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Danger detection with different data feeds

Joost Miljoen (1390813)

Supervisors:
Prof.dr. J.N. Kok & Dr. A.-W. de Leeuw

BACHELOR THESIS

Leiden Institute of Advanced Computer Science (LIACS)
www.liacs.leidenuniv.nl

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Abstract

The increasing threat of terrorism in Europe is a great concern for many event organizers. Every year more open events are organized and besides, the number of visitors per event increases rapidly due to improved accessibility. Those aspects make securing open events even more important for event organizers. In this research we investigate how different security tools can be combined to optimize the event security. So far, most heat maps are developed with just one input feed. We try to find a way how different security tools can strengthen each others effect by answering the research question: ”how can we prevent dangerous situations during events by using different types of data feeds?”

First part of this research is a literature research to the way pedestrians move through an event area. During this literature research we have chosen one model for pedestrian flows, the social force model, to make simulations for the second part of this research: the use of security tools for the detection of potentially dangerous situations. For this second part of our research we had several meetings with different parties, that are specialized in the use of data for the prevention of dangerous situations.

As a result of our research we made the conclusion that for an optimal event security, simulations of event areas have to been made. On the basis of these simulations event organizers can make a strategy for the use of security tools, especially the human sensor, sound sensors, cameras, WiFi-routers and telephone masts. A combination of these security tools give the most precise indication of potentially dangerous situations during events in open areas.

Contents

Chapter 1

Introduction

Event security has become an increasingly important aspect in the organization of an event. Because for visitors it has become a lot easier to visit an open event, by the improving public transport in European countries. In addition, there is a growing threat of terrorism during major open events, which we have seen at a concert in Paris in 2015 and at the Christmas market in Berlin in 2016. In both cases terrorists try to kill a lot of people at once. Because of the high concentration of visitors at the same place, there died a lot. For open events in the coming up years it is important to avoid such situations by optimizing the event security.

This research is focused on pedestrian flows on event areas of open events. For example, how can we prevent that people die during a possible panic situation? Or how can we map the pedestrian flows in a real-time way? During this research, a literature study is combined with a practical research. The literature part of this research is focused on how pedestrians move. Both in a normal situation, as well as in panic situations. The practical part is focused on the different types of security tools that can be used to secure an event area. For example, telephone or WiFi-routers, sound sensors and a human sensor.

1.1 Goal of this research

The main goal of our research is to find a way of securing open events in the coming up years, by creating an all-round solution that can be used in different cities and situations. Every city has his own existing security tools that can be used by event organizers. When an event organizer has a model for securing events in the right way, it will be possible to use these existing security tools in a better way than is be done nowadays. For example, the existing security tools of a city can be used to map the pedestrian flows in a city by adding some extra security tools on critical points.

First of all, we want to create an advisory report for a specific event, the finish of the Volvo Ocean Race in 2018 in The Hague. In this report we explain step by step how an event area could be prevented for dangerous situations. During this research a dangerous situation is defined as an situation with too many people at the same place. Later on we explain why this could be a dangerous situation.

1.2 Problem statement

During this research we will try to find an answer on our research question: "how can we make predictions about too crowded places at an event by using different types of data feeds?" The reason why we investigate this research question is the fact that crowd management is one of the most difficult aspects of the event organization these days. As described before it is much easier for visitors to visit an open event by using the public transport.

Besides there are more and more open security tools available that can be used to secure an event. For example, there are many public cameras in every city centre. When an event organizer gets the rights to use these cameras for securing his event, the costs for the event security as a whole will be lower and the event could be safer if the public security tools are used in the right way during the event.

1.3 Parties involved in this research

While conducting this research we will collaborate with different other parties. Parties involved in our research are among other things Leiden University, KPN, Prooost and The Hague Security Delta. They provide us extra information and data for creating an all-round solution. During this research the project is supervised by Prof. Dr. J.N. Kok and Dr. A.-W. de Leeuw from the Leiden University.

Chapter 2

The Approach and Methods

During this research we try to find a way we can optimize the use of security tools to prevent dangerous situations, especially for our case: the finish of the Volvo Ocean Race in 2018 at the beach of Scheveningen, The Hague. There are a lot of security tools that already have been used to monitor dangerous situations during events. For example, public cameras, security personnel, etc. However, it is still possible to optimize and combine the usage of these security tools. We have tried to find a way we can combine different types of security tools in one heat map, to detect dangerous situations in an early stage.

2.1 Methods used during our research

This research is split into two parts: a literature research and a practical research. In our literature research we try to discover the way pedestrians move and try to find a model that models pedestrian flows in different situations, namely: a normal situation and a panic situation. There have been done a lot of simulations of different models for pedestrian flows. These models are interesting for our research, because it gives us an indication of the evacuation time in different situations. It is important to keep this evacuation time low during events, because of the danger of terrorism.

For the second part of this research we did a practical research to find different types of security tools, that can be used for securing an event. To get an overview of these security tools we had some meetings with different parties, that facilitate different ways of securing events. For example, Dutch telecom provider KPN told us about the possibility to use data from telephone masts to follow the movement of pedestrians.

In the last part of our research we made different simulations for our case. The way we made these simulations is described in the relevant part of this research. These simulations were necessary to apply our research results on this case. Goal of this case was to find a way how the passage between the Kurhaus and Palace Promenade in Scheveningen, The Hague, could be prevented for dangerous situations. In other words too many visitors at the same place, which could lead to collisions and obstructions.

Chapter 3

Research on pedestrian flows

Figure 3.1: walking pedestrians

During a normal working day, a pedestrian flow in the city centre will be different from a pedestrian flow during a shopping night or Saturday afternoon. This also applies to the pedestrian flows during major events, whereby pedestrian flows will change during the event. As more visitors come off at an event, the opportunity to move on an event area take off. Because after all the available space on the event area is becoming increasingly more filled. This ensures on one hand that there are some pedestrian flows that will arise from people moving through the same path over an event area. Where a pedestrian could move criss-cross over the area in the beginning of an event. On the other hand, it is very important in a situation like this, that there are some opportunities for pedestrians remaining to leave the event area quickly in case of an emergency.

In this part of our research we will look at how people are likely to move in different situations. It goes without saying that these movements will change as the event area becomes full, or in case of an emergency during the event. For event organizers it is very important to know what the possible bottlenecks could be on their event area, so that they can manage the crowd when it is becoming too busy at these points.

