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A Video-Based Observation and Analysis Method to Assess Human Movement and Behaviour in Crowded Areas

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***Abstract*—**Human movement in the real world provides important information for developing human behaviour models and simulations. However, it is difficult to assess 'real' human behaviour since there is no established method available. As part of the AUNT-SUE (Accessibility and User Needs in Transport – Sustainable Urban Environments) project, this research aimed to propose a method to assess human movement and behaviour in crowded areas. The method is based on the three major steps of video recording, conceptual behavior modelling and video analysis. The focus is on individual human movement and behaviour in normal situations (panic situations are not considered) and the interactions between individuals in localized areas. Emphasis is placed on gaining knowledge of characteristics of human movement and behaviour in the real world that can be modelled in the virtual environment.

***Keywords*—**Video observation, Human movement, Behaviour, Crowds, Ergonomics, AUNT-SUE.

I. Introduction

CROWDS are an important consideration in many situations where there are people with different abilities and capabilities (for example people with disabilities and older people). Of particular interest to the AUNT-SUE project are transportation situations where people are journeying from one place to another. There has been considerable research related to human movement and behaviour in crowds in emergency evacuation situations, and crowd safety has always been a major concern. In general, the main objectives are to avoid the occurrence of dangerous crowd phenomena during exceptional events (e.g. fires, accidents, earthquakes, etc.), to reduce the numbers of people injured or killed should they occur and to improve the environment for the crowd in terms of the quality of the facilities, signage and communications. The crowd dynamics research in [1] is a typical example of this area.

There are many significant issues related to crowds such as how do humans move and behave within high density crowds? Do they tolerate or ignore each other during the movement, or do they move more slowly than they would in a low density crowd? If the focus is more towards older people and those with disabilities, there are significant issues such as how an elderly man might maintain his balance and choose his movement direction when people around move at a faster speed or how a disabled person with a wheelchair reacts when faced with a movement path containing obstacles (or bottlenecks).

In order to understand these issues, direct observation from the real world crowd is important for gathering information on the difficulties being faced and investigating the factors affecting the movement and behavior so as to minimize these difficulties. The video observation method provides an opportunity to observe some unpredictable or natural movement and behaviour of humans, although the issues of privacy and security require serious consideration. At the moment, there is no established method available to assess human movement and behaviour in crowded areas. Therefore, in this research a video-based observation and analysis method is presented as a possible method.

This research has its origins in the AUNT-SUE (Accessibility and Users Needs in Transport - Sustainable Urban Environments) project which emphasized the need to accommodate the largest possible range of people with diverse abilities and aspirations [2]. The project was of crucial importance in developing sustainable policies that deliver effective and socially inclusive designs in urban transportation systems [3]. The AUNT-SUE research did not however explicitly consider the issues of human movement and behaviour in crowded areas which is the focus of the research described here.

II. Research Using a Video Observation Method

The video observation method is widely applied in ergonomics and image processing research. In ergonomics research, video observation methods have been preferred over self-reporting because they offer better validity and reliability [4]. The video observation method has been widely applied to observe whole body movement such as assessing the loads in the low back, shoulders and lower extremities. According to Dempsey et al. [5] and Pascual and Naqvi [6] although there is still no universal method to observe all kinds of jobs, a wide variation of observation methods has been applied in ergonomics research. For example, Pehkonen et al. [4] applied the video observation method in real time from videotape to assess musculoskeletal load in kitchen work. Yen and Radwin [7] also applied the video observation method as an input for an interactive computer controlled video analysis system to

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compare analysis time and inter-analyst reliability using posture classification and spectral analysis.

One of the pro minent characteristics of systematic observation is the use of a predefined list of behavioural codes that have b een developed for particular observation studies. The coding schemes were the instruments of measurement for observation research where the beh aviours were specified based on the research objective [8]. Besides developing predefined lists of behavioural codes that reflect specific needs, there are many examples of behavioural codes developed to assist observation studies such as Rapid Upper Limb Assessment (RULA) [9], Rapid Entire Body Assessment (REBA) [10], Ovako Working Posture A nalysis System (OWAS) and Quick Exposure Check (QEC) [11].

