Storm Surge Evacuation Modelling and the Visualisation of Evacuation Behaviour: A Case of Takamatsu, Japan

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Summary

Strom surge has been a significant threat to many Japanese cities that are located in the western inland sea area because of frequent and intense typhoons that pass the area every year. This interdisciplinary research aims to simulate storm surge and flood evacuation behaviour of residents living in Takamatsu, Japan which is facing Seto Inland Sea. The tidal flow of Seto Inland Sea and storm surge flooding is simulated based on the 2004 typhoons data that seriously flooded the study area. The storm surge simulation informs the evacuation behaviour, which is simulated by using an agent-based model.

KEYWORDS: *Storm surge, typhoon, evacuation, agent-based model, visualisation*

1. Introduction

Not only the risks of earthquake and tsunami, but also the risks of floods and storm surge caused by typhoons have become increasing concerns to Japanese communities. This research aims to simulate storm surge evacuation behaviour to support decision making of a city that has increased risk of frequent and intense typhoons. To enable residents to evacuate to shelters in a timely manner, there needs a decent preparation and training in community level. The scheme for evacuation needs to be well discussed and agreed among community members in enhancing preparedness to disasters. This is a lesson from the 2011 Japan earthquake and tsunami disaster, by which many people lost their lives while they were evacuating. The principal goal of this research is to develop a 3D model that visualises the evacuation process at the time of storm surge, which will be used to discuss disaster prevention policy and community-level plan for enhanced preparedness. This conference paper is to report a part of the study - simulation of storm surge and evacuation modelling.

2. Background

Promoting disaster preparedness, response and recovery exercises including evacuation drills, training and the establishment of area-based support systems are imperative in reducing disaster risks and enhance resilience (UNISDR, 2015). For an effective emergency responses and management, agent-based model (ABM) has been developed as the most suitable method to address the challenges of simulating evacuation behaviour because it enables to capture interactions of diverse agents and dynamic responses in spatial environment over time (Dawson et al., 2011, Crooks et al., 2008, Chen et al., 2006). However challenges of using ABM is its nature of involving human agents with potentially irrational behaviour and complex psychology (Bonabeau, 2002). This research applies

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ABM as a method that captures dynamic responses in a spatial environment by addressing these challenges (Dawson et al., 2011). The knowledge of residents (Mostafizi et al., 2017) who evacuated at the time of the major disaster in 2004 in the case study area is considered in simulation, to reflect the observation of residents in terms of water flow and associated needs to change evacuation routes.

3. Method

The study area is Takamatsu city, Japan where there are average 20 typhoons hits every year. The most recent serious disaster is the series of Typhoons in 2004 which flooded extensive area. On 30 August 2004, by the typhoon 16, the water level of Takamatsu port exceeded 2.45m, which is the highest in its history. The high tide and the summer tidal current accelerated this phenomenon. In the city of Takamatsu, more than 15,645 houses were flooded and the area of 980ha was inundated, causing closure of major roads. Even the dedicated evacuation centres were flooded and evacuation of residents became chaotic. During the continuous typhoons, a number of landslide occurred and different areas were flooded according to the difference of tides, wind and rainfall. In particular, typhoon 16 and 23 caused serious floods.

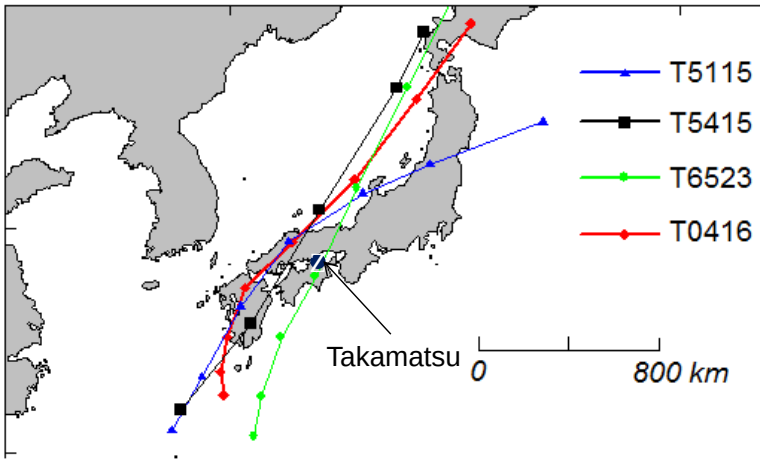

Figure 1 Location of Takamatsu, Japan and the typhoon trajectory that triggered storm surge (1949 – present)

