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Understanding crowd behaviour

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Chapter 1

Introduction

[August 22 2009, Hoek van Holland] It is 18:00hrs, with the sound of music the beach party starts. Like previous years, this Saturday is the evening that the beach festival takes place. However, this evening will take a different turn.

Visitors arrive at the site by public or private transport. The site is becoming increasingly more crowded and at 21.00 people are still arriving in large numbers¹. Usually, different artists perform at a variety of stages; people cluster together in front of the stage while dancing, others queue up for the use of toilets and bars, or stand together while drinking a beer. This is a typical snapshot of people's behaviours at a festival.

Among the partying visitors another group can be identified: hard-core-football supporters. The 'supporter' group forms and grows. While the majority of festivalgoers enjoy their evening, some of them experience a change in atmosphere [between 21.00 and 22.30 hours]. Suddenly, agitation develops as some from the supporter group recognise some plain-clothes law enforcement officers (henceforth LEOs). Initially 2, and later 4 LEOs are surrounded, and subjected to verbal and physical abuse. The LEOs retreat, but are chased by an aggressive group of unknown composition. During this time the LEOs receive back-up, and now number 45 LEOs; the aggravating group has also increased in size, totalling between 200-300 people. The situation continues to be hostile; the group starts a countdown - some warning shots are fired by the LEOs, yet the hostilities continue.

The LEOs retreat even further away from the site of the initial tensions by using an emergency exit into the dunes. Although the aggressors are initially halted by the fences, they tear these down and continue their pursuit of the LEOs. All kinds of objects are thrown at the LEOs: bottles filled with sand, planters and bikes, accompanied with continued verbal abuse. The situation escalates, and LEOs fire more warning shots, but again this fails to calm the situation. Some of the LEOs then fire targeted shots aiming at individual's legs. This leaves 6 people injured and one person mortally wounded. Mounted police arrive at the scene. After they have charged three times the aggressive group disperses and the LEOs are 'released' from their precarious position. The festival is stopped. The public are told that a minority spoiled the evening for everybody. Many

¹The number of people present this evening cannot be determined. The visitor amount was estimated between 25.000-50.000 people.

Box 1. Shopping

A typical shopping main street is crowded with people. Most people walk on their right side, resulting in two streams: upwards and downwards. Most of the people walk in small groups with their family, friend(s) or partner, but some walk alone. Shoppers wander through the streets and enter the shops of their preference. From a distance the street looks crowded, and the composition changes all the time as people are arrive, shop and leave, a continuous in and outflow until closing time.

Box 2. Supporting a sports team

Crowd behaviour at a football match starts well before the match. Fanatic supporters gather around the stadium, eat snacks and hang out together. Sudden yells and gestures mark the arrival of supporters of the opposing team. The stadium is open now, people stand in line to enter the building and to find their seats. As soon as the game starts the supporters gaze in the direction of the field in front of them. The public reacts to whatever happens during the match. One can hear a lot of oohh's, ahh's, clapping and singing. But there is also yelling, chanting and gesturing as a provocation or response to the rival supporters.

people, who did not know what had happened, felt that the party ended too early².

This thesis sets out to gain more understanding of crowd phenomena, just like the one that was just described. The situation described above contains several examples of crowd behaviour. Crowd behaviour exists in a broad range of situations. Shopping on a main street, supporting a sports team at a match and people demonstrating are all typical examples. Boxes 1 - 3 illustrate different crowd events. In talking about crowds a variety of words can be used to describe the atmosphere, such as calm, excited, hostile, grim, threatening or dangerous. During an event, behaviour varies over time, but behaviour can also differ quite a lot between events. For example, an emergency context (in which people flee) differs considerably from a riot situation (in which some people behave violently). Regardless of the diversity of behaviour, all these events concern behaviour of a large number of people that are physically present at a certain location.

The beach festival example raises a variety of questions about the nature of crowd behaviour. Crowds events occur every day, so what causes this one to turn into a riot? Furthermore, the violent behaviour was conducted by a small part of the crowd. Why did the others not behave this way? How can these violent situations be prevented? Or, when things have already escalated, how can one effectively intervene? What are the processes leading to escalation?

