KOSDI ISSN : 1976-2208 (Print)
ISSN : 2671-5287 (On-line)
www.sodi.or.kr

Journal of the Society of Disaster Information
Vol. 18, No. 3, pp. 495-506, September 2022
https://doi.org/10.15683/kosdi.2022.9.30.495

Original Article

비상상황에서의 인간 행동 특성화 연구

Characterizing Human Behavior in Emergency Situations

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ABSTRACT

Purpose: When a serious disaster occurred in East Japan on March 11, 2011, some evacuees in shock failed to avoid danger to the best of their ability. Why did they hesitate and waste their time? And why didn't they choose correct escaping routes? This study attempts to classify human behavior through psychological point of view and cognitive science and to interpret behavioral patterns based on animal behaviors from the field of biology. **Method:** This study first conceptually categorized walking behavior into intellectualization, automaticity and instinct based on the existing literature and matched these with empirical data. **Result:** The actual walking patterns observed failed to be compatible with these categories and consequently, this study suggests the following five categories: normal, busy, fast & straight, freezing and tizzy. This new classification of walking behavior is based on speed, variation of speed and change of direction. **Conclusion:** The method used in this study and the results can be applied to simulations of walking behavior and analysis of behavior in emergency situations.

Keywords: Walking Behaviors, Intellectualization, Automaticity, Emergency, Instinctual Behavior

요 약

연구목적: 일반적으로, 사람들은 일상생활 속에서 자신이 어떻게, 어디서 걷는지 등에 대해 많은 관심을 기울이지 않는 경향이 있다. 하지만, 심각한 화재나 지진이 일어났을 때, 사람들은 가능한 한 빨리 위험지역에서 벗어나려고 노력한다. 만일 사람들이 비상상황에서 의사결정 이론에 근거하여 탈출하게 된다면, 사상 자는 크게 줄어들게 될 것이다. 본 연구는 심리학적인 관점과 인지과학의 관점으로 인간의 행동을 보다 구체적으로 이해하고자 한다. **연구방법:** 본 연구에서는 유튜브, CCTV 등에서 얻은 비상상황에서의 영상자료를 수집하여 상황별 사람들의 보행 특성을 분류하였다. **연구결과:** 비상상황에서의 보행자의 속도나 방향 전환이 평상시와 전혀 다른 특징을 가지는 것으로 나타났다. 재난 발생 시 탈출 방향이 주로 한 방향이기 때문에, 방향전환이 적으며, 평균 보행속도가 상대적으로 높은 것으로 나타났다. 분석결과, 평상시에서의 인간의 행동은 살면서 학습한 습관에 기반하지만 비상 상황의 경우, 원초적인 본능에 기반하는 것으로 나타났다. **결론 :** 본 연구에서 활용된 방법론과 연구 결과는 비상상황에서 사람들의 보행 행태에 대한 시뮬레이션과 분석에 활용 될 수 있을것으로 판단된다.

핵심용어: 보행 행동, 지능화, 자동화, 비상상황, 본능

Received | 1 July, 2022
Revised | 29 July, 2022
Accepted | 11 August, 2022

Introduction

In the serious earthquake that hit East Japan on March 11, 2011, 92.4% of the fatalities were caused by drowning, which is totally different from other previous earthquakes where casualties were mainly caused by Tsunami. Since this disaster, a great deal of attention has been directed to the topic of evacuation from earthquake and Tsunami (Wegscheider et al., 2011; Charnkol et. al., 2006; Limanond et al., 2011) and researchers attempted to calculate the time that takes to reach shelters and the evacuation time of citizens (Lämmel et al., 2010; Proulx, 1995; Radwan et al., 1985). Different evacuation behavior may be seen under serious disaster situations (Helbing et al., 2000; Sugimoto et al., 2003; Charnkol et. al, 2006; Kim et al., 2017; Lee et al., 2018) and it is difficult to observe and collect real data under disaster due to a limitation of detecting the coverage area. This study attempts to identify and classify characteristics of walking behavior in normal situations as well as in emergency situations with the points of view from psychology, biology and cognitive science. This study focuses on the fundamentals of human behavior to explain how people walk under normal conditions and why they encounter problems when they must evacuate from a dangerous area. The decision making theory (Janis et al., 1977) suggests that people's decisions are based on the utility of each individual. However, it has not been explained that people's behavior could vary depending on the different situations of danger.

