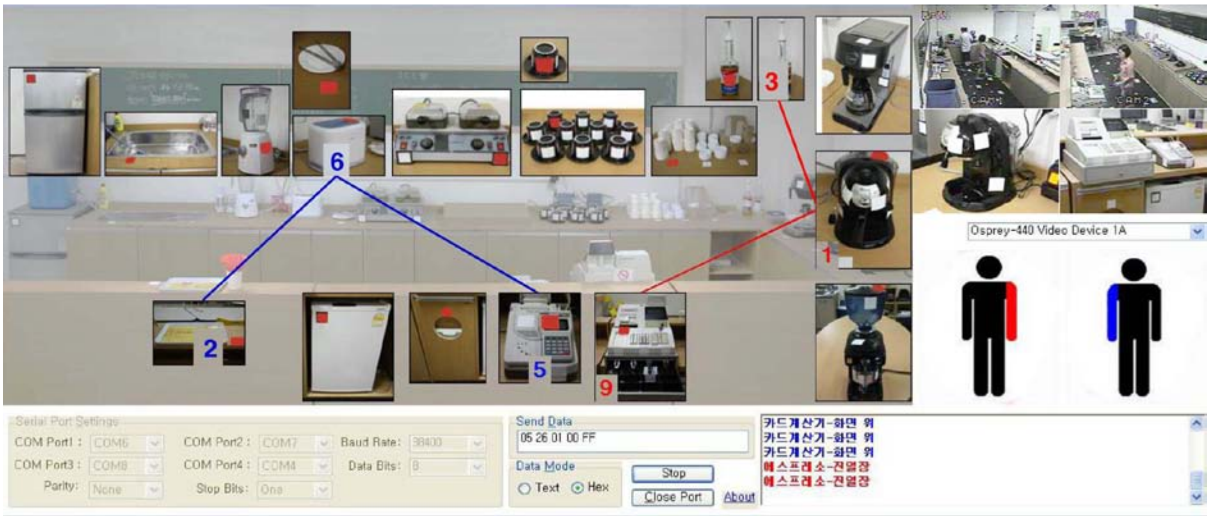

Figure 4. RFID Monitoring Software

The RFID monitoring module (Figure 4) performs two functions. First, this monitoring module logs the RFID tag data to the database server for further data analysis. The system records data such as log time, RFID tag IDs, object name, RFID reader IDs and video frames. Second, the monitoring module can differentiate RFID readers used by each user and hand, and provide the number of times how many each tag was detected on the screen in real time. Also, the module presents the path of user's movement in conjunction with the objects with which the user was engaged in for work. The path can be composed by connecting the RFID data from the objects user touched in time sequence. All the data including the video file from the cameras are synchronized in time and saved on the server.

The smart-floor monitoring system (Figure 5) was developed for monitoring user movement by analyzing the pressure sensor data. The system basically supports and double checks the RFID monitoring module for user movement path calculation. The system saves the pressure sensor data from the smart-floor monitoring module to the server for data analysis. To enhance recognition rate of the user movement on the smart floor, a total of 135 pressure sensors provide signal data in real-time. Faulty pressure sensor could be detected in real-time to allow easy maintenance. The smart-floor monitoring module can present the configuration of sensor arrangement on the floor and can also show movement path of each on the screen. The path is composed by connecting the pressure sensor point on the smart floor whose signal data exceeds certain threshold big enough to be considered as a user's step in time sequence. All the signal data are recorded on the server being synchronized in time with the data from the RFID monitoring module.

3. MONITORING EXPERIMENT

3.1 Beverage Serving Experiment

We tested the user monitoring system in the model coffee shop to find out if the system can be used to provide any improvement in service design. Two users, an experienced server and a novice server, respectively, wear a cap with a small wireless camera attached and wrist bands on both hands with the RFID reader.

Three experimental scenarios were provided for serving coffee, toasts, and iced tea. The users were asked to proceed to serve customers without restrictions on time or service orders. With two users working on the three scenarios independently, the data were collected from the RFID monitoring module and the smart-floor monitoring module and saved in a server wirelessly connected to the modules.