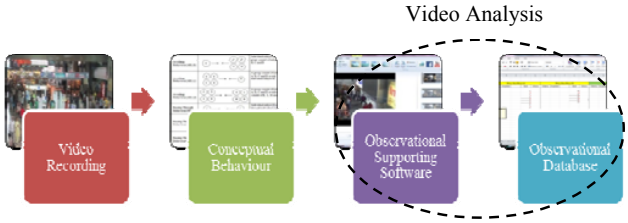

Fig. 1 The video-based observation and analysis method [12]

In this research, the video observation method was enhanced to asses s human movement and behavior in crowded areas. The method consists o f the three major steps of video recording, conceptual behavior modelling and video analysis as shown in Fig. 1. The main focus is the movement and behaviour of individual human beings in normal crowded situations (where no panic is involved), and the focus is on the interactions between individuals in localized areas. Human movement and behaviour in cr owds can be considered as random, complex and s ometimes unpredictable. Therefore, emphasis is placed on gaining knowledge of some of the characteristics of human movement and behaviour in the real world so that these can be modelled in the virtual environment.

III. Video Recording

Video recording is a p rocess to record human movement and behaviour in a crowded area. There were two i mportant considerations before conducting the video recording f or video observation purposes; the location selection and the recording conditions. In this research, the location selection related to t he objectives of the AUNT-SUE project whi ch were to promote research towards sustainable transport environments [3]. It also reflected the objective of recording human movement and behaviour in cr owded areas. Consequently, the Stesen Sentral transportation area in Kuala Lumpur, Malaysia was selected as th e video recording location. Stesen Sentral i s the largest transportation hub in Malaysia integrating all major transportation networks including trains, buses and taxis from Kuala Lumpur to other parts of Malaysia.

The transfer station also has special characteristics to be considered for crowd modelling and simulation such as differences in activities, time pressure and movement patterns [13]. In this research, the focus area was on the exit door (and its surroundings) located at the cr owded interchange connecting the public transportation system including trains, buses and taxis within the transportation hub. An overview of the selected location is shown in Fig. 2 where there is a ticket machine, a stall and a shop located at the ex it door area (highlighted area). The exit door was selected for the research since the area can supply considerable human movement and behaviour in a crowded area.

Fig. 2 Overview of the selected area for video recording [12]

The recording conditions refer to the recording time and length and the recording 'captured area'. The recordin g sessions need to be conducted during appropriate times when people are u sing the facilities including peak and off-peak times. This is to e nsure that the different characteristics of human movement and behaviour can be recorded. In this research, six one-hour sessions were conducted. During the video recording, images of humans in the crowd were captured from an aerial view so as to capture the whole human body from the top or head area. Thi s makes it easier to observe human movement and behaviour through the recorded video. The use of the top or head area as a reference point has been widely applied in image processing research such a s in [14] and in crowd experiment research by Kretz et al. [15] and Syried et al. [16].

IV. Conceptual Behaviour

Conceptual behaviours are a set of behaviour rules or codes that have been developed to assist the observational analysis of the recorded video. The conceptual behaviours were developed based on observing the physical movement of individual humans in crowded areas (without any contact or direct communication) and the und erstanding of human movement and behaviour from other research [17]-[21]. The process starts with defining the focus subject for the research which is t he individual human in a crowd. Each i ndividual human in a crowd is ob served to determine the movements performed. In th is research, the focus movements were categorized as free, same direction and opposite direction

movements.

The idea behind the conceptual behaviour is that human behaviour is developed based on different movements performed. For example, during opposite direction movement two different types of behavior are possible; Avoiding and Passing Through. Avoiding refers to the behaviour where an individual gives way to another person, perhaps by deviating from an intended route. On the other hand, Passing Through behaviour is where individuals do not consider others or their surroundings during the movement, and the major concern is to reach the targeted area by the planned route. Avoiding and Passing Through behaviours are examples of behaviours that can be experienced during movement in crowded areas. In this research a total of six behaviours were identified and have been discussed in detail in Mohamaddan and Case [22], [23].

The behaviour pattern is determined based on the movement and behaviour involved. Behaviour patterns are statements of how movement scenarios occur when individual humans move in crowded areas. The behaviour pattern might or might not be performed in the real world. In conceptual behaviours, human movement was considered as a scenario to acquire the human behaviour or behaviour pattern. The idea of deriving behaviour patterns from movement scenarios was based on scenario building that has been developed in product design.

