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METHODOLOGY TO VALIDATE THE 'FASTER IS SLOWER' CONCEPT

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1. INTRODUCTION

For years, a group of experts in Physics and Applied Mathematics has been researching the behaviour of inert particles flowing through a bottleneck [1] [2]. This methodology of movement analysis has been applied to people movement, a scenario in which we have performed tests under different conditions of stress and motivation [3] [4] [5]. In fact, collective behavior of human crowds has attracted the attention of physicists in recent years, because it has been shown that the dynamics of people can be represented, at least in some situations, by simple models [6].

Apart from previous studies with inert spherical particles, the researchers have realized studies of evacuation with sheep, where the door size and motivation are analyzed among other parameters of influence. In these cases the experimental protocol involves a flock of 90-100 sheep passing through a narrow door. For this, it was taking advantage that, every morning, the flock is taken out of the farmyard to clean it and place the feed. When the door is open the sheep crowd in front of the door and blockages occur. From the obtained results with sheep, it was concluded that reducing the pressure of animals in the door leads to an improvement of the transit time, and thus the evacuation time is reduced. Importantly, the improvement occurs through a reduction in long blockages which are, indeed, the one that can trigger the most serious accidents. The application of this methodology to the evacuation of people is what is described below.

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2. METHODOLOGY

The experiments were carried out with the collaboration of 90 students of the School of Architecture of the University of Navarra. In two mornings, the students run 60 evacuations (30 each day) with two different door sizes and encouragement conditions.

Figure 1: Sports Centre court and the limited area where students are located.

The students wore dark clothes and a red hat was provided. The purpose of this is to facilitate a further identification of each person in the video recordings and measure with precision the time between two consecutive individuals (Dt). The delay between one person and another is the variable that describes the phenomenon.

In a series of tests, the students were asked to leave in a calm way, without pushing. In another series were asked to leave hastily (but not exceed).

2.1. Previous works

These experiments have required the following operations prior to execution:

- Build a support for the high resolution camera, which records the evacuation from inside of the court. The camera is 1,5 m high from the railing of the stands and 1,2 m suspended towards inside. This camera records the area where the students are placed.

Figure 2: High resolution camera.

- Remote control. Since the high definition camera doesn't have a remote control, is built a device that allows switch it on and off. The aim is to avoid the films to be cut automatically when the file size reached 4 GB.

- Build a support for the security camera. A security camera is placed in the hallway above the exit door. A prop is used for this purpose. Fisheye lens is used to place the centre of the image 1,2 m from the door.

- Wiring. Power and data cables for the cameras.

- Scale. Get images that can be used for pixel/distance conversion in both, the high definition camera, and in the security camera.

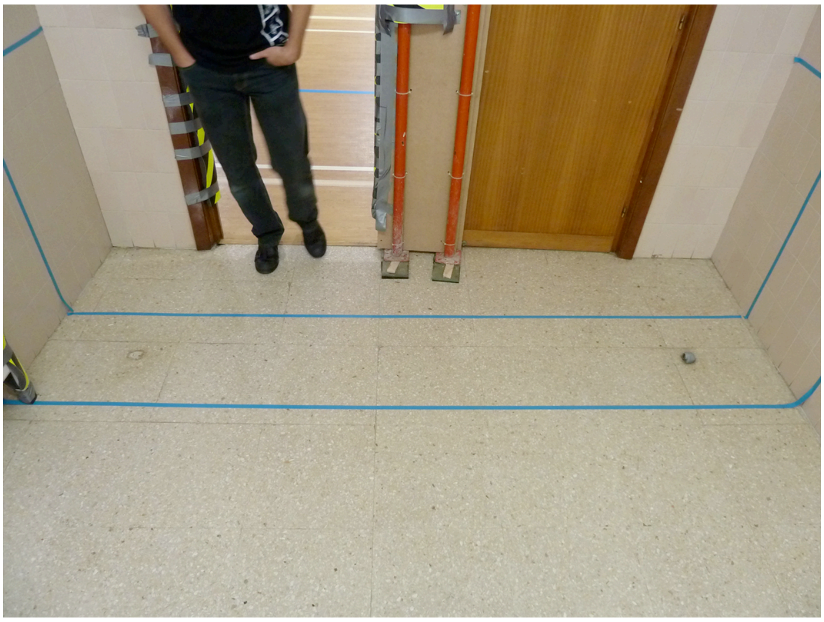

Figure 3: Reference lines on floor and walls to generate time-space diagrams.

- Remove the exit door. To prevent someone might be hurt with it, also the hinges are removed.

