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An 'Inclusive Design' Approach to Human Behaviour Modelling and Simulation

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Abstract — 'Inclusive design' is an important approach in product development that aims to estimate the numbers of people potentially excluded from the developed product. However, there is limited consideration of 'inclusive design' in computer aided design systems, especially in crowd modelling and simulation. This research aims to apply the 'inclusive design' approach to human behaviour modelling and simulation in crowded spaces based on video observation analysis. Conceptual behaviours are developed as guidelines to understand human movement and behaviour within the recorded video. The research is based on the 'inclusive design' approach and behaviours have been acquired from three major human movements of free, same direction and opposite direction movement. Almost 19,000 individual humans were observed within six hours of video recording and categorized into six different behaviours.

***Keywords*:** inclusive design, video observation analysis, human behaviour, modelling, crowd

I. INTRODUCTION

Inclusive design is an approach to create environments and products that can accommodate people with the largest possible range of abilities within the widest possible range of situations (e.g. environments, condition and circumstances). In product development, the inclusive design approach is applied to estimate the numbers of people potentially excluded from the developed product with a view to reduce this as far as possible [1]-[2]. Inclusive design is becoming an extremely important approach since the demographics of the world especially in developed countries have been changing steadily [3]. Longer life expectancies and a reduced birth rate are resulting in an increased proportion of older people within the adult population.

With increasing age comes a decline in capabilities, meaning that there are also an increasing number of people in the world population that can be considered to have disabilities. Having a poor memory, reduced strength or imperfect vision makes inclusive design important for maintaining quality of life and independent living for older and disabled people [3]. Inclusive design research is focused on various application areas such as packaging technology [4]-[5], product design [6]-[7], transportation research [8]-[9] and others.

This research originated from a major research project known as AUNT-SUE (**A**ccessibility and **U**ser **N**eeds in **T**ransport - **S**ustainable **U**rban

Environments). The AUNT-SUE project is based on the inclusive design approach where the objective is to develop a comprehensive 'toolkit' for journey environments from policy integration for city and regions down to the micro-level of streets, vehicles and facilities such as bus stops, signage and ticket machines [10].

This research is aimed at developing a computer program that is able to model and simulate human movement and behaviour within crowded spaces. Crowded spaces (e.g. train and bus stations) are public places used by people as interchanges and can involve a change in transportation mode (e.g. from train to bus). In general, crowd research can be divided into four main areas which are the crowd modelling, crowd simulation, crowd observation and crowd experimentation [11]. There has been only limited consideration of older and disabled people in crowd research [12] despite the fact that age difference can be a suitable parameter to differentiate older people [13].

In this research, a microscopic approach is applied in model and simulation development. The microscopic approach considers humans in the crowd as individuals where each movement and behaviour is important. This paper discusses how video observation has been applied as a method to acquire human behaviour data. The process starts with developing conceptual behaviours as a foundation or point of reference for the video analysis process.

II. Video Observation Method

Video observation was applied as a method to understand human movement and behaviour in crowded spaces. The video observation method was considered to be good method for capturing human movement and behaviour, but issues of privacy and security required serious consideration. Compared to laboratory experimentation [14]-[15], video observation provides 'real' human movement and behaviour where some of the unpredictable or natural movements/behaviours can be understand. In this research, video camera (Canon Legria, Model HF10) is used to record the crowd movement and behaviour. The observations focused on the normal situation where there is no panic involved (such as may found in emergency evacuation situations).

The video observation method has been widely applied in ergonomics research. For example, video observation method was applied with direct measurement to study individual human posture and movement during repetitive work in a poultry processing plant [16] and it has also been applied to assess musculoskeletal load in the kitchen work [17]. The video observation method has also been used to predict joint angle trajectories for sagittal lifting tasks in industry [18].

In this research, the Stesen Sentral transportation hub in Kuala Lumpur, Malaysia was selected for a case study. The selected area is a major transportation hub in Malaysia integrating all major rail transportation networks including the Express Rail Link (ERL) services to Kuala Lumpur International Airport (KLIA) and to the new administration center for Malaysia in Putrajaya [19]. The selected observation area is considered to be a large area. However, for the observation method there must be a specific area to be selected for the research purposes. Therefore, in this research the focus was on the exit door where considerable human movement and behaviour could be observed.



Figure 1: The observation area [20]

The observation area is shown in Figure 1. The observation area is the exit door that connects public transportation systems including trains, buses and taxis within the transportation hub. There is also a ticket machine and a number of shops located near the exit door. For this research, a total of six hours of video was recorded with sessions in the morning, afternoon and evening. The morning start time was 7:30 am, afternoon start time was 12 pm and evening start time was 5 pm. Each session lasted for one hour and was carried out both weekdays and the weekend making six one -hour sessions in total.