Generally, people tend not to pay so much attention on how and where they walk in normal situations especially on routine routes. However, when a serious fire or earthquake occurs, people try to avoid the dangerous situation as soon as possible. If people try to escape based on the decision making theory in these emergency situations, the casualties could be reduced significantly. Nevertheless, people often hesitate and waste their time, or they do not choose correct escape routes even when they know the location of the nearest shelter. Why do people change their behavior in emergency conditions and fail to make rational decisions? To explain these abnormal behaviors, this study attempts to understand human behavior in more detail with the points of view from psychology and cognitive science.

Literature Review

The walking characteristics of pedestrians have mainly been interpreted in terms of crowd flow. Understanding all the elements of individual pedestrian behavior is a very complex task, however, the general view of researchers is that it is possible to generalize behavioral patterns of pedestrians if viewed as crowd flow. Researchers have aggregated individuals into crowd flows and approached this behavior from the cognitive aspect of individuals, in other words, from the socio-cultural aspect. Also, efforts have been made to give explanation through systems that have similar mechanics, for example, fluid dynamics and queueing in transportation, operation research.

Researches that attempt to understand the pedestrian behavior psychologically tend to take an approach of examining religious events and crowd psychology.

Chakraborty et al.(2009) have approached crowd flow in the socio-cultural aspect. Especially, (Coleman et al., 1961;

Cheng et al., 2014; Aveni, 1977; Harmeet et al., 2009) identified the characteristics of pedestrian behavior in religious meetings. In addition, crowd flow has been highlighted by many researchers in the aspect of crowd psychology (Turner, 1991; Zhao et al., 2008; Bellomo et al., 2008; Lorenz et al.,2011; Durupınar et al., 2015).

However, most of the research based on crowd flow has been performed in a way that tried to understand crowd flow through similar systems rather than taking on a sociological approach. From this point of view, the walking characteristics of pedestrians have been studied by substituting pedestrian flow with crowd flow and understanding the characteristics. This approach includes studies that attempt to understand crowd flow based on crowd behavior in emergency and panic situations (Helbing et al., 2001; Isobe et al., 2004; McGuire, 2005).

Similar systems that can be utilized to model crowd flow include the queues used in transportation system as well as fluids and hydrodynamics used in dynamics. Studies tried to understand crowd flow through queues (Helbing et al., 2013; Coleman et al., 1961), possibly because it is suitable to model through queues when the crowd movement is toward a specific target point in the situation where the waiting time is uncertain. A special case of queues like bottleneck caused by irregular geometric conditions of sidewalks have also been studied (Hoogendoorn, et al., 2005; Rupprecht et al., 2011). Aveni(1977) classified crowd movement into three types and compared them each other. The motion of pedestrian crowd was modeled as the motion of gases and fluids, crossing behavior of stationary pedestrian crowd was modeled as pedestrian movement in the form of river-like streams, and footsteps of pedestrians were modeled as streamlines of fluids. Kadanoff(1985) used hydrodynamics and analyzed pedestrians walking in opposite directions using viscous fingering. The attempts to study pedestrian characteristics through observations of similar systems are well documented by Helbing et al.(2001).

Researches that apply the concept of fluid flow consider a crowd as a continuum with a flow. However, as a crowd is a group of objects with the ability to think and is expected to obey rational and scientific flow rules, it would be possible to forecast crowd flows more realistically if they can be compared with other similar forms according to McPhail(1991). Such studies that apply similar systems are also applied in the approach of understanding flocking behavior (Limanond et al., 2001; Moussaïd et al., 2010; Qingge et al., 2007). This is because the flow of flocking behavior is a collection of behaviors that follow the simple rules of individual emergency situations rather than a flow formed by the central control or coordination.

Efforts to replace human walking with crowd flow and understand it using other similar systems have a limitation that the nature of human walking can be obscured by the characteristics of the similar system used. For example, in transportation system, the movement of the queue is modeled by factors such as acceleration and arrival rate of individual vehicles whose behavior is controlled within lanes. However, it is difficult to reflect the irregularities of human walking caused by sudden changes of direction. Therefore, this study seeks to approach human walking through the psychology and perception of individuals that govern their behavior.