- Adjust the door size. A board is held with props to close the doorway leaving a gap of 0,75 m for evacuation.

- Placing the dynamical multi pressure sensors (Tekscan®) in the doorpost and protect them with foam.

- Choose the initial position of collaborators. Using tape we delimited an area of the court within which all the participants are placed. Its size is calculated in order to have an initial average density of four persons per square meter. The region has the same format 16:9 that the HD camera.

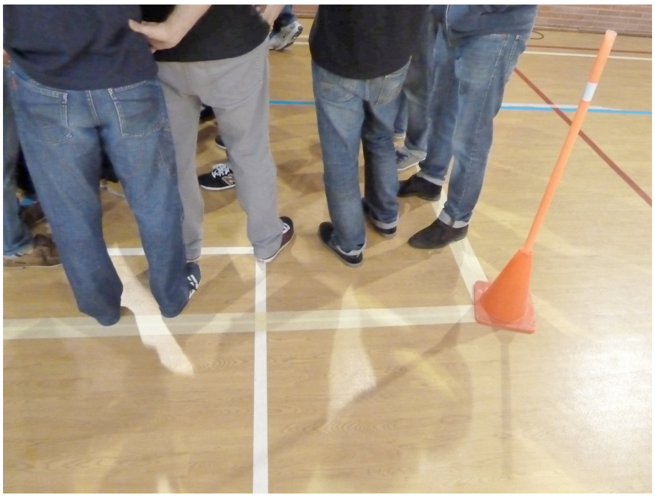
Figure 4: Detail of placement of students before each test.

2.2. Data collection

The data collected in the tests are:

- With the frames extracted from the security camera recordings (at 25 frames per second) a space-time diagram is obtained that will posteriorly allow to precisely determine the crossing time of each participant. The space time diagram consists on taking a line of pixels from each frame as the green line displayed in Figure 5 (left). Then, this line is stacked vertically in such a way that in Figure 5 (right) the ‘y’ coordinates is space and the ‘x’ is time. This procedure is akin to the Photo finish in field and track events.

- Evacuation time. Time spent in the drill measured by a collaborator with a chronometer. This time coincides with the time since the triggering signal to the passage of the last student as obtained with the spatiotemporal diagram.

- Student tracking velocimetry. Obtains the position at each time of the students in the room from the video recorded with the HD camera.

- The pressure made by students is estimated with pressure sensors placed in the doorpost.

4. EVACUATIONS

All the volunteers are allocated in the area of the court. We make a signal with a whistle and trigger the evacuation. The students start moving through the door to the hallway without stopping. After the drill finishes, students go back to the court, placing themselves in the starting area, but in a different position to start a new test.

It has to be said that students were informed in advance about what they were going to do, but they did not know the aim of the drills. This knowledge would have changed their natural behavior.

We found strikingly different result in the evacuation process depending on the motivation conditions. Compared with a calm situation, a hastily situation produces slower evacuations due to temporal interruptions of the flow (Fig 6).

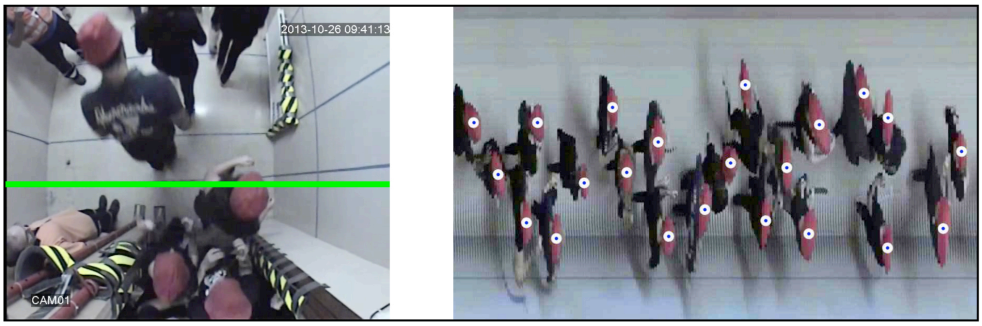

Figure 5: 'Photo finish' as an imaginary line using the outside camera.

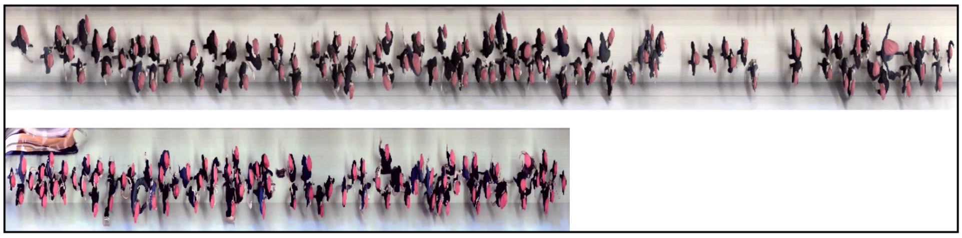

Figure 6: Space-time diagrams in a hastily situation (above) and a calm situation (below).