Typically, the attention of the media focuses on crowds that show the most striking, and unique behaviours or on crowds that show behaviour which is generally considered to be undesirable (e.g. the hostilities towards the LEOs at the beach festival). However, there is much more to crowds than striking or undesired behaviour. At the beach party, apart from the 200-300 persons involved in hostilities, the other 25.0000

²Source: Rapport Hoek van Holland (Muller, Rosenthal, Zannoni, Ferwerda, & Schaap, 2009; Wanders, 2009).



Box 3. Emergency

Crowd behaviour in an emergency situation involves a large group during dangerous circumstances. Events at the Love Parade on 29th of July 2010 in Duisburg may serve as an example. One and the same way served as both entrance and exit. The end of one activity (the parade) and the start of another activity (live-gigs) caused large streams of people moving away from and towards the festival area. At that moment it is estimated that 130.000 people were present. The density of people at the location where the ingoing and outgoing streams met became extremely high. The movement of individuals was severely restricted, and in the end most movement was the result of physical pressures rather than individual decision-making. People situated at the sides attempted to flee by climbing light-poles and a small staircase that was initially blocked by police. However, most people could not move and endured high pressures that caused an anxious and deadly situation. In the end 19 persons died as a result of suffocation and 342 got wounded. According to panic-researcher M. Schreckenberg the catastrophe was the inevitable outcome of physical factors (WDR, 2010b). [source: (WDR, 2010a; Dettweiler, 2010; Team, 2010)]

people present at the beach festival engaged in 'normal' festival behaviour (for further reading consult the evaluation report (Muller et al., 2009) and newspaper articles, such as (Wanders, 2009)).

In the beach festival example, people in a crowd exhibit behaviour that changes all the time. For instance, let us zoom in on a person in front of the stage: let's call him³ J*. First J* dances in front of the stage; then he walks to the bar, later he drinks beer and chats with his friends. Crowd behaviour is not uniform or static; it differs per person and changes over time. Zooming back to a group perspective, patterns emerge within the crowd, i.e. regularities in the form of movements and other types of behaviour can be observed. J* takes part in several typical crowd patterns, see figure 1.1 (a, b, c and d). While dancing, J* and the other people in front of the stage form an *arc-shaped* pattern (figure 1.1b). At a later point in time a pattern within the *lanes* of movement can be seen (figure 1.1c), when J* and others are heading to the bar. Even while talking to his friends J* forms a part of a pattern: the *companion clusters* of people that are standing close together or moving at the site (figure 1.1d).

In addition to the crowd patterns that J* forms a part of, the group which acts violently towards the LEOs, and the LEOs themselves, form patterns from their distinct behaviours. Acting in a similar way, such as drinking beer, is considered a behaviour pattern. Hence, a behaviour pattern is not restricted to actions involving movement. The hostile group displays aggressive behavioural patterns by shouting and throwing objects at the LEO's. These behavioural patterns arise in addition to those which are visible due to movement of the supporter group by surrounding the LEOs (i.e. an *arc* or *ring-shaped* pattern), or by chasing the LEOs that are retreating (i.e. *lanes*). Additionally, the LEOs themselves form a behaviour pattern as a result of retreating

³This thesis occasionally uses "he", "his", or "him". The male form was chosen as an act of gallantry towards the opposite sex, but refers to both sexes.