Researchers are studying pedestrian crowds for more than forty years now. Most of these studies were empirically studies, whereby pedestrian flows were observed. In some of these studies the main goal was to develop planning guidelines for pedestrian flows. In most cases we see the form of a regression relation in these guidelines. A regression relation is not in every situation well suited for the prediction of pedestrian flows. For example, in situations where pedestrian flows move through an exceptional architecture. Also these models are in most cases not suitable for evacuations. Therefore, a couple of simulation models have been proposed in the past. For example, the queuing models [L94], transition matrix models [Gar73] and stochastic models [NAM76]. These models are partly related to each other. Besides these models there are some specific models for the route choice behaviour of pedestrians [BT86b].

It is important to mention that many of these models do not take into account the fact that a pedestrian crowd can organize themselves. This way of organizing could lead to unexpected obstructions and collisions, as a result of mutual disturbances of different pedestrian flows. Such a mutual disturbance can occur during an event, whereby different pedestrian flows moving from one side to the other side of an event area in a contrary direction. For example, when an artist finished his performance and visitors want to move to the area with toilets and food stalls. Other visitors maybe want to move forward to the stage, to watch the next performance of a new artist.

Henderson came with his approach with an alternative for the already described models, whereby he suggests that the behaviour of pedestrian crowds is almost similar to gases or fluids [Hen74]. Of course these gas-kinetic and fluid-dynamic theory of Henderson must contain some corrections. Because pedestrians have particular interactions, for example avoidance and deceleration manoeuvres. Because of the development of artificial intelligence, we want to mention that there are already AI-based models for simulating pedestrian flows in urban areas [GS90].

3.1 Observations in normal situations

In this first part with observations we summarize the observations that different researchers have done in the past years in normal situations. A normal situation is defined as a situation wherein pedestrians can move freely or with a short delay as a result of a high pedestrian density.

3.1.1 Studies that have been used

To investigate pedestrian motion, we used the results of other pedestrian studies and observations to verify these results. These observations came from time lapse films of different big cities. While investigating pedestrian motion there can be found some regularities in the way pedestrians move in normal situations, besides chaotic individuals. A normal situation is defined as a shopping street on a weekday.

Studies that were used for our research are studies of D. Helbing, P. Molnr, I. Farkas and K. Bolay [DHB01] [Hel98]. Especially D. Helbing is one of the researchers who did a lot of research to find patterns in the way pedestrians move.

3.1.2 Conclusions on the observations

First of all, pedestrians feel an aversion against taking side roads or moving in the opposite way to the desired walking direction. Not only when the direct way is free of pedestrians, also when the direct way is crowded.

However, it is important to mention that there is some obviousness that pedestrians normally prefer the fastest way over the shortest one to their destination [Gan98]. So although pedestrians feel an aversion to taking side roads, some pedestrians will take side roads if the way to their destination is faster via these side roads. For event organizers this can be important while closing roads in the centre of a city, during an event as the Volvo Ocean Race in The Hague.

A second conclusion on the observations in other pedestrian studies is the fact that pedestrians are likely to move in their own speed. They prefer their individual desired speed over the speed of a pedestrian flow. In other words, a speed that bring them to their destination on time and which takes least energy of a pedestrian. In one of his researches to pedestrian motion L. F. Henderson concluded that the desired speed within pedestrian crowds are normal distributed. Whereby mean = 1.34 meter per second and standard deviation = 0.26 meter per second [Hen71]. However, it is important to keep in mind that the average speed of a pedestrian flow depends on different aspects. For example, the situation where the pedestrian flows occur, the average sex and age of the group with pedestrians, the time of the day and the purpose of a trip. When a pedestrian could not reach his desired walking speed, his frustrations increases. This means that a pedestrian will consider taking a side road to his final destination in a normal situation.

The last important observation of pedestrian studies tells us that pedestrians feel the most pleasant when they can keep a safe distance to other pedestrians in their surroundings. Also pedestrians are trying to keep this distance to streets, walls and other obstacles. This distance will decrease the more a pedestrian is in a hurry or the higher the pedestrian density is in an area. In case pedestrians do not move anymore, for example when they are waiting for their train or taxi, they will be uniformly distributed over the available area. This situation changes when there are acquaintances among the individuals, or in case of event, when there is a stage in front of an area. During a performance the density of resting pedestrians in front of the stage will be higher than at the end of the event area, unless the whole event area is filled with visitors.

3.2 Observations in panic situations

In this second part with observations we summarize the observations that different researchers have done in the past years in panic situations. A panic situation is defined as a situation wherein pedestrians cannot move freely or with a short delay as a result of an unexpected danger. For example, this can be the evacuation of an event area.

3.2.1 Studies that have been used

For event organizers one of the most important aspects of organizing an event is to prevent an event for panic situations. Nowadays the chance of panic situations is larger than ever before. Because it is much easier for visitors to visit an event by traveling with the public transport open events will be visited by more and more interested visitors. Besides, the danger of terrorism is growing whereby terrorists try to kill a lot of people at once. In the past years it has been found that panic stampede is one of the most tragic collective behaviours, because it often leads to dangerous situations wherein a lot of people die. People were either crushed of trampled down by others.

Although research on panic situations is becoming increasingly important, there is still little known about the behaviour of pedestrians in such a panic situation. As a result, the quantitative theories of predicting the pedestrian motion in panic situations is scarce.

3.2.2 Conclusions on the observations

One of the conclusions on the observation of panic situations in different movies and television clips is the fact that individual visitors of an event are getting nervous in a panic situation. Besides, people try to move faster than in a normal situation to find the exit of an event area as fast as possible. As we have seen before this leads to an unexpected disturbance in a pedestrian flow, because the exit of the event area will be a bottleneck in such a situation. As a result, individual pedestrians will start pushing others and interactions between pedestrians become physical in nature.

At the bottlenecks, in most cases the exits of an event area, it is not possible to coordinate the pedestrian flows anymore. Jams are building up around the bottlenecks of the event area and the physical interactions between the pedestrians involved in jams grows [Min51]. Studies to the jams of pedestrians at bottlenecks concluded that the pressure can increase up to 4.500 Newton per meter [ES93], which can tear down brick walls! This can be explained by the fact that pedestrians panic and do not get their desired walking speed, because of the obstructions. As a result of both, pedestrians will get more and more frustrated about the situation. They use physical contact to express their frustrations and to work them a way to the exit of the event area.

