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Simulation of the Neuschwanstein Castle: Egress of a fairy castle

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Abstract - The Neuschwanstein Castle, located at the very south of Germany, is one of the most famous sights in Germany and well-known all over the world. Initially designed by King Louis II in the late 19th century, it attracts more than one million visitors every year. One very challenging task it to provide safety for all visitors in case of an emergency: The complex geometry of the castle in combination with the fact, that the majority of the people are not familiar with the building, has to be considered when planning escape routes. Surplus, the temporal-spatial correlation during evacuation of this eight storey castle is difficult to address statically. In order to support the local building authorities and safety planners, a simulation was conducted to optimize the escape routes. The paper describes how the simulation supported safety engineers to address these challenges and how it led to improvements in escape route planning and thus reducing the overall egress time.

Keywords: case study; Neuschwanstein castle; stairs; evacuation simulation

1. Introduction

This paper describes a case study for pedestrian simulation. We examine the Neuschwanstein castle, which consists of a very complex geometry and small alleys on eight storeys that are accessible for visitors from all over the world - many of them not familiar with the layout of the castle. Due to the fact, that there are many visitors simultaneously located on several floors and only limited escape routes and exits exist, the safety officers have to cope with a huge challenge in order to create an escape route plan not only compliant with building regulations but an efficient one that works in case of emergency. We collaborated closely with the building authorities and fire safety engineers to analyze the existing escape route plan and created simulation scenarios to improve the plans iteratively.

Figure 1: The Neuschwanstein castle. Copyright by Thomas Wolf, www.foto-tw.de

2. Layout of the castle

The accessible areas of the castle are depicted in Figure 2. On the gray-colored floors, visitors are on a guided tour inside the castle, on the red-colored floors there are souvenir shops, restrooms and a cafeteria where visitors can move freely. The remaining three floors refer to stair cases leading to a tunnel which is the common exit of the castle after a visit.

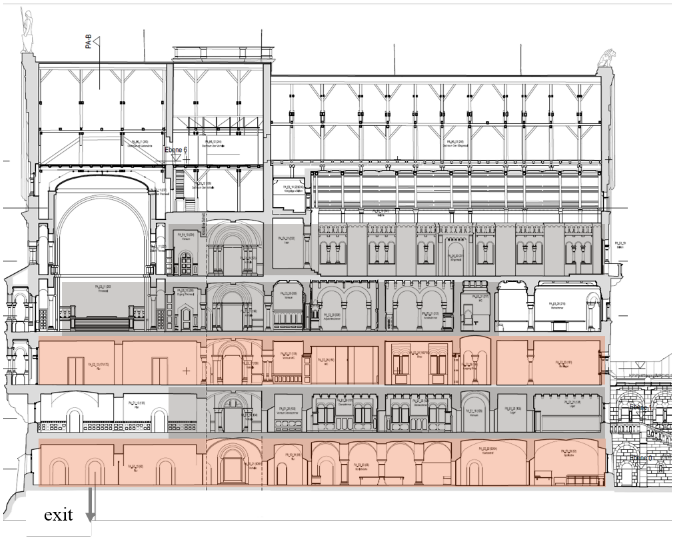

Figure 2: The Neuschwanstein castle by profile. Red colored floors are free flow areas, on the grey levels guided tours take place.

3. Simulation setup and procedures

In order to conduct the simulations, we first adapted the floor plans to our needs: We reduced information not needed, added safe areas and defined where people are located inside the castle at the time the alarm occurs.

We assumed the pre-movement times as follows: For visitors attending a guided tour, the pre-movement time was set to up to one minute, since the guides are instructed to lead their participants out of the building. For visitors moving freely on the floors, we assumed pre-movement times from one minute up to five minutes. The assignment of pre-movement times was upon consultation with the building authorities.

To determine the number of visitors inside the castle, the visitors have been counted at the entrance for several month to get the maximum number. To distribute the visitors on the different floors as realistic as possible, we referred the schedule of the guided tours and measured the duration of a guided tour.

Once the scenario was created and the input defined, we implemented the escape route assignment in collaboration with safety experts. We iteratively altered the assignments and ran the simulations again to optimize the route assignments.

4. Simulation model

We implemented the simulation using the Optimal Steps Model (OSM) [?]. This model is based on the idea to imitate the stepping behavior of agents: Using a disk with radius step width of the agent the possible area for the next step (see Figure 3) is defined. Inside this area, an optimization model is applied for the agent to find the best position with respect to getting closer to his destination and not bumping into other agents or obstacles [?] (see Figure 3). For the tactical layer, we use a visibility graph [?] that forms the basis for the route choice of the agents.