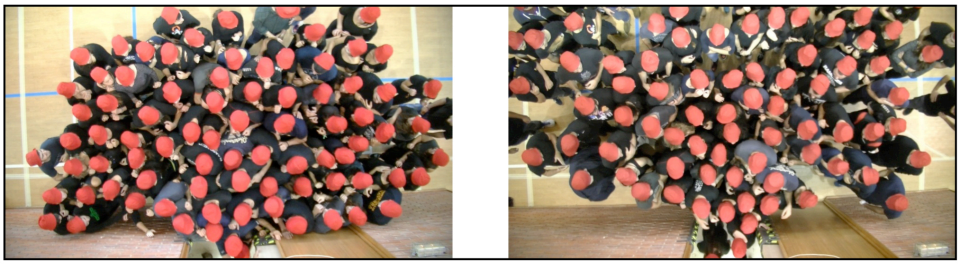

Figure 7: Students distribution in a hastily situation (left) and a calm situation (right).

3. CONCLUSIONS

The result that have been explained show -for the first time in an experimental way- that a decrease of pressure in a building door has a beneficial effect on the flow: the 'faster-is-slower' effect.

The tests have generated a wealth of information, of which from the moment only has been analyzed the crossing times of the time-space diagrams. Furthermore, with the films available, the analysis of the trajectory of students is being conducted to quantify important parameters as density of people depending on the distance to the door, or the block movements that arise when the student motivation increases. The latter may be correlated with an aspect which has never systematically studied and has dramatic consequences: the group falls. It is known that many of the crowd accidents ('Madrid Arena', 'Kiss Nightclub' in Brazil, 'The Station Nightclub' in USA…) are caused by people chain falls. In these tests there have been some group falls attempts and a real fall of about 10 people, at which the exercise was stopped [8]. The realization of a larger number of experiments together with a careful analysis of the trajectories of students, seems the most logical way to proceed to the characterization of the specific circumstances that lead to these falls.

In addition, let us remark that this kind of tests should be the basis for validating numerical methods. Only then some reliability can be attained to use computer simulations in order to better understand the extreme pressure evacuations, scenario in which the experiments are infeasible by its dangerousness [9] [10].

In addition it can be said that the researchers are carrying in parallel another project that relates BIM simulations, BPM processes and people trajectories with the use of RFID sensors. Both projects are expected to be added in the near future to generate highly innovative information [11].

5. AKNOWLEDGMENTS

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6. REFERENCES

[1] Janda, A. et al. - *Flow rate of particles through apertures obtained from self-similar density and velocity profiles, Physical Review Letters* 108, 248001, 2012.

[2] Zuriguel, I. et al – *Clogging transition of many-particle systems flowing through bottlenecks, Scientific Reports* 4, 7324, 2014.

[3] Gwynne S. M. V. & Kuligowski, E. D. - *Simulating a Building as a People Movement System, Journal of Fire Sciences*, vol. 27, n.4, 2009, p. 343–368.

[4] Helbing D., Farkas I. & Vicsek T. - *Simulating dynamical features of escape panic, Nature,* 407, 2000, p. 487–490.

[5] Garcimartín, A. et al., FisEs Congress, Orense, 2014.

[6] Helbing D. & Molnar P., *Phys. Rev. E*, 1995, 51, 4282–4286.

[7] He, G. et al - *A review of behavior mechanisms and crowd evacuation animation in emergency exercises, Journal of Zhejiang University SCIENCE C*, vol. 14, n.7, 2013, p. 477–485.

[8] Shen, T.-S. - *Building Egress Analysis. Journal of Fire Sciences*, vol. 24, n.1, 2006, p. 7–25.

[9] Seyfried A. et al - *New insights into pedestrian flow through bottlenecks, Transp. Sci*, n.43, 2009, p. 395–406.

[10] Zheng, X., Zhong, T., & Liu, M. - *Modeling crowd evacuation of a building based on seven methodological approaches. Building and Environment*, vol. 44, n.3, 2009, p. 437–445.

[11] Eguaras-Martínez, M., Vidaurre-Arbizu, M., & Martín-Gómez, C. - *Simulation and evaluation of Building Information Modeling in a real pilot site, Applied Energy*, v.114, 2014, p. 475–484.

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