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# A high precision visual localization sensor and its working methodology for an indoor mobile robot

**Key words:** Mobile robot, Localization sensor, Visual localization, Infrared-reflective marker, Embedded system

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# Motivation

- With the rapid development of robot techniques and an apparent urgent demand from the society, the indoor mobile robot will have a wide range of applications and provide services in diverse areas, such as transport, entertainment, and as a companion.

- Rapid and accurate autonomous localization is essential for the completion of these intelligent services. However, the traditional methods by themselves have low accuracy and poor robustness.

- Therefore, we design a high precision visual localization sensor for an indoor mobile robot.

# Method

- First, the hardware system of the localization sensor is developed.

- Second, we design a novel kind of infrared-reflective artificial marker whose characteristics can be extracted by the acquisition and processing of the infrared image. In addition, a confidence calculation method for marker identification is proposed to obtain the probabilistic localization results.

- Finally, the autonomous localization of the robot is achieved by calculating the relative pose relation between the robot and the artificial marker based on the perspective-3-point (P3P) visual localization algorithm.

# Major results

- Experimental results of marker identification and angle test are shown in Tables 1 and 2.



**Table 1 Experimental results of marker identification**

| Number of markers | Correct number | Accuracy | Mean elapsed time (ms) |
|---|---|---|---|
| 200 | 192 | 96% | 87 |

**Table 2 Experimental results of angle test**

| Number | Real angle (°) | Output angle (°) | Measurement deviation (°) | Confidence |
|---|---|---|---|---|
| 1 | 0 | 0.31 | −0.31 | 0.94 |
| 2 | 30 | 29.12 | 0.88 | 0.92 |
| 3 | 60 | 62.38 | −2.38 | 0.87 |
| 4 | 90 | 88.57 | 1.43 | 0.90 |
| 5 | 120 | 123.44 | −3.44 | 0.84 |
| 6 | 150 | 146.82 | 3.18 | 0.85 |
| 7 | 180 | 181.03 | −1.03 | 0.91 |
| 8 | 210 | 213.11 | −3.11 | 0.85 |
| 9 | 240 | 239.65 | 0.35 | 0.94 |
| 10 | 270 | 269.35 | 0.65 | 0.93 |
| 11 | 300 | 301.98 | −1.98 | 0.88 |
| 12 | 330 | 330.36 | −0.36 | 0.94 |
| 13 | 360 | 2.23 (362.23) | −2.23 | 0.87 |

# Major results (Con'd)

- Experimental results of position test are shown in Table 3.

**Table 3 Experimental results of position test**

| Number | Real position (cm) | | | Output position (cm) | | | Measurement deviation (cm) | | | Confidence, |
|---|---|---|---|---|---|---|---|---|---|---|
| | $X_R$ | $Y_R$ | $Z_R$ | $X_M$ | $Y_M$ | $Z_M$ | $\Delta X$ | $\Delta Y$ | $\Delta Z$ | $P(S)$ |
| 1 | −50.00 | −50.00 | 260.00 | −49.34 | −49.19 | 261.17 | −0.66 | −0.81 | −1.17 | 0.94 |
| 2 | −50.00 | −40.00 | 260.00 | −51.63 | −41.02 | 258.71 | 1.63 | 1.02 | 1.29 | 0.88 |
| 3 | −50.00 | −30.00 | 260.00 | −51.29 | −28.87 | 260.80 | 1.29 | −1.13 | −0.80 | 0.91 |
| 4 | −50.00 | −20.00 | 260.00 | −48.15 | −20.93 | 259.07 | −1.85 | 0.93 | 0.93 | 0.88 |
| 5 | −50.00 | −10.00 | 260.00 | −49.16 | −11.79 | 261.17 | −0.84 | 1.79 | −1.17 | 0.88 |
| 6 | −50.00 | 0.00 | 260.00 | −51.56 | 1.80 | 259.12 | 1.56 | −1.80 | 0.88 | 0.86 |
| 7 | −50.00 | 10.00 | 260.00 | −48.95 | 8.63 | 261.40 | −1.05 | 1.37 | −1.40 | 0.89 |
| 8 | −50.00 | 20.00 | 260.00 | −49.05 | 19.86 | 261.12 | −0.95 | 0.14 | −1.12 | 0.95 |
| 9 | −50.00 | 30.00 | 260.00 | −50.56 | 30.44 | 258.76 | 0.56 | −0.44 | 1.24 | 0.95 |
| 10 | −50.00 | 40.00 | 260.00 | −51.27 | 38.77 | 260.06 | 1.27 | 1.23 | −0.06 | 0.92 |
| 11 | −50.00 | 50.00 | 260.00 | −51.13 | 49.49 | 259.03 | 1.13 | 0.51 | 0.97 | 0.94 |

# Conclusions

- The proposed localization system can not only provide a sufficient number of markers but also reduce the interference of illumination variation and observation angle on localization accuracy, which improves the robustness of the localization system efficiently.

- The precision of the designed sensor is ±1.94 cm for position localization and ±1.64° for angle localization.

- The proposed visual localization sensor system satisfies the requirements of accurate autonomous indoor robot navigation and provides a novel indoor localization method for a home service robot.