The weekday sessions occurred at the peak time when people start using the transportation service to work place in the morning, lunchtime activities and

the return home in the evening. The weekend sessions represented an off-peak time when the transportation services were used for 'leisure' activities. Besides the consideration of peak and off-peak times, these sessions were at times when there was a wide diversity of people using the transportation area including the older and disabled people.

After the recording session, each video was viewed once to observe the overall activities and to generally understand human movement and behaviour. The need for more meaningful information required that an appropriate approach needed to be developed in order to analyze and to get an insight into the recorded videos. Consequently, conceptual behaviours were developed as a tool to assist in the video analysis process.

III. Conceptual Behaviours

Conceptual behaviours are the foundation developed to understand individual human behaviour within the recorded video. The conceptual behaviours were developed to get a better insight into human behaviour whilst avoiding any confusion that might arise from the large volume of human movement and behaviour within the recorded video. Conceptual behaviours were acquired from the major human movements of free, same direction and opposite direction movement. The study of movement was focused on the individuals and individuals within a group. The conceptual behaviours were based on the observation of the physical movement of the subjects and there was no contact or direct communication with the subjects.

The conceptual behaviours focused on four different subjects; adults, older people, disabled people and others. Others refer to children or workers moving around with trollies, cleaning devices and other equipment. The idea of observing different subjects in this way was to subsequently represent this diversity in the computer simulation. The conceptual behaviours have a similar role as scenario building in product design. Scenario building is a tool for exploration, prototyping and communication at the 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 [21]. In conceptual behaviours, a set of rules were developed based on human movement (as a scenario) to acquire the human behaviours.

In this research, free movement is considered as a human movement from one point of interest to another point of interest. The point of interest is considered as the observation area as shown in Figure 1. In free movement the human is considered as having enough space to move and not face any obstacle or constraint during the movement. In free movement, there are two types of behaviour that might occur; Moving Through Behaviour and Move-Stop-Move Behaviour. Moving Through is the behaviour where individual humans just move through the observation area without any specific concern. The only difference that observed was the speed of movement. Move-Stop-Move is the behaviour that occurs when individual humans have to stop for a few seconds or a few minutes to perform some other task such as buying a ticket, using a mobile phone or looking for information.

Opposite direction movement refers to the condition where a human meets another human travelling in the opposite direction within the observation area. Upon meeting each other during the movement, there are two possible behaviours that can occur; Avoiding Behaviour and Passing Through Behaviour. Avoiding refers to the behaviour where a human gives way to other people or performs some avoidance maneuver. On the other hand, Passing Through refers to the behavior where humans do not consider others or their surroundings during the movement, and their major concern is to reach the targeted area by the planned route.

Same direction movement consists of Queuing Behaviour and Competitive Behaviour. The Queuing and Competitive Behaviours can easily be observed when humans enter or exit a door. Queuing Behaviour is the manifestation of self-organization where individual humans create a line to enter or exit the door. On the other hand, in Competitive Behaviour humans have less consideration for each other and each individual tries to enter or exit the door as quickly as possible.

IV. Video Observation Analysis

After the conceptual behaviours were developed, the overall observation and analysis of the video was conducted. Two supporting pieces of software; Window Live Movie Maker Project (Figure 2) and Windows Media Player were applied to analyze the individual human movement and behaviour. The software was selected as it allowed the observation of

human movement frame-by-frame and in slow motion.

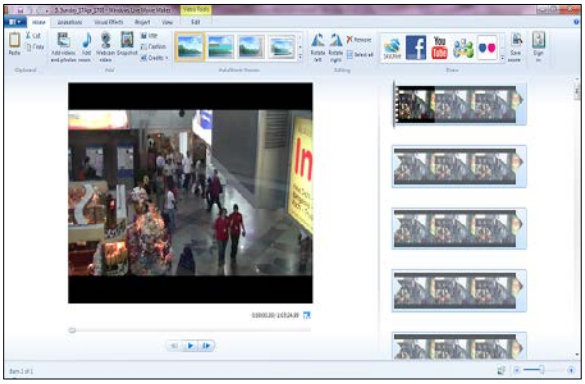


Figure 2: The observation software

During the analysis process, human movement was studied for around 30 seconds for every video frame. The analysis focused on individual movement within the observation area. During the analysis process, the conceptual behaviours are an important reference in avoiding any confusion or the exclusion of any humans from the data. The number of occurrences of each of the human behaviours observed were counted manually and entered into the observation database.

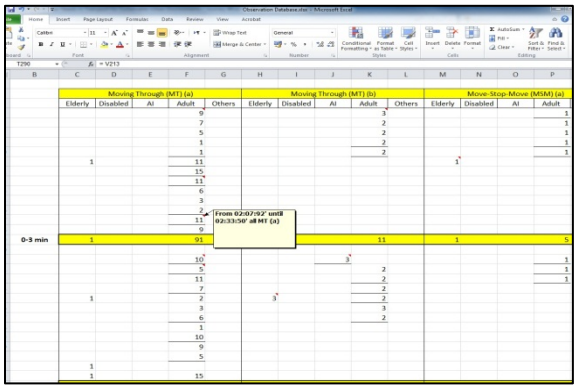


Figure 3: The observation database.