For the storm surge simulation, the difference of the height of tides depending on the direction of Typhoon in Seto Inland Sea is considered. A couple of scenarios (day and night) of storm surge are developed. It is assumed that all residents evacuate from their home or work/school to the closest dedicated evacuation centres immediately after a storm surge warning is issued either by foot or car. All agents' origin is home at night time. Population are randomly generated using Census 2015 statistics weightings (neighbourhood level), producing agents with following attributes – under 65 years old(employed/student), under 65 years old(stay at home) and over 65(stay at home). If employed or student, they are assigned to at random workplace or school location for day time scenario. Shortest paths are found using A* algorithm which is commonly used in literature. Limited number of private vehicle is used based on the lessons from the 2011 tsunami disaster (many people who used car for evacuation were caught in heavy traffic and were drawn). Pedestrian movement follows constant value of walking speeds (Takabatake et al., 2017). Time to evacuate from origin to evacuation centre is recorded in minutes. NetLogo, which is a high-level platform for simulating complex and stochastic systems is used. The advantage of using NetLogo is its GIS extension, which allows the creation of ABM using GIS data.

4. Results

Figure 2 shows the numerical simulation of tides of Takamatsu port area at a flood tide against west wind is set as 26m/s. Figure 3 shows the water level at the time of high tide when the speed of west

wind is set as 26m/s, which is the good agreement with 2004 typhoons.

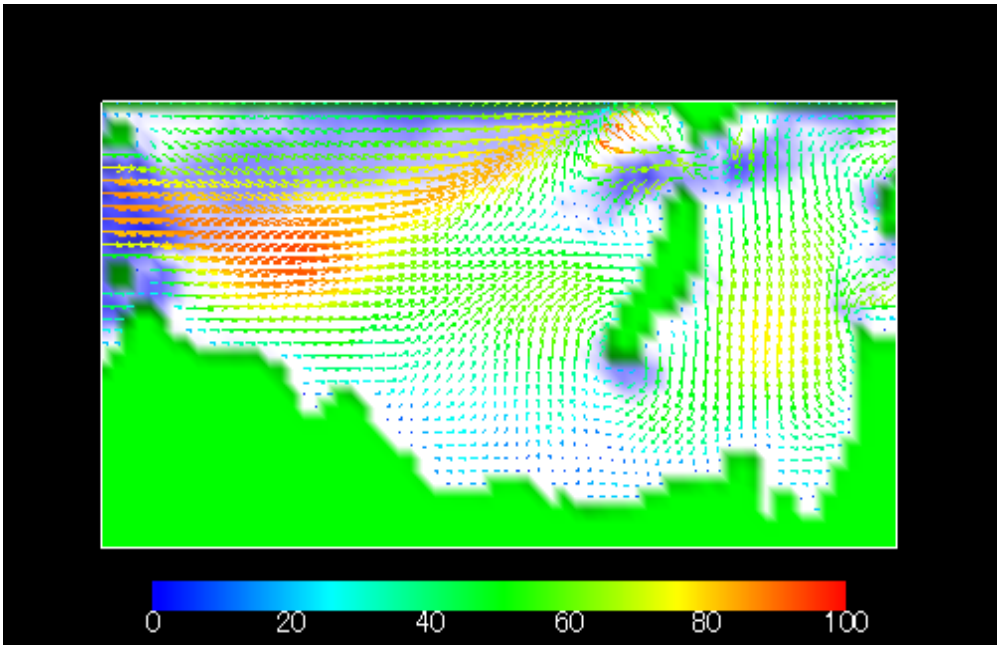

Figure 2 Simulation of tidal current of Takamatsu port area (flood tide against west wind is set as 26m/s)

