

A Comprehensive Review of Indoor Localization Techniques for Autonomous Robots

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Indoor localization in environments without GPS poses a fundamental constraint for cost and payload limited autonomous robots, where high precision often conflicts with practical deployment; optical motion capture systems deliver millimeter level accuracy at prohibitive cost, whereas low cost vision based and radio frequency based methods provide scalable alternatives with varying infrastructure needs and performance trade offs. First, radio frequency techniques such as received signal strength indicator fingerprinting, ultra wide-band time difference of arrival, Wi Fi round trip time and Bluetooth low energy beacon schemes are evaluated in terms of deployment density, update rate and typical positioning error. Next, hybrid frameworks that fuse inertial measurement unit data with visual input via Kalman filtering or simultaneous localization and mapping are examined for decimeter level accuracy and real time operation on embedded hardware. Vision only pipelines, both marker based and marker free, are then analyzed with respect to feature detection robustness, computational load and adaptability to dynamic indoor scenes. Commercial systems illustrate the cost precision dilemma and guide performance benchmarks, while comparative analysis highlights key gaps: sub decimeter accuracy under minimal infrastructure, real time performance on resource constrained platforms and adaptive calibration across diverse settings. Finally, we advocate future research on lightweight vision centric architectures augmented by occasional radio frequency cues and online adaptation to enable accessible high precision indoor positioning for budget constrained robotic applications.

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