The purpose of this study is to focus on understanding the human walking itself in psychological and cognitive aspects. This approach is easy to understand because walking is understood in terms of human behavior, and the selection of the parameters of behavioral characteristics through this can contribute to improving the reality of the modelling of walking behavior. The following sections are organized into three chapters. In chapter 3, we classify human walking conceptually. In chapter 4, we demonstrate the conceptually classified human walking based on actual case data. Finally, chapter 5 concludes with a summary of the study and suggestions for future research.

Characterization of Human Walking

Freud(1923) suggested that intelligence and basic instinct are utilized to explain all decisions of human behavior. This study applies this theory to define the fundamentals of walking behavior of human. Based on Freud’s theory, walking behavior can be divided into two: intellectual and instinct.

A behavior can be called intellectual if it is learned by repetition, practice and study because learning is a more proximate definition to explain the intellectual behavior of human. Walking behavior resulted from purposes to find the shortest path or detour are mainly related to intellectual behavior because making actions based on what you learned can be interpreted as having intentions.

People should be concentrating on their movements when they walk along streets, however, people tend not to. This can be explained by the “Stroop effect” suggested by Stroop et al.(1935) as shown in Fig. 1. If someone asks us about the color of the word in Fig. 1, in which the color of the word ‘WHITE’ is black, we have to think more carefully even if saying the color out loud is easier than silent reading.

Fig.1. Stroop effect

Even though reading involves higher intellectual skills than saying, it has been trained so much and used automatically. ‘Automaticity’ explains a demonstration of reducing the reaction time of a task inside a brain, because when people learn and practice something enough, the brain follows a customized or habitualized manual in their own memory to save its energy. Langer(1989) explained the reduction of reaction time of a task inside a brain in that ‘Automaticity’ has a different way of thinking and is usually the result of learning, repetition, and practice so it is related to learning and practices. For example, people usually don’t think much while walking in a normal routine situation. At first, people have to learn how to walk or think to choose the route and direction and have some rules in mind to avoid collision with others and so on. As time goes by, these actions are repeated and people require less effort to think. Finally, these actions change into automaticity.

On the other hand, if a behavior occurs without studying or practicing, it might be a kind of instinctual behavior naturally taken over from the ancestor. The abnormal running or hesitation that get seen in evacuations from fire accidents can be explained mainly by the instinctual movement.

In a nutshell, three different walking behaviors can be derived. In a normal situation, people mainly use ‘automaticity’ and do not need to concentrate on walking so much in a habitual situation. When the street is crowded, people concentrate on walking and mainly use ‘intellectualization’ to reach the destination in a short time or to avoid collisions with others. However, in a serious emergency situation, evacuee behavior is different because people easily fall into a panic state (Parisi et al., 2005; Helbing et al., 2000) so their behavior may follow ‘instinct’ as depicted in Fig. 2.

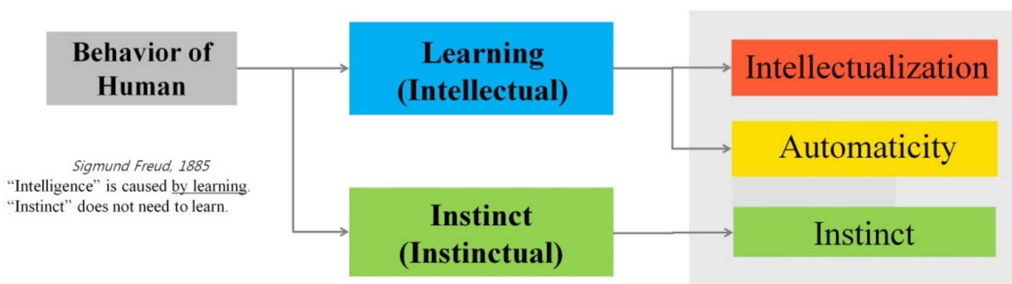


Fig. 2. Conceptualization of human walking

Demonstration

This chapter will look into how the walking behavior conceptually classified into three types can be matched with actual data such as CCTV and YouTube videos.