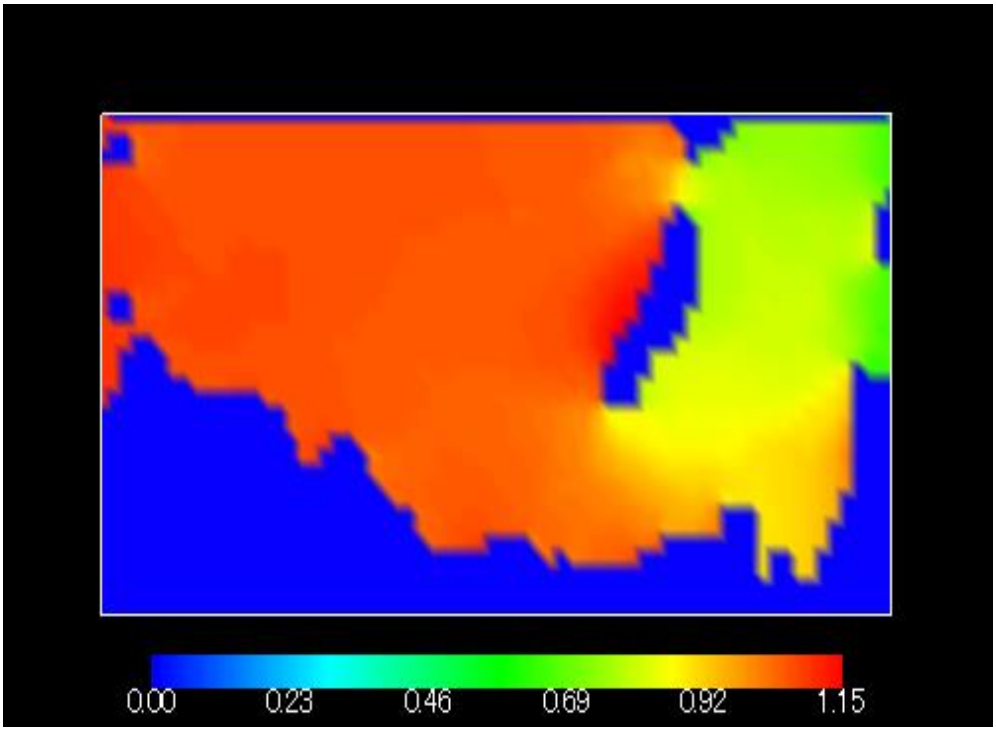

Figure 3 Water level at the time of high tide when the speed of west wind is set as 26m/s

In this extended abstract, we present day time evacuation simulation in the area which was significantly flooded at the time of 2004 typhoon. The area is high-dense spread from eastern side of city centre to the western side of Tsumeta River (area:7,200m^2, population:7,400 (as of March 2018)). GIS data which is publicly available from the Geospatial Information Authority of Japan was loaded into the NetLogo GUI. Produced agents were pedestrians and cars, with speed of 5km/h and 30km/h

respectively. Considering the experience of 2004 typhoon, 10% of population is assumed to evacuate to nearest shelters. It is assumed that elderly people (over 80) use cars. The rest of the population stay at higher storeys of home or office buildings. Overall, 735 pedestrians and 80 cars were created and initially assigned to home/work locations. The average time to evacuate was taken over 10 runs, to account for randomness in population generation. No congestion effects were considered. The average evacuation time calculated based on the simulations is 47.6 minutes.

