A NEW MEASUREMENT METHODOLOGY TO IMPROVE BUILDINGS SAFETY

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SUMMARY

• Background
• The problem
• Methodology
• Experimental data of the proposed methodology in the first experimental experience of a building evacuation
• Conclusions
ANCIENT TIMES

One of the earliest evacuations dates back to as early as 480 BCE in Greece. Themistocles, a Greek state and navy commander, ordered an evacuation of Athens in response to the approaching Persian army. His strategic countermeasure led to approximately 100,000 inhabitant's survival and safety.
BACKGROUND

HISTORY OF BUILDING EMERGENCY EVACUATION

Historically, the biggest threat to architecture has been fire, and architecture has evolved to resist it. In the 1700s, the best that building occupants could do in the event of a fire was to shout for firemen, who would bring the "fire escape": essentially a cart with a ladder on it.
BACKGROUND

HISTORY OF BUILDING

EMERGENCY EVACUATION

AT THE BEGINNING OF 1900

BUILDINGS WERE BUILT WITH

FIRE ESCAPES.

FIRE ESCAPES TURNED OUT TO BE

INEFFECTIVE.
BACKGROUND

MODERN TIMES: FIRE ESCAPE PLAN

FIRE ESCAPE PLAN

Legend:
- You are here
- Escape route
- Emergency exit
- Emergency telephone
- First aid
- Fire extinguisher
- Fire hose reel
- Fire alarm callpoint
- Fire emergency telephone
- Evacuation assembly point

SAFETY NOTICE
The drawing is based on the example found in ISO 7240: 2001
It was created using Visio
Building Basic and an edition
Fire Escape method catalogue.

MIN  ISO 7240 Example
- Location
- Fire Plan with risk评估
- Fire extinguisher
- Fire hose reel
- Fire alarm callpoint
- Fire emergency telephone
- Evacuation assembly point

[Diagram of Ground Floor with arrows indicating escape routes]

[Diagram of fire escape plan]

[Diagram of building layout]
BACKGROUND

MODERN TIMES: Egress microsimulation software
MODERN TIMES

- In the evacuation of the World Trade Center high-rise office towers following the terrorist bombing in 1993, the tens of thousands of building occupants successfully and safely traversed some five million person-flights of stairs.

- The physical demands made on occupants often exceed the capabilities of many.

- In addition, the process of evacuating some of the largest high-rise buildings in the world may take upwards of two hours.
THE PROBLEM

- Currently the investigation of real-time evacuation path information is based on the use of video footage or accelerometric sensors.

THE SOLUTION
The paired Bluetooth-based Beacon technology and the use of smartphone applications can allow devices to receive small messages within short distances. This technology was initially introduced as a system to give more information about a commercial product to a client and it has showed a great importance also for other issues such as the localization of people inside buildings.
A GLIMPSE OF FUTURE: USE OF BEACONS IN BUILDING EVACUATION

• New studies seek to investigate the implementation of new technologies in the building evacuation scenarios. New technologies such as smartphones, specific sensors and Bluetooth-based Beacon can allow planners to organize and guide people paths for the fastest and safest exit.


THE METHODOLOGY:

• OUR Methodology is to place a beacon set in a building in some key points.

• These points are identified such as special nodes in a sequence of links of an evacuation path such as stair nodes or the beginning, center and end of the corridors.

• When someone walks within the radius of a Beacon radio emitter the estimated distance between the Beacon and the smartphone is read by the application on the smartphone. Readings from every smartphone can be transferred to an elaboration unit. The single positions and trajectories of people in the building can be obtained by a post elaboration on the elaboration unit.
THE METHODOLOGY:

- Radio waves under the portals allow to estimate the moment users walk through the portal.
The first experimental experience of a building evacuation was conducted at the Department of Civil Engineering at the University of Calabria using 3 beacons per floor plan (2 floors) plus 2 for the stairs (8 beacons tot).

- Beacons were positioned along the suggested (shorter) escape routes.
- The experiment involved 2 participants for each of the 10 rooms, generating a total of 20 trajectories to the shortest escape exit.
THE FIRST EXPERIMENTAL EXPERIENCE OF A BUILDING EVACUATION

It was asked to participants to maintain as much as possible a constant speed while exiting the building.

• Cameras have been used to check the coherence of movements along the path with the given graph.

• Cameras have also been used to estimate with absolute certainty the real actual times of people passage through the various portals.
THE FIRST EXPERIMENTAL EXPERIENCE OF A BUILDING EVACUATION

• The application on the various smartphones recorded the RSSI signal and consequently the distance between the device and the beacon portals.

• The following figure shows an example of the distance signal detected by a single smartphone for the three beacons positioned in the first floor.