Data

This study collected data of people’s trajectory to define walking behavior under normal conditions and emergency situations. For walking behavior under normal conditions, pedestrian movements at Shinjuku station (Fig. 3(A.a)) were collected on January 26, 2011, with the total of 1,632 people during one hour. For walking behavior under emergency situations, the study collected trajectory data at Narita Airport (Fig. 3(B.a, B.b, B.c)) and videos from YouTube (Fig. 3(C.a, C.b, C.c), Fig. 3(D.a, D.b, D.c)).

Due to lack of data, it is difficult to observe real human behavior in emergency situations and only a few cases were found on YouTube. The first case is a video of the inside of Narita Airport in the event of an earthquake. In this case, two evacuees suddenly run outside because they felt the shaking as can be seen in Fig. 3(B.a). A few seconds later, more people run outside to follow these two people (Fig. 3(B.b)) and finally, everyone rushes out through the door in a short period of time (Fig. 3(B.c)). Fortunately, this video has a yellow line on the floor on the left side of the frame and the thickness of this line enables the calculation of the speed and walking directions of people, which will be discussed next

<A. data collection sites for normal walking behaviors>

A.a. Shinjuku Station (Video image capture)

<B. data collection for walking behaviors under emergencies, Narita Airport>

B.a. At the beginning of the Earthquake

B.b. More people ran (During the earthquake)

B.c. Everyone ran during the earthquake (Followers)

<C. Data collection for walking behaviors under emergencies, randomly chosen household>

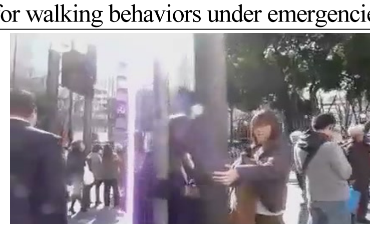
C.a. People are shocked at the beginning of the earthquake

C.b. People gather together and wait until the vibration stops

C.c. People are waiting at the main gate

<D. data collection for walking behaviors under emergencies, Ikebukuro Station>

D.a. One person cannot move and is holding a pole.



D.b. Two people cannot move and are holding a pole.

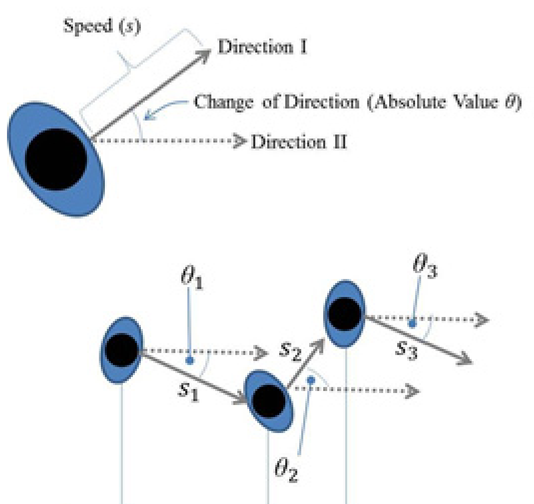
D.c. Many people are walking together or are standing.

Fig. 3. Different sources of data collection for walking behavior

chapter. In the second case as shown in Fig. 3(C.a, C.b, C.c), three people are in the house when the earthquake occurs. The exact distance and speed of the movements of people cannot be extracted from this video, but the movements can be observed for around two minutes. When the earthquake occurs, people are shocked as can be seen in Fig. 3(C.a), they hesitate for a while (Fig. 3(C.b)), and finally they try to go outside and open the door (Fig. 3(C.c)). In the last case as shown in Fig. 3(D.a, D.b, D.c), some people do not move and hold onto a pole when the earthquake occurs as can be seen in Fig. 3(C.a) and 3(B.a), and others walk together or stand on the street even when the earthquake stops after a few minutes.

Methodology

With the data collected, walking behaviors of people such as speed and change of direction are observed and analyzed with the method shown in Fig. 4, which is to observe the differences between normal walking and busy walking. Equation [1] expresses the average change of direction which is the average of the sum of the absolute values of the angles rotating left and right based on the direction of travel every 0.1 seconds. In other words, it is the sum of the absolute values of the angles between the direction of destination (direction II) and the direction of movement diverted from the destination (direction I) at the time of observation. Equation [2] refers to the average speed measured every 0.1 seconds.