The quantity of obstacles around the exit of an event area will grow during the escape. This is a result of people who fall or get injured while trying to come to an exit. A research from J.P. Keating on the myth of panic shows us that people tend to do what other people in their surroundings do during an escape [Kea82]. He also concludes that alternative exits on an event area are often overlooked or not efficiently used during an emergency. This will result in a situation that get more and more uncoordinated, whereby the physical interactions between people are growing.

Chapter 4

A model for pedestrian flows

In this chapter of our research we investigate different models for the prediction of pedestrian flows. There have been developed a lot of models for traffic flows in the past decades, that can be used for predicting pedestrian flows. However, not every model is suitable for the prediction of pedestrian flows on event areas. We try to compare different models and try to find the model that fits the best for our research to pedestrian flows.

4.1 Research to suitable models for pedestrian flows

People's behaviour is often irregular and unpredictable. When a pedestrian is confronted with a standard situation however, a pedestrian will react automatically in most situations. Instead of thinking about a logical response to the situation. On the one hand this can be explained by the fact a person has a lot of experience in certain situations. On the other hand, a person can react by unexpected panic in dangerous situations. This makes it very difficult to develop a comprehensive model that can predict the behaviour of people in a pedestrian flow. However, there are some models that can be applied to pedestrian flows.

For several decades, researchers investigate different types of traffic flows. The aim of the developed models for these traffic flows was to solve problems as serious traffic congestion and predict the quantity of traffic flows. These traffic flows are broadly in line with pedestrian flows, so that the models for traffic flows can be used for predicting pedestrian streams.

4.2 Different models for pedestrian flows

In 1999, Nagatani brought out a one-dimensional model for the prediction of pedestrian flows [Nag99]. This model was based on the nearest-neighbour sites effect, which has been proposed in a one-dimensional lattice model for traffic flows. Nagatanis model tells us that the transition from a normal situation to a crowded situation in pedestrian flows matches the conventional phase transition where gas turns into liquid. Because in a normal situation, pedestrians can move freely. But when a higher density of pedestrians leads to a viscous pedestrian flow: the liquid phase in the conventional phase transition model. In this model the pedestrian density, in case of Nagatanis research the car density, correspond to the volume. The inverse of the delay time of pedestrians corresponds to the temperature.

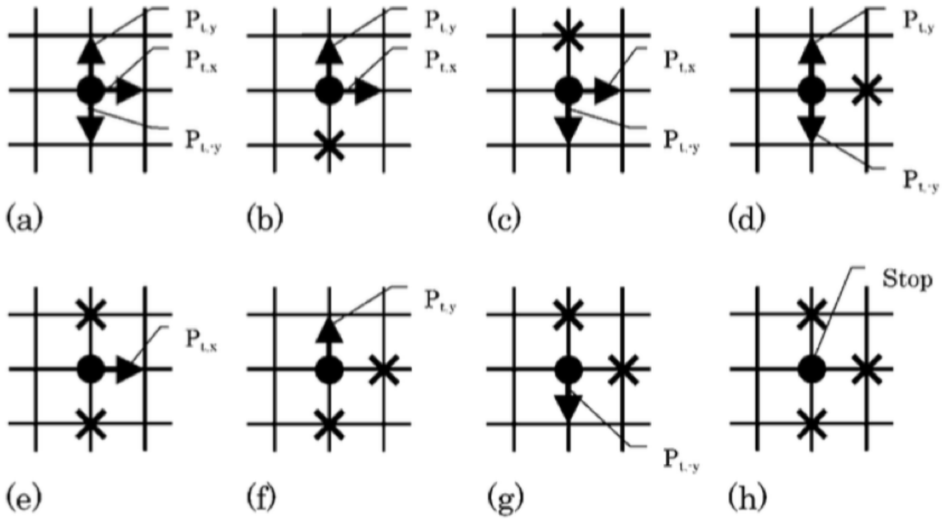


Figure 4.1: Nagatani's model from 1999

However, Nagatanis model does not take into account that pedestrians use the available space in a flexible way and react in a deviating way when they are panicking. Besides those reasons for not using the Nagatanis model we have to find how behavioural changes of pedestrians are guided. Lewin find that most of the behavioural changes are guided by so-called social forces or behavioural forces [Lew51]. These social forces determine the amount and the direction of systematic behavioural changes of pedestrians. This concept was not only applied to pedestrian and vehicle traffic, but also to opinion formations and migration. Those applications were not as successful as the application on pedestrian and vehicle traffic was [Hel02].

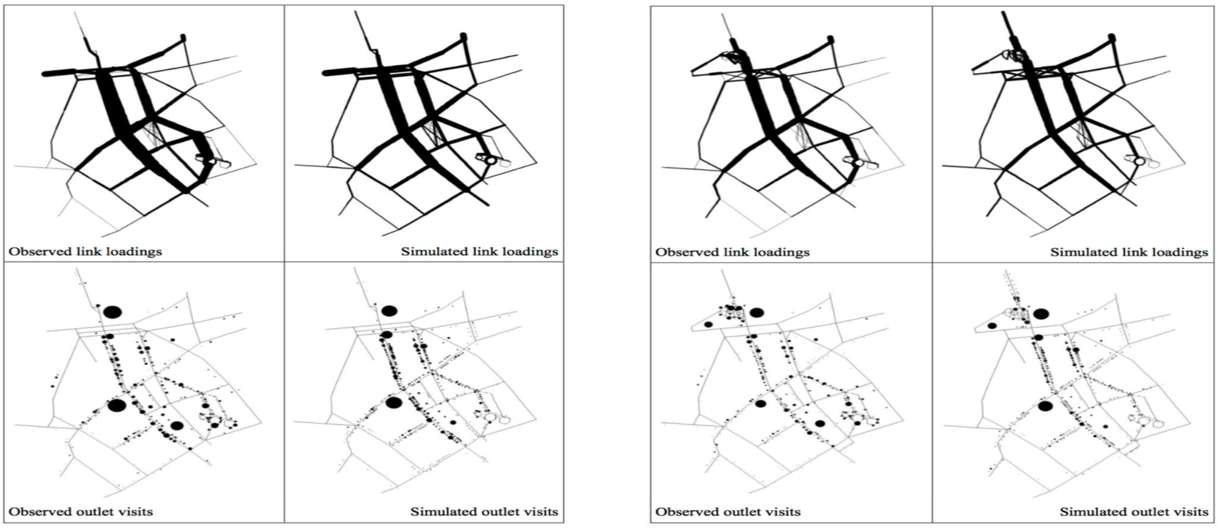
For creating a model for pedestrian flows it is enough to have a good indication of the percentage of pedestrians that move to the right, to the left or do not change their direction. There are different ways to measure this percentage. For example, we can empirically measure how many pedestrians change their direction in different situations. However, it is easier and more precise to use route choice models. One of those route choice models that can be used is a model designed by Borgers and Timmermans [BT86a].