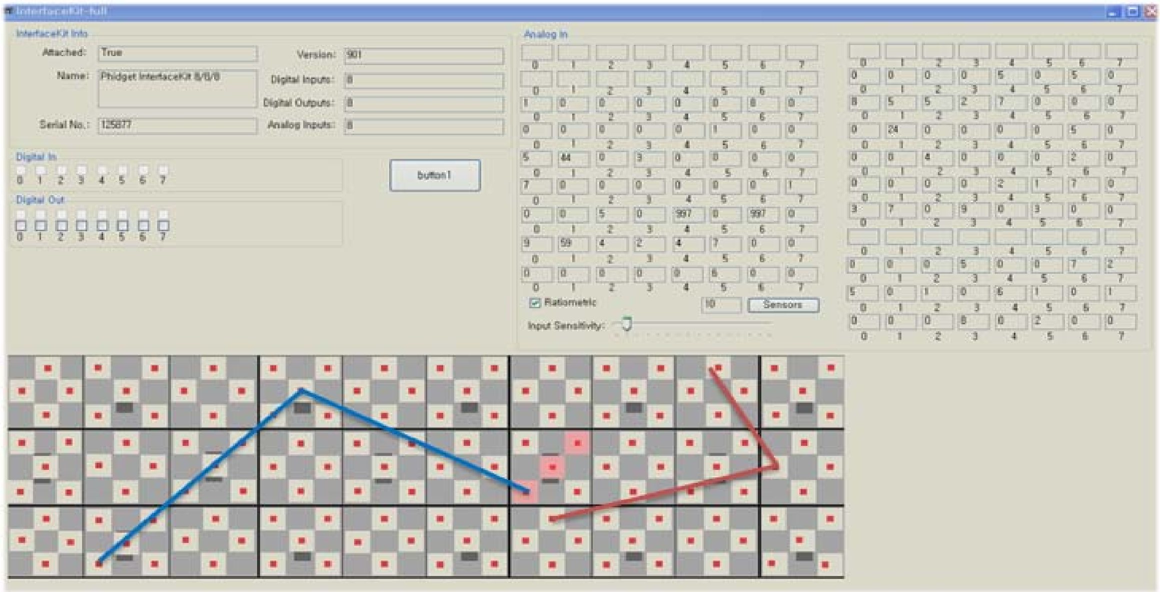

Figure 5. Smart Floor Monitoring Software

Data from the two modules were synchronized in time when and integrated into one. Recorded video data from four video cameras were also synchronized with the data from the two modules. Figure 6 shows a user performing coffee-making services to a customer according to a scenario. Table 1 shows the machines and objects required for use to perform the services and the use frequencies according to the task scenario.

Two servers participated in the experiment: one experienced server and one inexperienced server. Each server takes the same order, and was asked to produce the item and serve the customer as fast as possible. Beyond taking simple observation of the working process, we have observed differences in quality of product and services.

The experienced participant was a male in his twenties and had had 3 months experiences in a coffee shop. The novice participant was also a male in his twenties and knew how to make beverages basically but had no previous experiences. Both were introduced to the experimental setup and provided with the scenarios. The experiment in each trial started with greeting customers, and proceeded to taking orders for an iced-tea, or an Americano, and ends up with serving the customer with what s/he ordered. Ten trials have been taken for each type of beverage. Adequate rest was afforded between each trial to avoid participant’s fatigue. For monitoring convenience, we assumed that only one customer comes and place an order in a trial for each server.

Table 2 shows sample rules to configure automated analysis of user behaviors from the RFID tag data.

3.2 Results and Analysis

In this paper, only the result for the 1st scenario would be analyzed and presented. Figure 7 shows an example result of activity flows for the tasks performed by each server in a diagram. Figure 7a shows how the experienced server made an Americano coffee using the machines and objects provided in sequence and presents the number of times visited for each machine/object with the size of nodes. The activity flow displays the amount of time to be taken in previous node to next node, the time spent to perform sub tasks and total task, intuitively.

Figure 6. Coffee-serving tasks by a user wearing a camera-mounted cap and wrist bands with RFID reader

Table 1. Dimensions of the DPG Matrix

performance		**Tracking Objects (process & frequency)**					
Scenario 1	**User A** americano	Card counter (2)	Grinder (12)	Espresso machine (20)	Cup (4)	Hazelnut syrup (1)	Take out place (5)
	User B iced-tea	Cup (2)	Ice-tea (7)	Water purifier (12)	Tea-spoon (2)	Take out place (4)	
Scenario 2	**User A** toast	Card counter (3)	Refrigerator (7)	Toast dish (4)	Toaster (17)	Refrigerator (3)	Take out place (7)
	User B iced-tea	Cup (3)	Ice-tea (6)	Tea-spoon (2)	Water purifier (11)	Take out place (3)	
Scenario 3	**User A** fruit juice	Cash counter (8)	Refrigerator (4)	Blender jar (2)			
	User B fruit juice	Cup (2)	Vanilla syrup (1)	Blender (5)	Blender jar (7)	Cup (2)	Take out place (5)

Table 2. Behavior tracking rule base example

R1: IF(Checked credit card counter =True) THEN Credit payment

R2: IF(Checked grinder =True & Checked Espresso machine = True & Checked a water purifier =True), THEN Americano

R3: IF(Checked refrigerator=True AND Checked blender=True AND Checked syrup bottle=True), THEN Fruit juice

Server’s movement path for service was comprehended by extracting a trace from the pressure sensor data logged through the Smart-floor module. The RFID-module synchronized with the smart-floor module was used to compare the task processes between the novice and experienced server.