• In this way, for each beacon and smartphone, it was possible to identify an estimate of the instants in which participants in the evacuation would walk under the portal.
The First Experimental Experience of a Building Evacuation

All trajectories obtained with the systems were compared to the real one obtained from the control cameras. Results show that an error is always present in estimating the passing time of participants under the portals. For each beacon of floor one the resulting distribution of error in the measurements is presented in Table. Each device is subject to a delay in the estimated instant due to the latency of the signal. In other words an advanced reading of the RSSI signal must be taken in consideration when estimating the passing under portals.

<table>
<thead>
<tr>
<th>BEACON</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>2.70</td>
<td>1.39</td>
<td>2.19</td>
</tr>
<tr>
<td>Variance</td>
<td>7.07</td>
<td>4.62</td>
<td>2.05</td>
</tr>
<tr>
<td>Sta.Dev.</td>
<td>2.66</td>
<td>2.15</td>
<td>1.43</td>
</tr>
<tr>
<td>Median</td>
<td>2.54</td>
<td>1.33</td>
<td>2.32</td>
</tr>
<tr>
<td>Root Mean Sim.</td>
<td>1.88</td>
<td>1.71</td>
<td>1.02</td>
</tr>
<tr>
<td>Min</td>
<td>-0.83</td>
<td>-2.63</td>
<td>-1.68</td>
</tr>
<tr>
<td>Max</td>
<td>8.47</td>
<td>5.49</td>
<td>4.88</td>
</tr>
</tbody>
</table>
## THE FIRST EXPERIMENTAL EXPERIENCE OF A BUILDING EVACUATION

A sample of total evacuation times

<table>
<thead>
<tr>
<th>Room</th>
<th>Space</th>
<th>Travel time</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27,460</td>
<td>20,488</td>
<td>1,340</td>
</tr>
<tr>
<td>2</td>
<td>26,390</td>
<td>15,631</td>
<td>1,688</td>
</tr>
<tr>
<td>3</td>
<td>27,741</td>
<td>17,516</td>
<td>1,584</td>
</tr>
<tr>
<td>4</td>
<td>29,625</td>
<td>15,722</td>
<td>1,884</td>
</tr>
<tr>
<td>5</td>
<td>31,132</td>
<td>20,286</td>
<td>1,535</td>
</tr>
<tr>
<td>6</td>
<td>26,555</td>
<td>20,025</td>
<td>1,326</td>
</tr>
<tr>
<td>7</td>
<td>25,332</td>
<td>19,738</td>
<td>1,283</td>
</tr>
<tr>
<td>8</td>
<td>20,136</td>
<td>15,163</td>
<td>1,328</td>
</tr>
<tr>
<td>9</td>
<td>13,965</td>
<td>10,205</td>
<td>1,368</td>
</tr>
<tr>
<td>10</td>
<td>12,728</td>
<td>11,271</td>
<td>1,129</td>
</tr>
</tbody>
</table>
CONCLUSIONS

• The proposed methodology is simple and free from position triangulation problems, as beacon portals are used almost exclusively to determine the pass-through times under the portals and not all the trajectories of the smartphones. In this methodology, therefore, only the instant of passing under the portals created by the beacon are used to approximate trajectories.

• In this first experimental experience of a building evacuation it is possible to notice how, in fact, every smartphone suffers from a latency in receiving the RSSI signal. This results in errors that can be considered distributed with a Gaussian distribution. The error distribution in receiving the signal is not constant because it depends on the location of the beacons themselves as a function of local characteristics of the room.

• From results it is possible to notice that the error is greater in receiving the signal from beacons positioned in an open area (beacon 1 and 4). While it is lower in other beacons that are positioned in small rooms since the signal is more concentrated under the portal as it would be in the case of photoelectric cells.

• Moreover as a result, it can be noted that, for applications such as those the proposed methodology, it is convenient to contain the signal emitted by beacon to a maximum of 2 meters from the source.
CONCLUSIONS

• The use of portals is much simpler cheaper than classic triangulation, as less beacons are necessary to study an entire building. The sensors, in fact, are arranged only along specific portals with a set up that can be decided by the person responsible of performing the measures.

• On the basis of data obtained applying the proposed methodology it is possible to create a security index for sorting generic buildings from the point of view of emergency evacuations. Moreover it allows planners to take into consideration specific abilities (or lack of) relative to the actual occupants of the building to improve the index.

• The presented methodology could allow to reorganize the evacuation plan of a building by reallocating paths and/or people. The workers with walking disabilities could benefit of rooms that are closest to the escape routes. Paths could be reorganized according to the real experimented evacuation times.