With this model we want to discover the pedestrian route choice and allocation behaviour within city centres. The situation in a shopping street in the city centre is comparable with the situation on an event area, while assuming a normal situation on the event area. This means that pedestrians can move freely or just with a short delay through the event area. With this model we want to capture the main characteristics of pedestrian behaviour, so that we can use these observations for the prediction of pedestrian flows on event areas.

4.3 Route choice behaviour model of Borgers and Timmermans

From other researches that have been done in the past years we can conclude that the behaviour of pedestrians is closely connected with the location of entry points of city centres and the location of popular stores inside the city centre. These popular stores, also called magnet stores, attract most of the visitors in the city centre. As a result of this conclusion the commercial viability of other establishments seemed to be largely depended upon the degree of functional integration of these establishments into the general pattern of pedestrian route choice.

An example of a simulation with the Borgers and Timmermans' model is shown in the image below. The black dots in the lower images are different outlet stores in a city centre. The upper images show the way the different dots links to each other, in relation to the pedestrian flows in the city centre.



(a) (b)

Figure 4.2: Borgers and Timmermans' model, in two situations [Bor05]

With the results of Bennison and Davies research to pedestrian movement and the functional use of shopping centres we got more support for the model of Borgers and Timmermans [Par17]. Bennison and Davies concluded that the movement of shopping pedestrians in a city centre showed a high degree of organization. More specifically, Bennison and Davies conclude that shopping streets with the largest popular stores attract the most pedestrian flows. This result shows the importance of a really small group of shops in a city centre in the organization of the pedestrian flows.

For event organizers these findings are interesting, because on an event area there are some of these magnet stalls. For example, a drink stall will be more interesting for visitors of an event than the souvenir stalls. The placement of these boxes can therefore have an impact on the pedestrian flow on an event area.

The research of Bennison and Davies suggest that changes in the location pattern of stalls in case of an event might have an impact on the revenue of parts of the event area. For example, the part with food and drink stalls will have a higher revenue when these stalls are centred. In case a couple of these stalls will be moved to another part of the event area, this will have an impact on the revenue in the part where the stalls were located before. The degree of such an impact will likely depend on the position of a part of the event area in the network of pedestrian flows. Not only stalls on an event area will have an impact on the route choice behaviour of pedestrians. Also the different stages at an event area can influence the pedestrian behaviour, because pedestrians are likely to move to the stage with an artist that they prefer above other artists. With this information for event organizers it will be possible to coordinate pedestrian flows on event areas, by placing their stalls on strategic locations.

4.4 The occurrence of congestion

On an event area there can be a lot of possible dangerous situations as a result of bumps of pedestrians. For our case in Scheveningen, The Hague, we can tick off some of these places around the Kurhaus. As an example of these possible congestions of pedestrians we take the narrow passage between the Kurhaus and the Palace Promenade. It is plausible that there will occur bumps in this passage. To create a universal definition of possible dangerous situations like the described passage, we will do some simulations of pedestrian flows in a narrow passage.

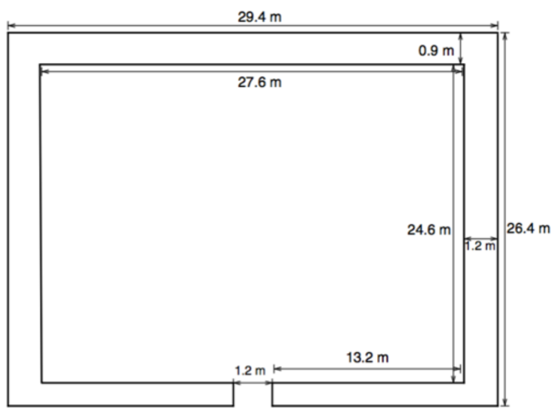


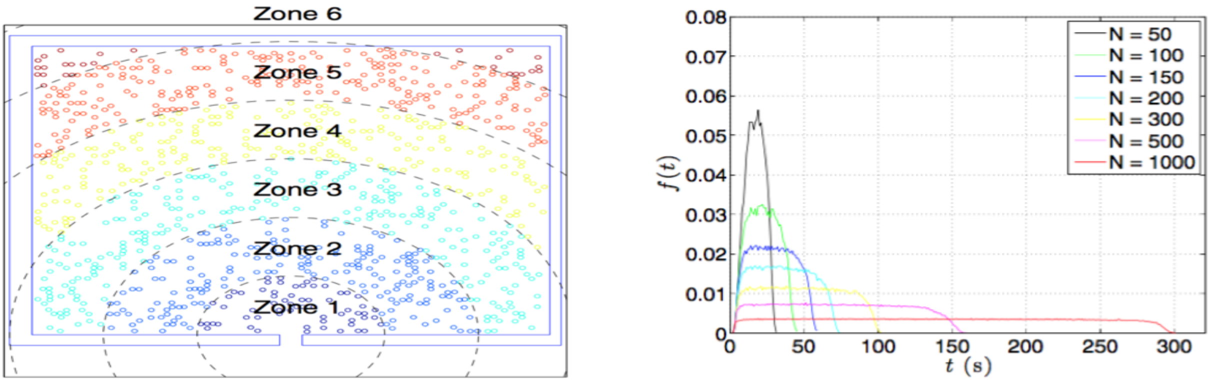
Figure 4.3: test area [Vis14]

We already have some data from an existing research [Vis14], wherein such a simulation has been done with different numbers of agents. This research is not specifically useful for the situation in Scheveningen, The Hague, but we can use the results for our universal definition. In this research simulations were done in a space of 27,6 meters by 24,6 meters with a narrow passage of 1,2 meters. Simulations were done with 50, 100, 150, 200, 300, 500 and 1.000 agents. Agents were randomly dropped in this area. For each group of agents there were done 100 simulations to create a reliable outcome.