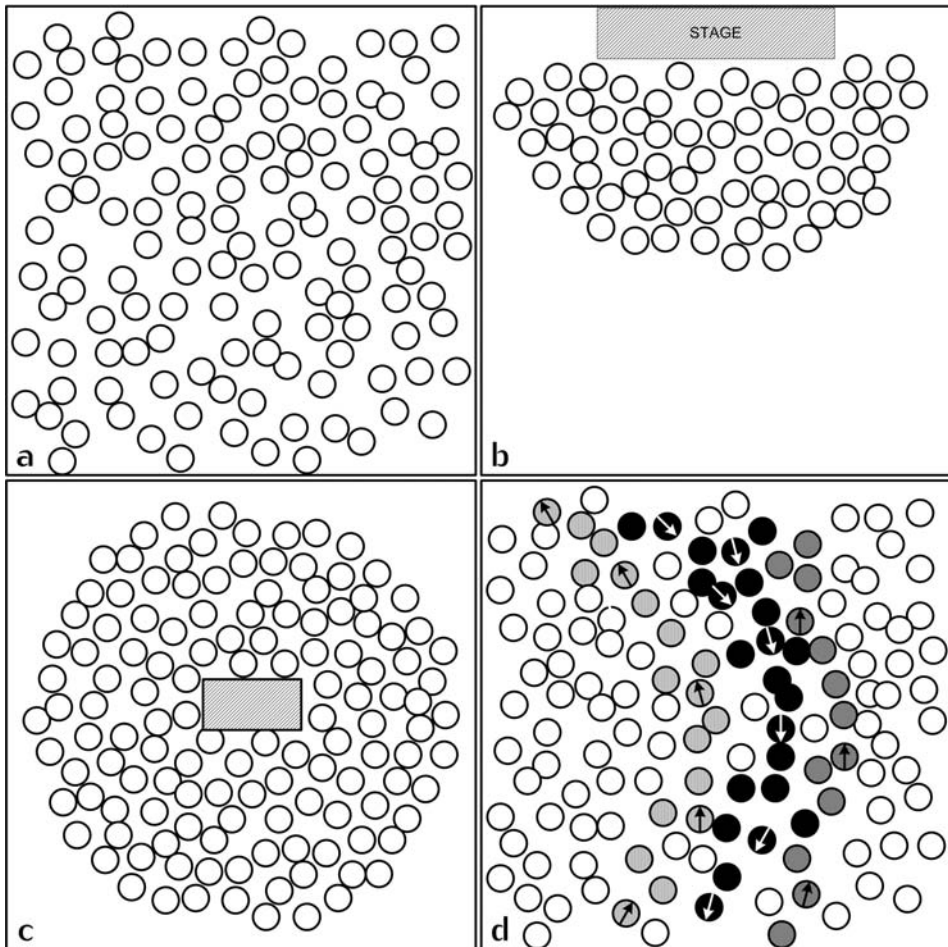


Figure 1.1: An overview of some typical behaviour patterns shown in crowds: a) Companion clusters, b) Arcs; c) Rings and d) Lanes.

and clustering together.

These behaviour patterns are an aggregate of the behaviour individuals display. The patterns show behavioural diversity, they are dynamic and vary in size, duration and composition. These emergent patterns of behaviour usually draw attention, especially if the behaviour is considered to be deviant or if it occurs unexpectedly. The patterns link people in a crowd based on the behaviour they show. They represent a dynamic notion of the changing subgroups within a crowd. The question may be raised how these patterns come about and what information can be derived from the patterns in order to facilitate the effective management of crowds?



1.1 Why is understanding crowd behaviour important?

Societies have various ways of managing crowds and behaviour. For instance, the LEOs deal with crowds by maintaining public order, event organisers provide entertainment and transporters provide mobility at airports and train stations. These organisations should take into account the way that crowds behave. But do they know how people will behave? What affects or steers crowd behaviour? What determines whether a potential riot is emerging? Or in what way people will flee in case of an emergency? And, when using a preventive measure, to what degree can the impact of such be known?

To improve safety and public order issues in crowds, practical experience is the main guide and source of knowledge for practitioners (Adang, 2006). The advantage of experience-based knowledge is that it is usable, goal-oriented, fast and implementable. A good intuitive feeling about a crowd situation and how to deal with it is important, and practically valuable, but within unclear boundaries. It is difficult to make implicit knowledge explicit and transferable, which implies it is hard to learn or to teach. In addition, it is difficult to test whether implicit experience-based knowledge is valid. And importantly, experience-based knowledge is situation specific, the usefulness in an even slightly different crowd situation is not clear. Experience-driven knowledge does not involve general understanding or explanation of the phenomenon of crowd behaviour itself.

Science aims at understanding and explaining a phenomenon (i.e. by gaining systematic knowledge). Existing crowd research has its limitations: there is a strong focus on disorder where the role of the social context is stressed. Generally, the methods used to study crowds are observation, post-hoc reviews of incidents and media-analysis.

The theories which underpin crowd research have developed significantly since the 1800s. For now, it is important to note that the historical path which crowd researchers have followed may have constructed misconceptions (i.e. myths, about crowds and their supposedly extraordinary behaviour). For example, for a long time the most dominant and popular view on crowds was the supposed existence of a '*group mind*'. The idea of a group mind refers to individuals losing cognitive control when entering a crowd and behaving at the will of this group mind (LeBon, 1895).