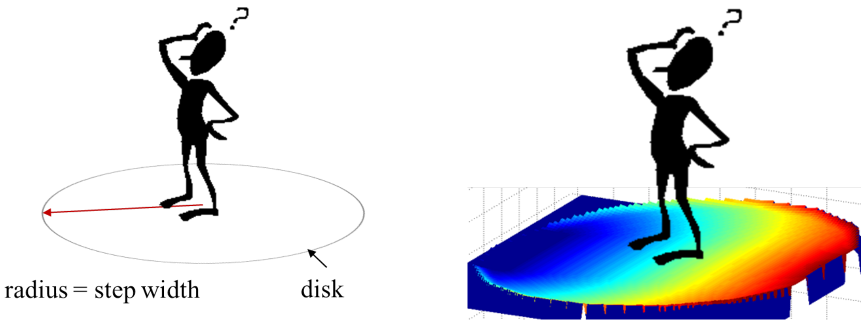

Figure 3: Left: The disk the agent can step on. Right: the disk overlayed with the utility function. The agent tries to step along the gradient of the field.

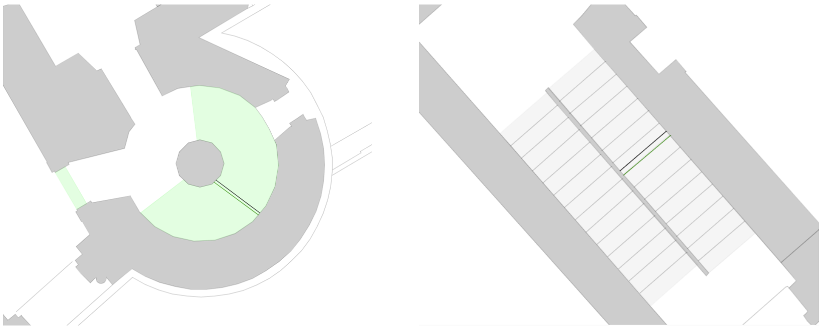

Figure 4: Left: The spiral staircases, modeled with scaled velocity areas. Right: straight stair cases, modeled with the extended Optimal Stair Model.

4.1. Special Challenges

As we were faced with a special building that consisted of many stair cases, we had to cope with manifold challenges.

The castle consists in total of

- eight floors which are accessible by visitors
- three exits on three different levels
- four stair cases connecting floor 4 to floor 0
- one stair case connecting floor 0 to floor -3

which leads to a very confusing geometry where people have difficulties to orientate themselves.

In order to model the castle as realistic as possible, several issues had to be addressed: We had to cope with eight floors and a result representation such that the safety experts could follow the results clearly. Surplus, since the stairs are the bottleneck of this castle, we wanted to model staircases as realistic as possible. Therefore, we extended the stair model, suggested by [**?**] for straight stairs: We integrated the change of a floor while being on a staircase and the integration of stairs in agents' action plan. Two of the stair cases are spiral cases - we modeled these two stairs with the common technique: slowing down with a factor. Figure 4 shows the screenshots of both modelings.

The several floors are connected via portals. The original simulation model is in 2D. To glue the different floors together, we use so-called portals. Portals are lines, consisting of two points and indicating the end of a floor. As soon as an agent is close enough to such a portal, he can ”‘perceive”’ the next floor and all agents closer or equal his individual perception radius. Once he crossed the portal, he enters the new floor and orientates himself on that floor.

To cope with common CAD modeling standards, we place the portal on a stair tread to indicate the new floor. An example is given in 5. With such modeling the advantage is that the model looks very similar to common guidelines and thus it simplifies the modeling of stairs.

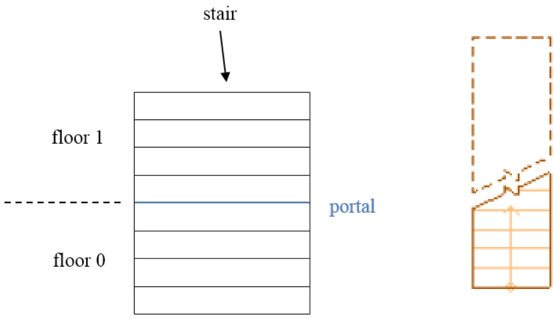

Figure 5: Left: Stairs modeled in the simulation model. Right: Stairs modeled with CAD software.

5. Results

In this section, excerpts of the results are presented to point out the neuralgic areas that formed during the evacuation process and analyse the improvements we could achieve in changing the escape route assignments.

In the first iteration, two congestions occurred on the same floor which lasted up to four minutes: Visitors from the floor above already blocked the stair case, and thus the visitors from the current floor could not enter the stair case. Those two congestions occurred in front of one spiral and in front of the neighboring straight stair case. (see Figure 6). The congestion in front of the straight staircase lasted for a little more than two minutes.