It is important to note that researchers assumed that each agent has preferred speed of 1,3 meter per second and a maximum speed of 2,6 meter per second. Every agent has a mass of 60 kilogram.

As a result of the simulations done by the researchers we can note that agents in the social force model wait patiently for their turn to move through the passage when the passage becomes congested. Hereby there will occur a wide area with waiting pedestrians around the passage with the highest density close to the passage. As an event organizer you want to prevent such a congestion of pedestrians, because it can result in dangerous situations as they block other passages on an event area.

Besides the results on how the congestion occurs in different situations, there are some results of the evacuation times as well. For the social force model it turns out that a group of 200 agents can be evacuated in about 75 seconds. A group of 500 or 1.000 agents will be evacuated in respectively around 155 and 300 seconds. This means that with 1.000 agents only the first zone will be evacuated in 75 seconds.



(a) definition of zones in simulation area

(b) evacuation time distributation

Figure 4.4: Results of the V. Viswanathan et al research [Vis14]

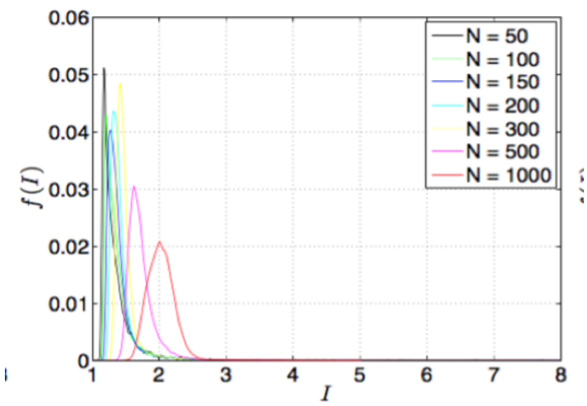


Figure 4.5: distribution of the inconvenience [Vis14]

The third aspect to look at in this research is the inconvenience of agents during a simulation. We define inconvenience as the difficulty for an agent to move through the crowd passing the passage. As we can see in the distribution of the inconvenience there is a higher inconvenience as the group of agents is bigger. The limit value is around 300 agents. With larger groups of agents the inconvenience will grow fast.

From these different results of the simulations in this research we can conclude some important things for our own simulations and model for the situation in Scheveningen, The Hague. First of all an event organizer has to try to make sure that there are not more than 200 pedestrians in a passage with a width of 1,2 meters. In case the group of pedestrians is bigger, it can result in dangerous situations because of a growing evacuation time and inconvenience. For an evacuation time of more than 1,5 minute pedestrians in the zones 2-6 run a big risk when there occurs an incident as terrorist attack, a fight or an oppression.

In addition, the crowd density around a passage can be measured with the distance between the passage and the last pedestrians broad wise.

Chapter 5

Possible security tools

Nowadays there are a lot of security tools that can be used to detect potentially dangerous situations on event areas. It is important to make a split between public security tools and security tools deployed by the event organization. An event organization can use cameras from cafes and restaurants for example. On the other hand, event organizations can use their own cameras to monitor places where there are no public security tools.

We have created an overview of different types of security tools that can be used during an event. It is important to mention that we worked together with telecom provider KPN during our research. Very likely an event organization can co-operate with several other telecom providers, to get information about the location of event visitors.

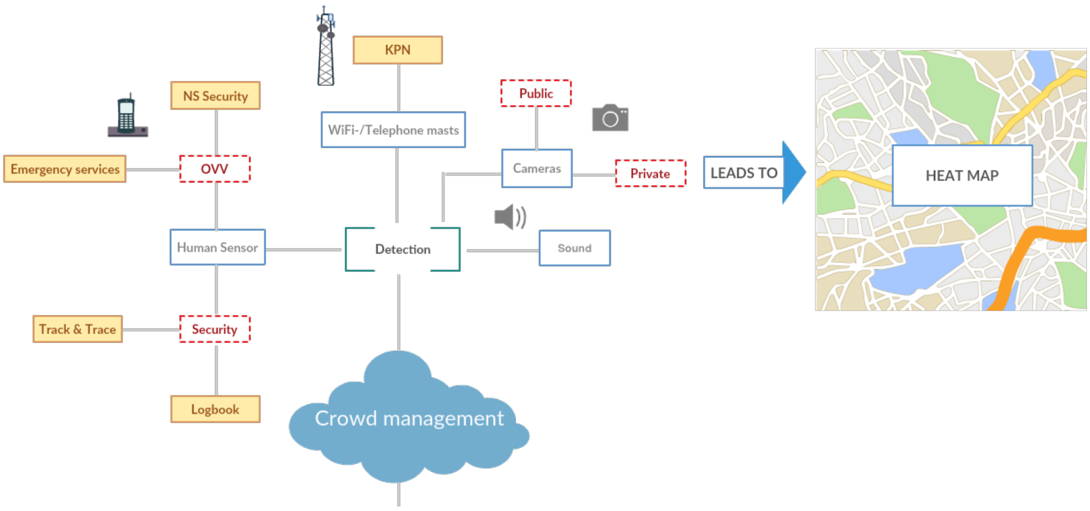


Figure 5.1: an overview of security tools

During our research it becomes clear that four different types of security tools can be used to secure an open event area: the human sensor, WiFi-/telephone masts, cameras and sound sensors. We can add another type of a security tool, namely information from the usage of an event app on mobile phones. Because of the fact not every open event uses an event app, we have not mentioned this type of a security tool. Besides the location of mobile phone users was integrated in the desired heat map by using the signals of WiFi- and telephone masts.

To detect potentially dangerous situations during the event, we want to create a heat map with different types of data feeds. The four types of security tools are the input for this heat map. Nowadays most of the heat maps are generated with just one or two types of data feeds, whereby the heat map is not as accurate as possible. Besides it costs an event organization a lot of extra work to generate the input data, because they do not use public security tools in an efficient way.