In the last 20 years significant advances have been made in the field of crowd research. Observational studies have challenged the dominating myths and major insights have been gained that provide the foundations of modern crowd research. Chapter 2 describes this in detail. The main insights indicate that contrary to previous perspectives crowd behaviour is affected and generated by individuals; is situation dependent; is a social and dynamic phenomenon. Despite the advances, the current state of crowd research does not provide systematic knowledge or testable theories that allow a full explanation or understanding of crowd behaviour. This knowledge-gap results from both theoretical and methodological causes.

1.1.1 Theoretical issues in understanding crowd behaviour

Current theory of crowd research is fixed on disorder with an explanation that stresses the social context. To cover crowd behaviour in general, the current focus and the level of detail that is used to explain crowd behaviour from a mono-disciplinary perspective is not sufficient.

Disorder is a specific situation that typically involves a part of the crowd behaving confrontationally or violent. In addition to the fact that most crowds are not violent, it is not this specific behaviour (violence) that will help to achieve a general understanding of behaviour in crowds. For that, it is important to distinguish between specific behavioural outcomes and general mechanisms that give rise to crowd behaviour.

The role of the social context on the other hand has been shown to be crucial. However, the social context is not the only influence on behaviour, as crowd behaviour is situation dependent. For instance, the physical environment (e.g. a fence, or wall) and the internal (or cognitive) state of a person (e.g. being thirsty or afraid) also influence behaviour. The role of influence factors are not constant, they are variable. Let's go back to J* dancing in front of the stage. J* is surrounded by other people that are certainly part of his social environment. His local social surrounding affects J* as he enjoys being part of a huge group at a beach festival. J* likes it even more because his friends are dancing next to him. The people around J* are also physical objects that affect J* just by being obstacles or pushing forces that cannot be neglected in explaining J*'s behaviour. In addition to J*'s external situation, he also has an internal world where he notices he is thirsty which, at some point in time, makes him decide to move towards the bar. The fact that he enjoys this particular scene is a personal preference. This example illustrates the continuous interplay between external and internal factors that give rise to the behaviour of an individual in a crowd (i.e. situatedness). One second the role of the social environment might be important, and in the next, physiology and/or mental states might be more important.

In understanding crowd behaviour in general, the level of detail used in a theory defines the explanatory power. Although current theories acknowledge the individual as the atom of behaviour generation, the level of detail to explain the generation of individual behaviour does not describe *how* and *why* individual behaviour is chosen. Take for example, the situation that J* is going to the bar because he is thirsty. When the internal state of J* is not 'externally accessible' for this kind of information, it may well be that he is moving to the bar because he wanted to be social and join his friends (and not because he needs a drink). The behaviour J* shows is not explaining why he acts the way he does⁴. This information is crucial to gain understanding of individual behaviour and thus of crowd behaviour patterns. Regarding individuals as black boxes limits the explanatory power to understand why certain behaviour is chosen at a particular time and a given internal setting, and consequently this restricts the explanation of behaviour patterns.

Crowd research is, like most of the social sciences, usually approached from a mono-disciplinary perspective. Hence, the focus and way of explaining crowd behaviour is related to the scientific field the researcher is from. Despite the insight that

⁴Not only does this give insight in the reason for acting this way, it also says how an individual is influenced. For instance by observing someone else a 'false' attribution can be made and consequently the behaviour is influenced.



crowd behaviour is situation dependent, this is not incorporated when research disciplinary boundaries are reached. In this thesis, crowd behaviour research is regarded to typically need a broader scope. Not only because of the diversity of the behaviour it should encompass, but also because the relevant aspects that affect human behaviour originate from both the external (physical and social factors) and internal (physiological and cognitive) world. Studying crowd behaviour in general is too broad to neglect the other communities. The selection of relevant elements should be based on the question at hand, instead of on the discipline or the method used.

In summary, current theories are too narrow and specific scope, while providing little detail in describing human behaviour which can be used to develop testable general theories that allow to understand general behaviour dynamics. Modern crowd research forms the fundamental base for the work done in this thesis.

