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Performance analysis of visual markers for indoor navigation systems

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Corresponding author: Gaetano Carmelo La Delfa
E-mail: gaetano.ladelfa@dieei.unict.it
ORCID: http://orcid.org/0000-0002-1842-5467

Motivation (1/2)

- Today there is a massive diffusion of smartphones. They have high computational capabilities, good cameras, integrated GPS, and embed a lot of sensors. Thanks to these features, the smartphone has become the perfect gateway between real world and digital world.
- The diffusion of smartphones enabled a lot of services based on the position of the user in an environment (LBS: Location Based Services), and opened a lot of applicative scenarios.
- While outdoor GPS is almost a standard the facto for localization and navigation, for indoor scenarios currently there is not a unique solution and the topic is still matter of research.

Motivation (2/2)

- Various approaches for indoor localization, that exploit the smartphone's hardware in different ways, were proposed in literature. Almost all of them, however, do not meet the following criteria:
  - Low cost
  - Scalability
  - Ease of implementation of commercial solutions
  - Accuracy
- In the actual technological landscape, the development of solutions capable to fill the existing gap between the indoor and outdoor localization systems is crucial and it has to meet as much as possible the previously seen criteria.

Main idea (1/3)

- Starting from the observation that when the user launches an indoor localization app, the camera will be in the palm of his hand and will be necessarily directed towards some part of the floor, in our previous paper we proposed an approach to the indoor localization problem which uses Bluetooth Low Energy and a 2D visual markers system deployed onto the floor to estimate the position of the user *("Accurate indoor navigation using Smartphone, Bluetooth Low Energy and Visual Tags" - Gaetano Carmelo La Delfa, 2014).*
- Each marker has an associated 2D position on a previously generated indoor map of the building.

Main idea (2/3)

- A computer vision algorithm will decode the visual markers in order to obtain the position of the user in the indoor environment.
- Deploying the visual marker system onto the floor has several advantages which make the computer vision algorithm more efficient:
  - Almost uniform, prior-known background pattern of the floor.
  - Almost fixed, prior-known size of the marker inside the frame.
  - Major probability for the marker to be in the upper part of the frame.

Main idea (3/3)

- A critical point of such system is the choice of the most appropriate visual markers system, which must have:
  - Small size (to reduce the invasiveness of the system).
  - Real time detection (to make the auto-localization process through visual markers transparent for the final user).
  - Robustness to changes in light conditions, and in detecting blurred or out-of-focus markers.
- We analyzed the most important visual markers in scientific literature and focused on three of them: **Vuforia** (by Qualcomm Technologies, fig. 1a), **ArUco** (by A.V.A. group, University of Cordoba, fig. 1b), and **AprilTag** (by Edwin Olson, University of Michigan, fig. 1c).

Method (1/2)

1. For what concerns our solution, the accuracy of the markers system is directly related to the number of times the marker is correctly decoded, under different conditions.
2. We tested the markers in light (Fig. 2a), medium (Fig. 2b), and dark floor pattern (Fig. 2c), for various marker size (6.5 cmx6.5 cm, 5.0 cmx5.0 cm, 3.2 cmx3.2 cm) in various light conditions, and for various distances camera-device (80 cm, 100 cm, and 120 cm) and angle of scanning. In order to facilitate the detection we added a little white border around markers.
3. The tests were performed with an iPhone 5S.

Method (2/2)

(a) (b) (c)

Fig. 1: Vuforia marker (a), Apriltag marker (b), Aruco marker (c)

(a) (b) (c)

Fig. 2: light floor pattern (a), medium floor pattern (b), dark floor pattern (c)

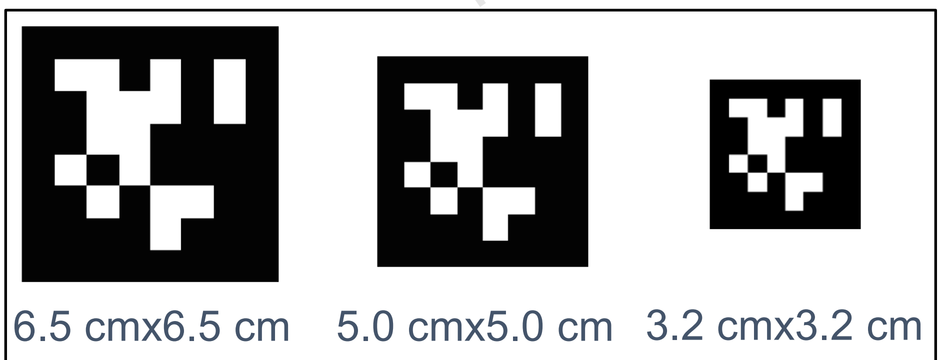
Major results (1/2)

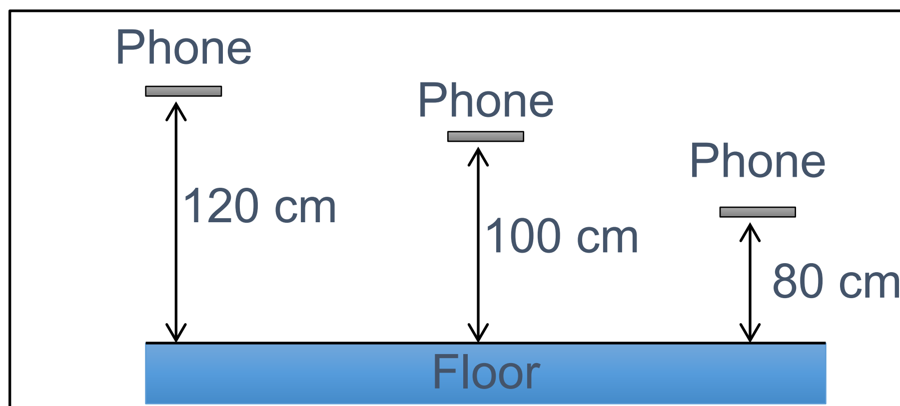
- The results show that **AprilTag** works very well in all tested light conditions, and for almost all tested sizes and marker-camera distances, in any type of floor.

Qualitative performance evaluation table

Marker Size (cm×cm)		6.5×6.5			5.0×5.0			3.2×3.2		
Marker-camera distance (cm)		80	100	120	80	100	120	80	100	120
Light Conditions	Good	+	+	+	+	+	+	+	+	+
	Average	+	+	+	+	+	+	+	+	+
	Poor	+	+	+	+	+	+	+	+	–

'+': marker is always decoded. '–': marker sometimes is not decoded. '×': marker is never decoded.





Major results (2/2)

- Moreover:
  - The availability of the decoding library source code (which lets the developer to modify the algorithms in order to adapt them to the floor features).
  - The speed of the system.
  - The small marker size we can obtain.

These characteristics make AprilTag the best choice for an indoor, marker-based localization system.

Conclusions

- This paper addresses the problem of choosing the best marker for an indoor navigation system with visual markers deployed onto the floor (based on the idea that when the user launches the application to navigate inside the building, his camera is necessarily directed towards the floor).
- The analysis led us to choose three visual markers which have features that match with our scenario: Vuforia marker, ArUco marker, and AprilTag marker.
- The results of our tests has conducted us to choose AprilTag.