5.1 Human Sensor

The Human Sensor is a term for a diversity of security services. Within this group are the emergency services (police, fire brigade and healthcare providers), public transport security services (HTM Security, NS Security, Arriva Security, etc.) and the security staff of an event. The security staff of an open event can be provided with a track and trace-system; with which it is possible to monitor their location. From the security control room, it is possible to coordinate the way they move through the event area by using portable phones during an event. Besides their portable phone and track and trace-system, security staff will be provided with a system with which it is possible to make notes during the event. Also now it is possible to monitor these notes from within the control room of the event and take action where necessary.

When these notes can be integrated in the heat map it would be much easier for an event organization to monitor potentially dangerous situations. Especially when these notes were combined with the three other types of security tools. For example, a riot will cause an increase in the number of decibels and will attract people to this place. The heat map indicates both; an increase in the number of decibels, an increase in the numbers of event visitors on a certain place and a note of the security personnel.

To optimize the deployment of security personnel during an open event, it would be a good idea to provide security personnel of public transport with such a system. By involving these security personnel in the securing of an open event, the event organization needs to employ less staff, or can spread the staff better. This will lead to a decrease of costs or an increase in the event security. Instead of using the same system, public transport security services maybe have their own systems. In this case the information from the central controller of these security services could be integrated in the heat map.

5.2 WiFi-/Telephone masts

Another type of a security tool that can be used as an input for the heat map, are WiFi- and telephone masts. There are different telecom providers with their own network: KPN, Vodafone and T-Mobile. Tele2 has partly their own network, because for a 3G-connection, Tele2 users use the network of T-Mobile. These telecom providers have a lot of valuable information about the location of event visitors. This information should be integrated in the heat map to get an overview of the degree of hustle and bustle on the event area.

Before an event organization can use these information, it is important to mention that because of privacy reasons the data should be anonymized. During several meetings with telecom provider KPN it becomes clear that for KPN it is possible to deliver anonymized data to event organizations. Besides the data from telecom providers as KPN, Vodafone and T-Mobile, data from WiFi-routers can be used. In our case in The Hague we can use WiFi-routers at the Scheveningen boulevard.

It is also possible for event organizations to use their own WiFi-routers on an event area, to monitor the degree of hustle and bustle by themselves. With WiFi-routers we can measure the number of connections that has been made, what gives us an indication of the number of pedestrians on a certain place.

5.3 Cameras

The third security tool that can be used for the detection of potentially dangerous situations are cameras. Cameras come in two types, namely: security cameras and cameras which can count the number of people on a certain place. In our research the last type of cameras is the most useful, because an increase of the number of pedestrians could lead to a dangerous situation. With a typical security camera, it is possible to watch suspect persons, the situation on a certain place, potential riots, etc.

Also now it is important to anonymize the data of these cameras, to prevent privacy issues. In this case this means that movie images may not be saved and images may not be traced back to specific persons. This may not be a problem for our heat map, because we are only interested in the number of pedestrians on certain places. With this kind of cameras, it is possible to get more information about the number of pedestrians, the busiest walking routes over an event area and the places where pedestrians stay for a longer period. For example, a stage or food stalls.

The use of cameras that count pedestrians is relatively new, so there are not much of these cameras in city centres yet [Par17]. For the use of these cameras event organizations need to install them by themselves, as described by the WiFi-routers.

5.4 Sound sensors

Sound sensors are the last type of security tools that could be integrated in our heat map. Like the cameras for counting pedestrians the use of sound sensors is relatively new in city centres. With these sound sensors it is possible to detect an increase in the number of decibels. A lasting increase of the number of decibels could be an indication of a potentially dangerous situation. For example, a single scream shall not be a signal of a dangerous situation in most cases. A series of screams however, could be an important signal.

The combination of sound sensors with the measurement of the movement of pedestrians could be very interesting. Because an increase in the sound level could be an indication of danger for pedestrians, whereby a large group of pedestrians will move to another (safe) area. For example, think of terrorists that scream or shoot, whereby the sound of their guns in combination with screaming pedestrians leads to a heavy increase of the sound level. An increase of the sound level on a heat map in combination with the movement of pedestrians, could be a serious indicator for dangerous situations.

As described before, sound sensors have to be installed by the event organizations. In most cities these sound sensors are not used yet. It could be interesting for event organizations and a local governance to install these sound sensors together. After all, sound sensors are not only interesting for events on open areas, they are interesting for every event in a city. Other examples of events are a day at the beach for people from the city or a day of shopping.

Chapter 6

Simulations of pedestrian flows

It is difficult to determine the places where security tools must be used on an open event area. In most cases an open event area is relatively big, so that there are a lot of small passages where security tools are not used yet. For example, think on events in a city centre. Besides the place where security tools must be used, it is important to get an overview of the existing security tools on an open event area. With such an overview it is possible to use public security tools in an efficient way and decrease costs for the security of an open event.

To find the best places for the use of security tools, it is recommended to make different simulations of the event area. There are different existing type of simulation software, that can be used for crowd management. In our research we have chosen for the use of AnyLogic Simulation Software, because this program complies with the pedestrian model described earlier.

6.1 Simulations with AnyLogic

Before making our simulations with the AnyLogic Simulation Software, we uploaded a map of our case (Scheveningen, The Hague). By drawing the different walls on this map, it is possible to simulate the different pedestrian flows that will exist. First we made a simulation, specific for the passage between Kurhaus and Palace Promenade. For this simulation we assume that pedestrians walk from the Gevers Deynootweg-side to the beach and the other way around. The width of the passage between Kurhaus and Palace Promenade is 9,2 meters and the width of the passage inside the Palace Promenade is 4,0 meters.

Because the Volvo Ocean Race will be on the beach in 2018, we chose for a rate of 100 pedestrians per minute from the Gevers Deynootweg to the beach, a rate of 12 pedestrians per minute from the Palace Promenade to the beach and 10 pedestrians per minute the other way around.