1.1.2 Methodological issues in understanding crowd behaviour

Theoretical progress in understanding crowd behaviour is mainly hindered due to the methodology that is used. In crowd research a variation of instruments is used, for example media analyses, case-studies, *backward study of incidents*⁵, interviews and observation studies. Observation studies are currently the main research tool used in crowd research. However, in moving further from description to explanation, the difficulty of performing controlled experiments form the biggest constraint on progress in crowd research.

This limitation arises from the nature of crowd phenomena. Crowds are typically complex and dynamic phenomena, which means that a multitude of (interconnected) factors can play a role in the behaviour that emerges over time. This multitude of factors is hard to control for, when performing experiments. It is this methodological restriction that stagnates the formation of testable theories. Without experiments, generating an empirically based explanation of how and why crowd behaviour patterns emerge is difficult.

In addition to the difficulty of controlled experiments, there are also ethical considerations - it can be dangerous for the subjects. Performing experiments might be possible for smaller groups concerning behaviour that does not cause high pressure levels or violence. But for most crowd situations pressure levels are part of the phenomenon. In addition to that, the focus on disorder is driven by a need to prevent and manage disorder. But experimentation in a disorder setting is not possible as the well-being of the subjects cannot be guaranteed in such an experiment⁶. Consequently, it is almost impossible to experimentally test theories and thus take the necessary steps to understand and explain crowd behaviour.

An increased understanding, based on a body of systematic knowledge would enhance the ability of authorities to prevent undesired situations and to intervene in

⁵The described beach festival riot is an example of this backward study. After an incident took place a research is set up to investigate the cause and responsibility of the escalation (Muller et al., 2009).

⁶In addition to a few exceptional cases done by the research institute TNO during military training (van Vliet & de Bruin, 2007; Bruinsma-Jakobsen, 2007) and training of the riot police (Wetzer, Kamphuis, van Hemert, in 't Veld, & Kerstholt, 2010) and the police academy in The Netherlands (Bruinsma-Jakobsen, 2007).

them. Similarly, in crowd research, this development would be a huge step forward by explaining why and how crowd behaviour emerges, by moving beyond observation based studies. The current state of the crowd research indicates two issues: the need for a generic testable theory and the need for a methodology. First, there is a need for a testable theory that explains why and how behaviour patterns emerge. Secondly, a method is required that allows theories of crowd behaviour to be tested. In this thesis the focus lies on both issues by developing a crowd model using an integrative, multi-level and situated approach that is explored by performing computer simulation experiments.

1.2 Understanding crowd behaviour


To understand crowd behaviour it is important to explain why and how crowd behaviour patterns emerge. To be more specific, this thesis tries to answer the general research question:

Which mechanisms underlie crowd behaviour patterns?

By resolving these theoretical and methodological issues this thesis takes significant steps to answer the research question. The mechanisms represent general rules that describe the way crowd behaviour patterns form and change. Consequently, both theory and methodology need to support the ability to explain why and how crowd behaviour emerges. Modelling crowd behaviour from a general perspective combined with an approach that integrates relevant theories and influence factors, should allow for a general understanding of how a situated crowd is realised. With use of a simulation, the model can be explored and tested by setting up simulation experiments. The combination of an integrative approach in modelling and the use of simulation experiments is expected to provide the necessary ingredients for understanding crowd behaviour.

The model that was developed is CROSS, a model that represents crowd behaviour that simulates situated individuals. In developing the model the following choices were made: the model focuses on explaining crowd behaviour in general rather than specific behaviours, such as violence or fleeing. The base of the CROSS model is formed by the main insights gained by current crowd research: the individual-level of agency, the role of (social) context and the dynamic nature of crowd behaviour. Crowd behaviour patterns are a property of the group level description of a crowd. However, to explain this group level property it is necessary to include the level at which behaviour is generated, i.e. the individual level. This makes understanding crowds a typical project with a multi-level approach.

In the model, the role of the context comes about by incorporating the relevant factors of the physical and social environment, as well as the individual internal properties, which involve a merger of multiple relevant theories. These dynamics represent the interactive properties of crowd behaviour over time. A current state in crowd behaviour is regarded as the result of previous interactions of individuals with their environment. Overall, developing a model of crowd behaviour involves an integrative and multi-level approach in which the role of the individual, situation-dependency and dynamics play a central role.