- Average Change of direction: $\frac{\sum|\theta_i|}{n}$ [1]
- Average Speed: $\frac{\sum|s_i|}{n}$ [2]
- Direction I: individual movement direction (1 sec.)
- Direction II: group movement direction (1 sec.)

Fig. 4. Method of analyzing walking behavior

Results

With proposed method, non-emergency walking behaviors at Shinjuku station in Fig. 3(A.a) is analyzed. In contrast to Fig. 3(B.a, B.b, B.c), 3(C.a, C.b, C.c), and 3(D.a, D.b, D.c), pedestrian movements in Fig. 3(A.a) are relatively stable in speed and direction, which can be seen in normal situations. In this study, movements with stable speed and direction are defined as normal walking, and movements with varying direction and higher speed, which can be found during peak hours, is defined as busy walking.

In Fig. 5, busy walking is shown as the largest dots on the streets (7.4% of total). The differences in speed and change of direction between normal walking and busy walking are 0.25 m/s and 0.1 degree/s respectively. The difference in change of direction between normal walking and busy walking is very large because busy walking has large variations and the change of directions is more dramatic and sudden compared to normal walking. Average speed of normal walking is 1.23 m/s, which is lower than busy walking.

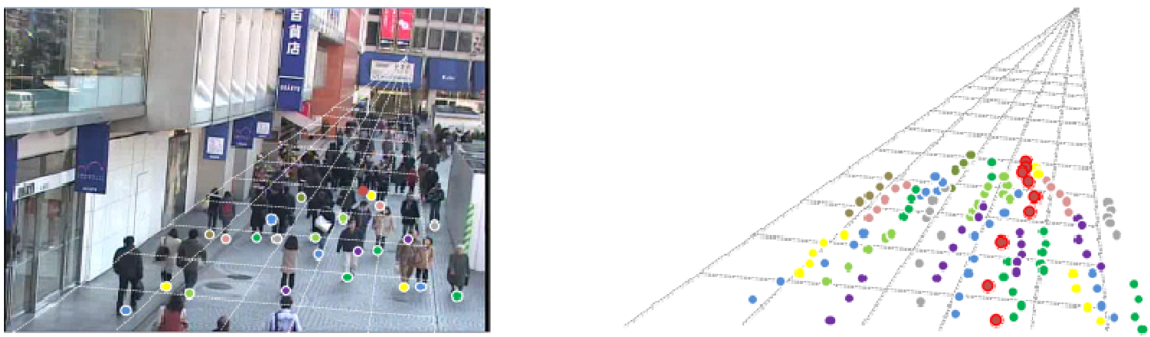


Fig. 5. Characterization of Non-emergency walking

In terms of speed and change of direction of pedestrians, the movements under emergencies are totally different from normal or busy walking. This is because the behaviors of people mainly followed their instinct at least for a second, so it is necessary to derive a new classification to define this behavior using the instinctual behaviors of animals.

Reflecting this, the study classified walking behaviors into five groups (see Fig. 6). In normal walking (A), people walk along the straight line (average walking speed: 1.23 m/s, average change of direction: 2.8 degree/s in Table 1), but in busy walking (B), they change their speed and direction frequently (variation of speed: 0.11 m/s, variation of change of direction: 67.1 degree/s). In emergency situations, it is assumed that evacuees are in panic and the evacuation behaviors can be divided into three groups: Fast & Straight, Freezing and Tizzy. In the case of Fast & Straight, the average speed (2.0 m/s) is faster than that of busy walking, however, the degree of change of direction is smaller because there is just one direction for escaping and people follow the crowd. The average speed can be very high because evacuees runs as fast as they can and they do not need to change direction to avoid people running towards them.

We could not measure the speed and direction of "Freezing" and "Tizzy" movements directly from the video, however, we could capture the change of direction which was found to be very large as shown in (D) and (E) in Fig. 6. We combined the patterns in Fig. 6 and the observation results in Table 1 to draw Fig. 7 as the summary of the observation results. The normal walking (A) has smaller variations of speed than busy walking (B), but the speed of Fast & Straight (C) is faster than that of busy walking (B). While Tizzy (E) has the largest value of change of direction among the five behaviors observed, this value of Tizzy (E) is not measured directly so is assumed to be just large. The locations of panic (instinctual) movements from (C) to (E) are located in each corner point in Fig. 7.