This results in the situation below, after 30 minutes:

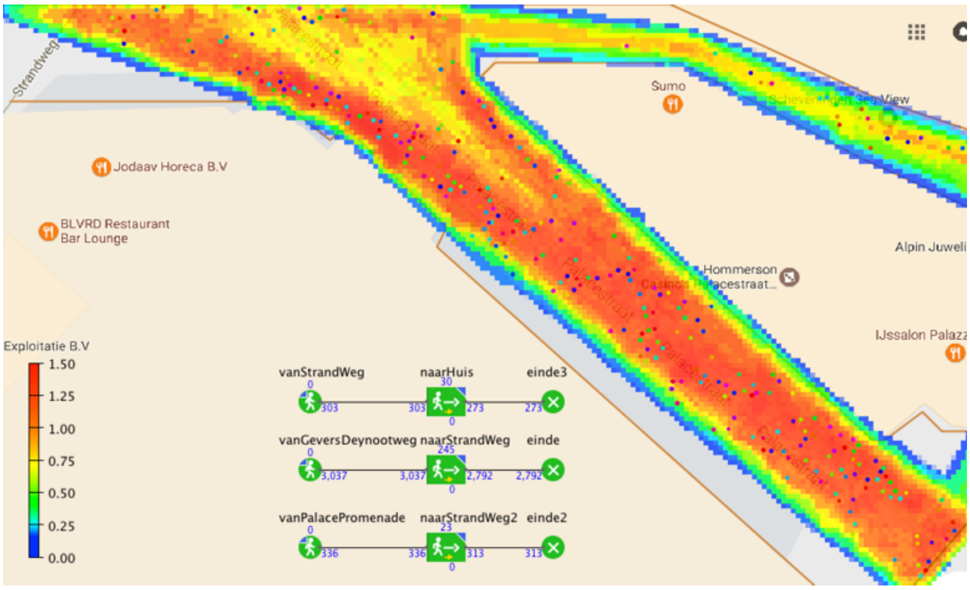


Figure 6.1: first simulations on our case situation

As you can see in the image, the red spots are the most crowed places in this passage. The different dots are pedestrians walking to or from the beach. In this situation there are no big collisions or congestions between pedestrians, because the pedestrian flows are mostly one way. When we change the way of the pedestrian flows in a two-way pedestrian flow, the situation will change.

For this second simulation, we chose for a rate of 100 pedestrians per minute from the Gevers Deynootweg to the beach, a rate of 12 pedestrians per minute from the Palace Promenade to the beach and 45 pedestrians per minute the other way around.

This results in the situation below, after 30 minutes:

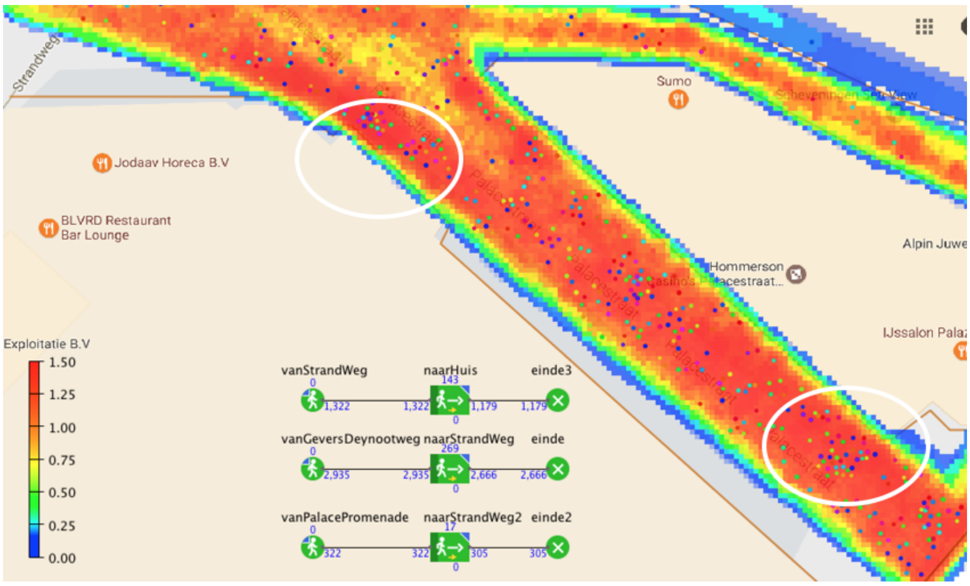


Figure 6.2: second simulation on our case situation

Now we can detect different places where collisions and congestions will occur, indicated by the white circles. With this second simulation, for event organizations it will be possible to place security tools on the best places to detect a potentially dangerous situation. For example, we can use sound sensors and WiFi-routers on these places to measure the sound level and the number of pedestrians in this area. When the sound level constantly increases, without a change in the direction of pedestrian flows, it could be too busy in this passage. Now the event organization could steer the security personnel of the event to this passage in an early stage, to prevent a dangerous situation.

Making simulations is an easy way to predict the bottlenecks on an event area. As an event organizer you want to prevent your event for such bottlenecks, because of the dangerous situations that could occur. With this simulation software of AnyLogic it is possible to simulate parts of the event area. By making different destination and starting points on the map, it is possible to simulate places with stalls or podiums. Pedestrians will walk to these stalls, stay here and leave to their next destination. This makes these software very complete for simulating pedestrian flows on event areas.

As done in the example above, for event organizers it is interesting to make a lot of simulations with a different number of pedestrians from en to the starting and destination points on the map. The whole of simulations gives an event organizer a realistic image of the potential bottlenecks and the number of pedestrians that will cause these bottlenecks.

Chapter 7

Conclusions

During this research we have investigated different types of security tools to monitor pedestrian flows in normal and panic situations. Goal of this research was to find a way different security tools can be combined to secure an open event, because the growing danger of terrorism and the rising number of visitors during these events. After this research we can conclude that it is possible to find ways of securing an open event by using different types of security tools. To optimize the use of security tools, an event organizer has to make different simulations of his event area. These simulations give an event organizer an indication of the potential dangerous places and bottlenecks. It is recommended to make simulations for different situations, with a different number of visitors.

On the basis of these simulations security tools can be used for monitoring the potential dangerous places on the event area. Security tools that can be combined to get a complete image of the situation on these places are sounds sensors, the human sensor, cameras and WiFi-routers. The use of WiFi-routers is more recommended than the use of telephone masts, because WiFi-routers could be used by the event organisers themselves. Information from telephone masts must be obtained from a telecom provider.

A combination of different security tools in one heat map creates the possibility to prevent dangerous situations. For example, when the number of decibels suddenly increases there may occur a panic situation. Such a situation can be prevented by coordinating the security personnel of the event organisation and public transport services to this place.