Scenario building is a tool for exploration, prototyping and communication at an early stage of the product design process. The scenario is defined as a set of users, a context and a set of tasks that users perform or want to perform [24]. Thus, conceptual behaviours provide a foundation for future observation and analysis leading to a better insight into human behavior. This approach is particularly important during the observation process as the large volume of movement and behavior information within the recorded video could easily lead to confusion.

V. Video Analysis

Video analysis is the process of analysing the recorded video based on the developed conceptual behaviours. The proposed video-based observation and analysis process is shown in Fig. 3. The process starts with the selection of the recorded video. The video was analysed in thirty second segments using observational supporting software. Thirty seconds was considered to be a manageable time for analysis whilst avoiding any confusion.

Each individual in the 30 seconds of video was observed manually to determine the types of movement performed and classification of the behaviours. Two types of observational supporting software (The Windows Live Movie Maker Project and Windows Media Player) were applied to assist the process. The software was selected due to the ability to review the recorded video at any desired speed or arbitrary sequence (real-time, slow motion, fast motion, or frame-by-frame in either forward or reverse direction).

During the process of recognizing the movement and classifying the behaviour, the conceptual behaviour was referred to as a document to assist the observation analysis. The process of observing and recording the individuals with their behaviours was conducted every 3 minutes. After 3 minutes, the number of individuals observed was counted in the observational database. Since manual observation is considered to be a tedious process, the 3 minutes allocated for every session were considered to be a manageable time in order to maintain the focus during the observation analysis.

The observational database is a set of data consisting of information regarding individual human behaviours that were observed and analysed using the video observational supporting software based on the conceptual behaviours. It consists of recording session, focus movement and behaviour, behaviour pattern and any comments related to the movement or behaviour that was performed. The process of analysing the human movement and behaviour for each recorded video was conducted until the end of the video. After all recorded videos were analysed, the behaviours were referred again to understand the factors affecting human movement and behaviour or other related findings. The factors affecting human movement and behaviour were based on the similarity of the movement and behaviour or similar events or scenarios that occurred in the video. Picture snapshots (from the video) are used to help the process

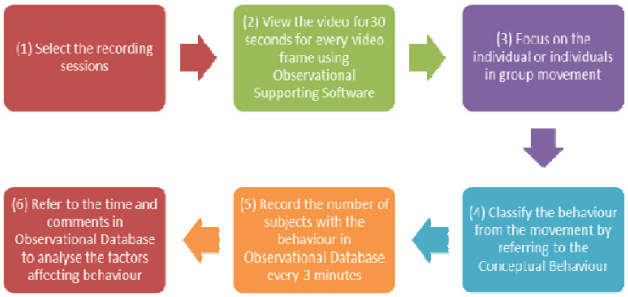

Fig. 3 Proposed video-based observation and analysis process [12]

VI. Conclusion

In general, this paper has presented a video-based observation and analysis method to assess human movement and behaviour in crowded areas. The method provides advantages in observing the natural movement and behaviour of people in the real world. However, human movement and behaviour is considered to be dynamic and unpredictable. Therefore, there is a need to develop rules in order to simplify the movement and acquire selected behaviours based on the research objectives. In this research for example, emphasis was placed on gaining knowledge on some of the human movements and behaviours in the real world and modelling them in a virtual environment.

Conceptual behaviours were developed as a framework to acquire the 'real' movement and behaviour. It can be considered as scenario building in ergonomics research that requires a set of users, a context and a set of tasks that users perform or want to perform. Focus was given to the individual human characteristics in a normal situation and the interaction between them in localized area. Older people and people with disabilities are always the main consideration due to their

different abilities and capabilities especially during movement in crowded areas.

Crowded areas offered considerable variety of human movement and behaviours. However, understanding the individual human characteristics in the crowded area using a video observation method is a tedious process. Hundreds or thousands of people may appear within the recorded video. There is a need to use other supporting tools such as the video observation software and develop the observation database to refer to and analyze the recorded behaviours. Additionally, some assumptions based on other behaviour research need to be made since there was no contact or communication between the observer and humans in the crowd.

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