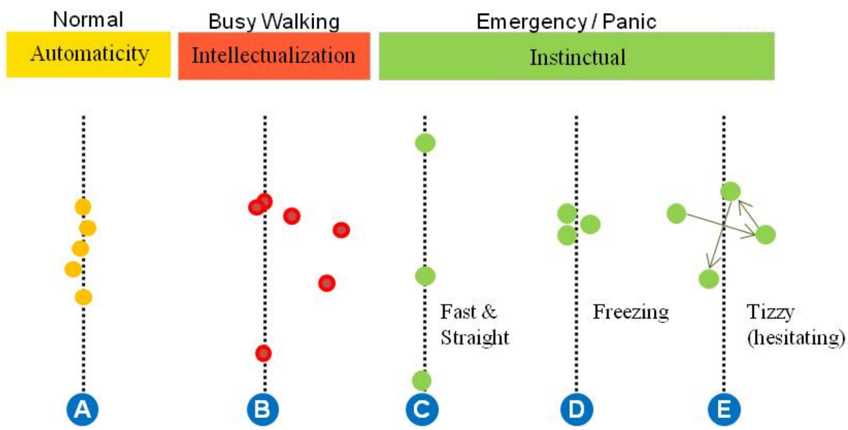


Fig. 6. Conceptualization of walking behavior

Table 1. Speed and direction of pedestrians and evacuees

		Speed (m/s)		Change of Direction (degree/s)	
		Average	Var.	Average	Var.
"Intellectual"	A. Normal Walking (N=4,132)	1.10	0.21	11.2	8.2
	B. Busy Walking (N=602)	1.89	0.85	13.9	27.8
"Instinct"	C. Fast & Straight (N=144)	2.01	0.12	*	-
	D. Freezing (N=25)	*	-	*	-
	E. Tizzy (N=4)	*	-	**	-

*: Not measurable, but expected to be a very small value
**: Not measurable, but expected to be a very large value

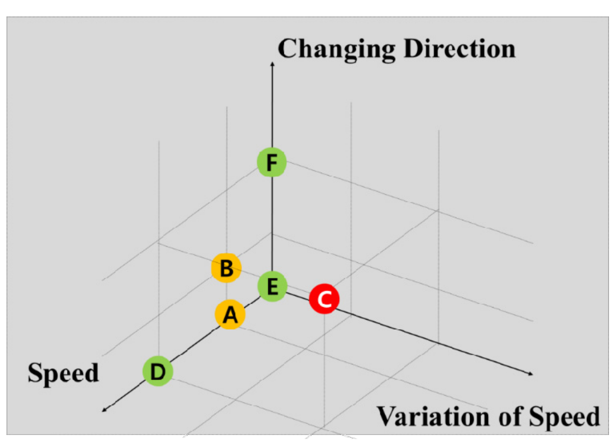


Fig. 7. Five types of walking behaviors

Conclusion

This study attempted to analyze human behavior in emergency situations from the aspect of instinct and found that automaticity, or behavior based on learning, is similar to basic instinct. In order to analyze behavior by instinct, this study referred to animal behavior and found that there are differences between behaviors that are based on intellectual learning and those that are not. Busy walking and panic walking showed slight differences in speed and the degree of change of direction, which were also different from those of normal walking. To apply these findings to human behavior, this study collected and analyzed video data of human behavior in normal conditions and emergency situations. As a result, it was found that human behavior in normal conditions comes from automaticity while that in emergency situations comes from basic instinct.

Applying this to animal's instinct, three behaviors were observed: fast & straight, freezing, and tizzy (hesitating). Under panic conditions, especially, behaviors of freezing and hesitating can be observed from animal behavior and similar behaviors were found from the data of pedestrian evacuation movements.

In conclusion, the method used in this study and the results can be applied to simulations of walking behavior and analysis of behavior in emergency situations. Defining and analyzing pedestrian behavior is not as easy as dealing with vehicle movements. This study can suggest some ways to numerically define pedestrian movement and apply them to designing walking simulation models.

Acknowledgement

This work was supported by the Korea Foundation of Nuclear Safety (KoFONS) [Development of methodology for emergency traffic control in nuclear power plant accident (grant No. 2104040)]

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