Besides these conclusions on the way security tools could be used to prevent dangerous situations, we have learned a lot of the way pedestrians moves. Each pedestrian has his own preferred walking speed during his walk to a predetermined destination. A pedestrian want to walk in a direct line with the shortest distance to his destination, avoiding side roads. As a pedestrian could not reach his preferred walking speed, his frustrations increases. In a normal situation a pedestrian is inclined to take a side road to his destination. During panic situations these frustrations will result in physical contact with other pedestrians in his surroundings. This results in dangerous situations, such as congestions and fallouts.

So the combined conclusion of this research is that panic situations must be prevented, by creating possibilities for pedestrians to reach their preferred walking speed. To do so a combination of security tools must be used on the potential dangerous places of an event area, that have been found by making different simulations with computer software. When a place gets to crowded, security personnel must be coordinated to these places to get the crowd scattered over different side roads.

7.1 Discussion

Although our research has yielded several results, there are some points that could be improved. The most important improvement could be the implementation of different security tools in one heat map. During this research we worked together in a team of six persons, where every member of the team has his own research part. The combination between the software architecture, the heat map and the useful security tools is missing. For the use of the recommendations in this research there must be made a link between the software architecture, the data feeds of security tools and the heat map.

Besides the link between the different parts of our research team, there could be use another model for simulating an event area. The software we used in our research, AnyLogic, is interesting for the smaller parts of an event area. When we want to simulate a large town, for example The Hague as a whole, AnyLogic is a time consuming model for making simulations. Every wall has to be created, before the simulations can be made. There are complete maps of the bigger cities in The Netherlands in a 3D-model. It would be great if these models could be integrated in simulation software as AnyLogic. As we have seen in our research this is not possible with AnyLogic.

A third point of discussion of this research is the possibility to use data from other organisations during an event. For example, the data of telecom providers and the information of security personnel of the public transport services in cities. The data of telecom providers contains privacy sensitive information, that must be anonymized before an event organiser can use this data. It depends on the size of an event how easy it would be to get this data. For bigger events it should be possible to co-operate with the telecom providers, but for smaller events this is in all probability more difficult.

7.2 Future research

For the future the most important thing to investigate is the first point of our discussion: the implementation of different types of security tools in one heat map. By implementing these different security tools in one heat map, researchers can create a unique product that helps preventing dangerous situations on an event area. To come to one heat map, it is important to investigate the nature of the different data feeds and the way they are provided by different parties.

When we know how the data feeds are provided, we can make a platform where the different data feeds can be plugged in. These platform is a continuation of the software architecture for the system behind an open event as a whole. The app that can be used by event visitors and the dashboard for the security personnel of an event are also part of this architecture. From this moment the heat map can be integrated in the dashboard of the security personnel of an event organiser to secure an open event.

Another point to mention for further research is the way simulations can be done on a bigger plan. For example, The Hague as a whole. An open event has usually a big event terrain crossing the different neighbourhoods of a city. For these events it would be great if the simulations could be done for the city as a whole, instead of for different neighbourhoods.

Bibliography

[Boro5] & Timmermans H. J. P. Borgers, A. Modelling pedestrian behaviour in downtown shopping areas. *10th International Conference on Computers in Urban Planning and Urban Management, London, United Kingdom*, 2005.

[BT86a] A. Borgers and H. Timmermans. City centre entry points, store location patterns and pedestrian route choice behaviour: A microlevel simulation model. *Socio-Economic Planning Science*, (20):2531, 1986.

[BT86b] A. Borgers and H. Timmermans. A model of pedestrian route choice and demand for retail facilities within inner-city shopping areas. *Geographical Analysis*, (18):115128, 1986.

[DHB01] I. Farkas D. Helbing, P. Moln ar and K. Bolay. Self-organizing pedestrian movement. *Environment and Planning*, (28), 2001.

[ES93] D. Elliott and D. Smith. Football stadia disasters in the united kingdom: Learning from tragedy? *Industrial & Environmental Crisis Quarterly*, (7 (3)):205229, 1993.

[Gan98] J. Ganem. A behavioral demonstration of fermats principle. *The Physics Teacher*, (36):7678, 1998.

[Gar73] D. Garbrecht. Describing pedestrian and car trips by transition matrices. *Traffic Quarterly*, (27):89109, 1973.

[GS90] S. Gopal and T. R. Smith. Navigator: An ai-based model of human way-finding in an urban environment. *Spatial Choices and Processes*, page 169200, 1990.

[Hel98] D. Helbing. Pedestrian dynamics and trail formation. *Traffic and Granular Flow 97*, page 2136, 1998.

[Hel02] Farkas I. J. Molnar P. & Vicsek T. Helbing, D. Simulation of pedestrian crowds in normal and evacuation situations. *Pedestrian and evacuation dynamics*, (21(2)):21–58, 2002.

[Hen71] L. F. Henderson. The statistics of crowd fluids. *Nature*, (229):381383, 1971.

[Hen74] L. F. Henderson. On the fluid mechanics of human crowd motion. *Transportation Research*, (8):509515, 1974.

[Kea82] J. P. Keating. The myth of panic. *Fire Journal*, pages 5761+147, 1982.

[Lew51] K. Lewin. Field theory in social science. *Harper & Brothers*, 1951.

[L94] G. G. Lvas. Modelling and simulation of pedestrian traffic flow. *Transportation Research*, pages B 28, 429443, 1994.

[Min51] A. Mintz. Non-adaptive group behavior. *The Journal of Abnormal and Normal Social Psychology*, (46):150159, 1951.

[Nag99] T. Nagatani. Tdgl and mkdv equations for jamming transition in the lattice models of traffic. *Physica A: Statistical Mechanics and Its Applications*, (264):581–592, 1999.

[NAM76] M. OLeary N. Ashford and P. D. McGinity. Stochastic modelling of passenger and baggage flows through an airport terminal. *Traffic Engineering & Control*, (17):207210, 1976.

[Par17] Het Parool. Wifi-sensoren en telcamera's gaan drukte wallen meten, 2017.

[Vis14] Lee C. E. Lees M. H. Cheong S. A. & Sloot P. Viswanathan, V. Quantitative comparison between crowd models for evacuation planning and evaluation. *arXiv preprint*, 2014.