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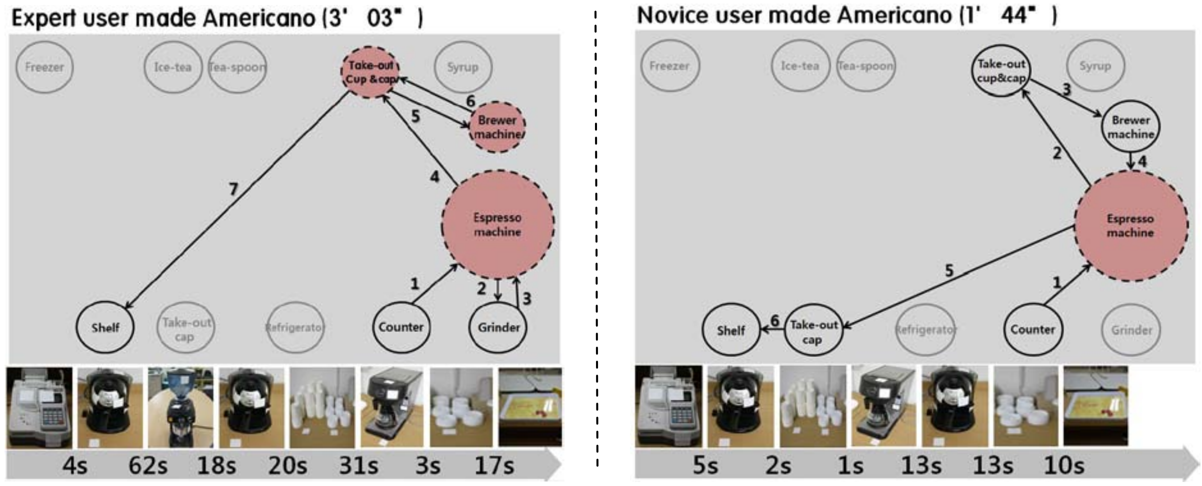

Figure7. (a) Experienced server activity flow (b) Novice server activity flow

The experienced server made an Americano coffee in 3 minutes and 3 seconds. There was no repeated or omitted visit to each machine/object, and seemed to perform the optimized procedures in each trial. On the other hand, the novice server followed the procedures diagramed in figure (b) to make an Americano coffee. Even though there was no waste in movement path flow, comes the same machine (Espresso machine) repeatedly, and skipped a grinder machine to grind the coffee bean into powder. It was observed that the novice server used the grinder machine once in two trials, while grinding 2-serving amount of beans a time to save the powder in a potter for the next service. This made the total task time of the novice (1’ 44”) shorter than that of the experienced server (3’ 03’’).

A further user performance was evaluated for both of the novice and experienced servers based on the quality of service provided to the customer. Time to take for serving was a key performance evaluation metric, while the service quality in terms of taste was another though it was hard to be quantitatively measured. While there was a missing procedure for the novice server, the quality of beverage served by the novice server also lacked the required quality in terms of freshness. The problem here is that there should be a clear statement or a goal to achieve in terms of quality of service so that certain procedures are required to take place by any means to stick with the goal. In this context, the quality of product would be the more important factor than shorter task time. By setting the priority in service requirement, servers would never omit any procedure in working process to their convenience and the quality of service can be maintained at a certain level

4. CONCLUSION

This study presents a new system to monitor user behaviors in a work environment carrying out relatively dynamic works more efficiently and accurately using sensor-based technologies and wireless communication technology. Automated data collection was possible through the automated user behavior monitoring system. The data analysis could provide misbehaviors of the server in providing a quality service. The system can be used as a guide for training novice servers and checking for improvement in work behaviors for maintaining a required service quality.

To determine the reliability of the system, the analysis result from the system was manually compared with the recorded video data. It was found that the automated monitoring system provides as valid and reliable analysis result with the RFID tag data producing an object tracking diagram, and the pressure sensor data from the smart-floor producing the movement path diagram as any current manual

monitoring system such as video surveillance systems, making the system a comprehensive analysis tool for service analysis and re-design. The average success rate of the system for object recognition for RFID tag was measured to be 95.7 percent. We found that the recognition rate could be enhanced with modification of the direction of the RFID antenna on the wrist band, and the RFID tag attached on the objects with metal surface results in poor recognition.
To improve the recognition rate of the RFID tag data, a variety of sizes and types of the RFID tag needs to be further tested. The data from the smart-floor with pressure sensors was measured to be correctly extracted at 95% based on the comparison from the video To improve the recognition rate of RFID tagging would be the key to improve the overall system performances in accuracy and reliability.

Future study will be focused at various contexts of work using the developed system. For example, the cases in which many orders are placed to create a service queue and customers are waiting to be served, and the cases in which each server would have specific roles to cover and there are more than two servers would provide a valuable insight for the use of the automated monitoring system and for the service re-design. We can further design a usability evaluation toolkit using the current automated monitoring system that can provide more detailed information on server's using each machine and tool in the workshop. Furthermore a different model shop would be applied for more generic application of the system to be possible.
The system can be extended to a multi-user real-life usability evaluation system once more detailed analysis modules can be developed in the future. The ultimate purpose of the system would be to construct a usability evaluation system that not only monitors user behavior but also provides detailed analysis and prediction on user performance and recommends the desired change in the work environment design.

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