With the second iteration, no congestion occurred in front of the spiral staircase. Since on that floor other staircases have not reached their capacity limits, we could adopt the escape route assignments. The jam in front of the straight staircase was still present, but could be reduced to a maximum of 90 seconds.

On the other floors, no congestion occurred at all - neither in the first iteration, nor in the second iteration.

Figure 6: Left: Congestions, occurred in front of the staircases during the first iteration. Right: Congestion in front of staircase during the second iteration.

The duration of stay in the observed area in front of both stair cases are depicted in Figure 7 and Figure 8. One can observe from both iterations, that not only the congestion in front of the sprial staircase disappeared, but that the duration of the congestion in front of the straight staircase was shorter as well.

The results of the simulation showed that the statically planned escape routes led to huge congestion in front of one staircase. Using the simulation, the distribution of the visitors to the stair cases could be optimized and led to a reduction of the overall egress time.

6. Conclusion

The simulation revealed the spatial-temporal relations in such a complex building during evacuation. Although the existing escape route plan was compliant with all regulations, congestions occurred in front of two staircases. Using simulation techniques, we could enhance the escape route assignments significantly and barely congestion occurred any more. In collaboration with safety experts we iteratively worked on improving the route assignments. So, not only the overall evacuation time could be reduced,

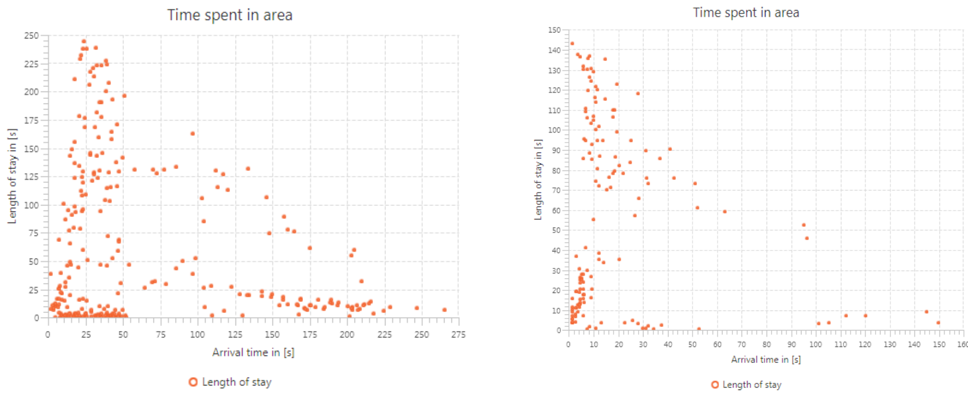

Figure 7: First iteration. Left: Congestion duration in front of spiral staircase. Right: Congestion duration in front of straight staircase.

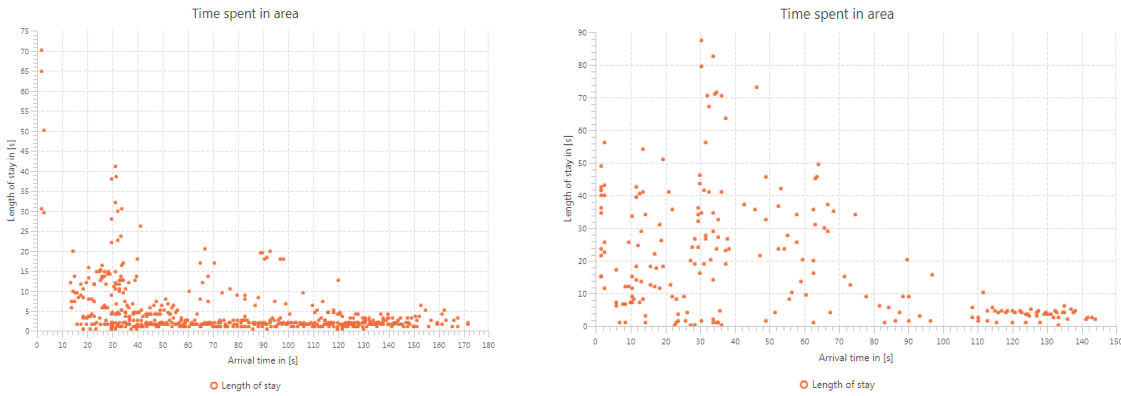

Figure 8: Second iteration. Left: Congestion duration in front of spiral staircase. Right: Congestion duration in front of straight staircase.

but by reducing the congestions, the risk of people starting to feel uncomfortably could be reduced as well. The simulation results will be taken into account for the new fire protection concept.

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