The observation database is a set of data consisting of detailed information regarding individual human behaviour that was analyzed from the observation supporting software. Figure 3 shows an overview of the observation database spreadsheet. The database consists of all the recording session information and behaviour section. The color code system was applied to differentiate the behaviour. Each behaviour section consists of four different subjects; the older people, disabled people, adults and others.

The database consists of the number of subjects in each behaviour with the time the behaviour occurred and a short commentary on the subject. The process was conducted for all six hours of video recording. After the database was completed, the observation data was compared with the conceptual behaviours to evaluate the behaviours. In this process only selected behaviours were evaluated.

During the video analysis process there were times when the humans in the crowd were considered to be moving in a high density crowd. During that time there were difficulties in recognizing individual human movements and behaviours. In this case, the individual behaviour was counted only once based on the first behaviour which appeared within the observation area. Besides that, the observation software had to be replayed a few times so that precise information could be extracted from the recorded video.

V. Results And Discussion

The observational results are shown in Table 1 and Table 2. In total 18,946 individuals were observed within the six hours of video recording. Higher numbers were observed during weekdays (58.8% or 11,138 individuals) compared to weekends (41.2% or 7,808 individuals). In both recording sessions, greater numbers of individuals were observed during the afternoon (12 pm to 1 pm) than the morning (7:30 am to 8:30 am) especially during the weekend where only 1,152 individual humans were observed.

Table 1: The observational results

Recording time	Number of subjects	
	17 April 2011 (Weekend)	21 April 2011 (Weekday)
7:30 am - 8:30 am	1,152	3,020
12:00 pm - 1:00 pm	3,402	4,182
5:00 pm - 6:00 pm	3,254	3,936
Total Subjects	7,808	11,138
Grand Total	**18,946**	

Table 2: Human behaviour based on subjects

No.	Behaviour	No. of Older People	No. of Disabled	No. of Adults	No. of Others	TOTAL
Free Movement						
1.	Moving Through (MT)	268	15	15,192	388	15,863
2.	Move-Stop-Move (MSM)	71	1	1,770	87	1,929
Opposite Direction Movement						
3.	Avoiding Behaviour (AB)	13	0	588	8	609
4.	Passing Through Behaviour (PT)	14	0	248	18	280
Same Direction Movement						
5.	Queuing Behaviour (QB)	1	0	162	1	164
6.	Competitive Behaviour (CB)	2	0	98	1	101
TOTAL		**369**	**16**	**18,058**	**503**	**18,946**

Table 2 shows the human behaviour based on the subjects. Within the 18,946 human observed, the majority of the human behaviours were free movement where 83.7% or 15,863 human performed the Moving Through Behaviour and 10.2% or 1,929 humans performed the Move-Stop-Move Behaviour. Since most of the humans had free movement, the humans in the crowd were considered to have had enough space to move without facing any obstacle or constraint during the movement. The results show that, during the observation time the observation area is considered to have a low crowd density where the majority of the humans could maintain their personal space.

Besides free movement, there were 3.2% or 609 humans that performed the Avoiding Behaviour and 1.5% or 280 humans performed the Passing Through Behaviour. The Avoiding and Passing Through Behaviour were derived from the conceptual behaviour of opposite direction. Another 0.9% or 164 humans performed Queuing Behaviour and 0.5 % or 101 humans performed Competitive Behaviour. The Queuing and Competitive Behaviour derived from the conceptual behavior of same direction movement.

Although the observation process attempted to cover various recording times so as to record a diversity of subjects, the number of older and disabled people within the six hours of video recording is considered low. The older and disabled people were only 0.02% of the total subjects. Adults were most frequently observed with 95% of the subjects while others were 0.03% of the total. The disabled people were only observed performing free movement. There were no disabled people observed performing the opposite direction and same direction movement. The older people were observed more in free movement especially on Moving Through Behaviour.

VI. Conclusion And Future Work

This paper describes the application of a video observation method used in understanding individual human movement and behaviour in crowded spaces. The behaviour of nearly 19,000 individuals in the video recording has been analyzed using the observation supporting software. Most of the subjects were observed during the weekend session especially during the afternoon.

Conceptual behavior plays an important role as a guideline to achieve the research objective of considering individual movement and behaviour for computer simulation. The inclusive design approach is applied within the conceptual behaviour and was detailed up in the observation database. The observation database can be used in the future to gain more insight into human movement and behaviour in crowded spaces.

For future work, the recorded video will be analyzed further especially as regards understanding the factors affecting the human behaviour in crowded spaces. Additionally, simulation software will be

applied to simulate human behaviour within a virtual environment. Several case studies will be developed to examine the observation data. This includes simulating the Stesen Sentral Kuala Lumpur in a virtual environment.

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