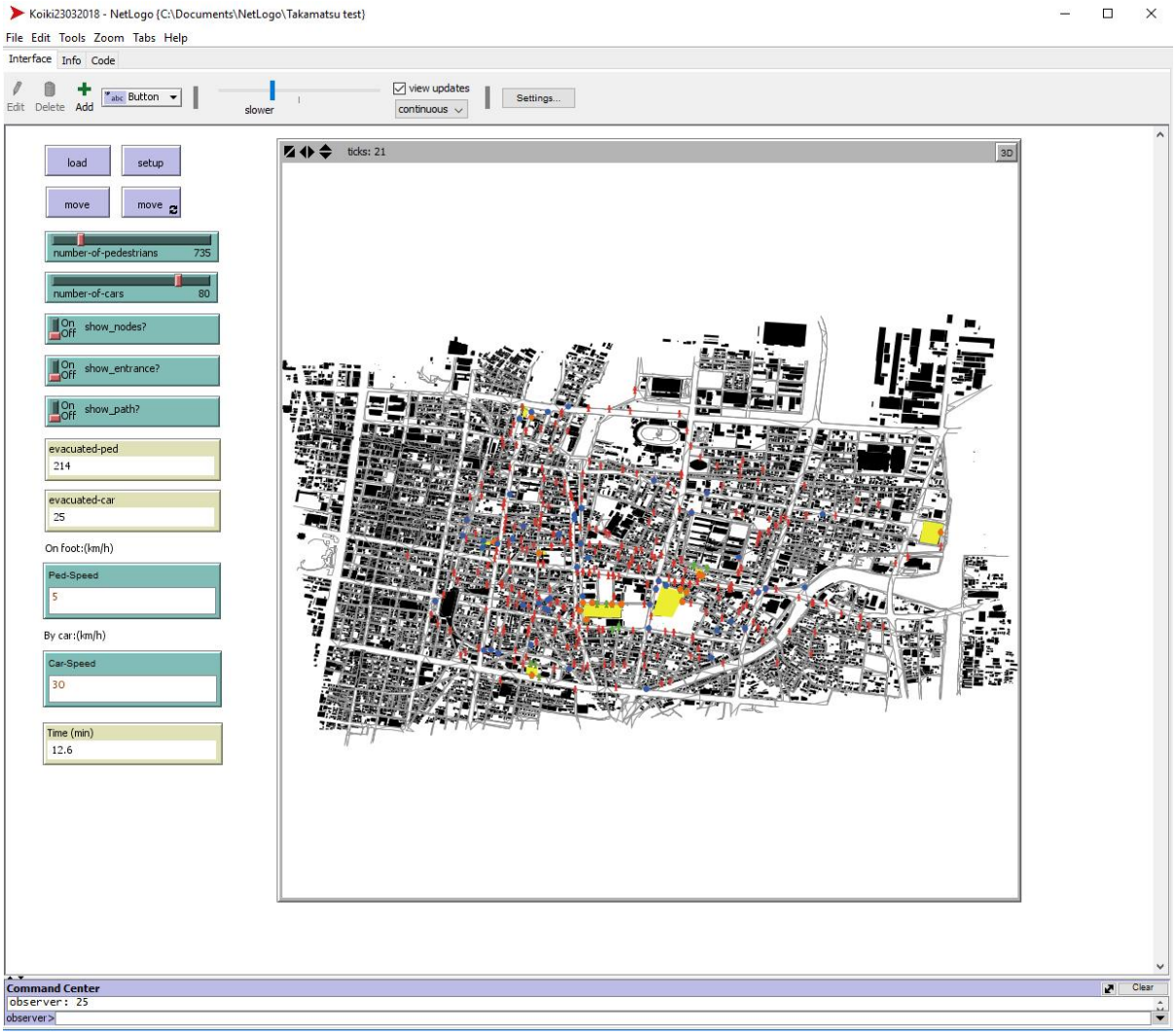

Figure 4 Screenshot of NetLogo GUI (red:pedestrians, blue dots: cars yellow buildings: shelters)

5. Next steps

We are currently refining the model based on the discussion with residents and local governments by applying different types/number of agents and speed of movement. The difference of evacuation milling times and sudden change of behaviour by unexpected incidents (assisting family member/friends, sudden closure of routes etc.) will be discussed and reflected on the simulation.

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Biography

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Dr Hitomi Nakanishi is an Associate Professor of Urban and Regional Planning at the University of Canberra where she is a course convener of the Master of urban and regional planning. She has been an adjunct senior research fellow at Kagawa University Japan and visiting scholar to University College London since 2016.

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