The model consists of a framework that includes both the environment and individuals. The environment can be filled with physical and social elements, in which this study includes relevant influence factors such as the density level (physical) or the amount of leaders (social) in a crowd. The environment reflects descriptions of a crowd on group level. The individuals on the other hand generate behaviour while being influenced by their external and internal world. This implies that whatever influence factor is incorporated into the model (either at group or individual level), it must explain the way by which this factor affects an individual. In this thesis individuals are considered human information processing units (i.e. cognitive systems). All influences go via the individual, which implies that in explaining group level patterns, an explanation should be sought by relating the group level to the (intra-) individual level.

An individual in a crowd is regarded as situated, which means that an individual is both *embodied* and *embedded*. Embodiment refers to the physical characteristics of having a body influencing human information processing. For instance, only what is perceived influences behaviour, thus something that happens behind a person that is not perceived will not affect their behaviour. To be embedded says something about the current external and internal setting that needs to be incorporated to reproduce situation-dependent behaviour. To regard an individual as a cognitive system includes being embodied, but also to have internal representations that allow an individual to interact with the world around him. The level at which behaviour is described allows for tracing *what* behaviour is chosen and *why*, given the internal state of that person at that time.

In addition to the contribution to theory, this thesis wishes to make a methodological contribution as well. Computer simulation supports understanding of crowd behaviour as it allows for limitless experimentation, only the theory limits the boundaries of exploration. Furthermore, it allows for exploring the dynamic aspect of crowd behaviour, which sets out an important point of view from which crowd behaviour is explained. Before simulation experiments can be run, a computational model is needed. By formalising CROSS into programming code (i.e. a computational model), crowd behaviour can be generated and thus explored. Every relation that is described in the conceptual model needs a computational structure (e.g. an algorithm), every concept a representation of a computational element (e.g. a variable or class). This step of computational modelling makes the theory more concrete and easier to communicate.

The computational form of CROSS is used to perform simulation experiments. In performing experiments the options are endless, however to be able to grasp and validate what happens it is important to start simple. This thesis describes two experiments: one that explores the role of density (a physical factor) and one that explores the role of leadership (a social factor). Both factors are of practical relevance as both play an important role in crowd behaviour. In addition, both density and leadership are potentially of influence in real life, which make them even more relevant for exploration.

1.3 Thesis map

This thesis describes the road to understanding crowd behaviour, see figure 1.2. Chapter 2 describes the crowd research area. Current crowd research forms a solid base to proceed from, but also formulates a need for a generic testable theory and for a method that allows for testing theories. This description of crowd research in chapter 2, is followed in chapter 3 by a description of the theoretical model of crowd behaviour CROSS developed for this study. Chapter 4 then deals with the use of simulation as a methodology to explore and test theories. The last part of the thesis focuses on the use of the CROSS model to gain understanding of crowd behaviour. First, a computational version of the CROSS model is described in Chapter 5, followed by the description of simulation experiments in chapter 6 and 7. In these experiments the role of density (chapter 6) and leadership (chapter 7) in crowds is explored. The thesis concludes with chapter 8 by reflecting about the contributions made to crowd research and future steps in understanding crowd behaviour.

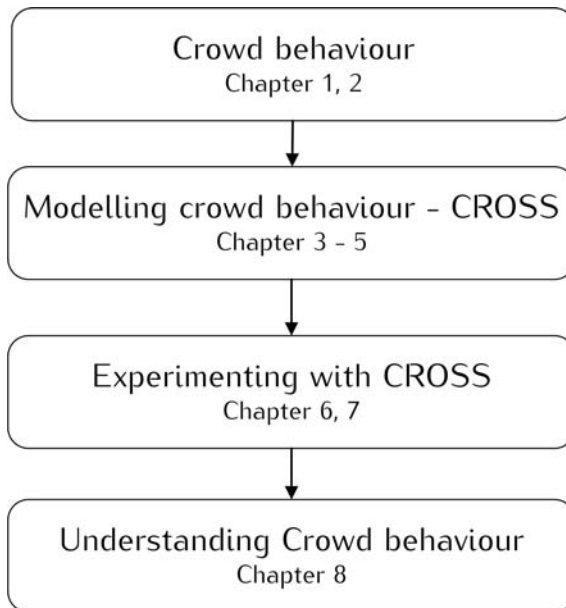


Figure 1.2: Thesis map visualisation