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# Hidden Markov Model-based 3D Path-matching using Raytracing-generated Wi-Fi Models

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## ABSTRACT

We propose an efficient approach to probabilistic 3D indoor path-matching based on Wi-Fi-signal measurements using Hidden Markov Model-based (HMM) algorithms. Given a 3D model of the building, we derive high-resolution emission probabilities (EP) and transition probabilities (TP) from raytracing-generated Wi-Fi-signal propagations using both the generated signal-strength values and the geometric information of the model. The modelling allows easy adaption to changes of router positions or the environment. Based on EP, TP, and sequences of Wi-Fi-signals, we apply HMM-based algorithms to compute the complete path probabilities. This provides a scalable, low-effort solution to derive accurate and high-resolution paths through a building.

We qualitatively compare our HMM-based algorithms with state-of-the-art Particle Filter-based (PF) algorithms for both path-matching and localization accuracy using both simulated and real-world Wi-Fi measurements. In simulation, HMM outperforms PF regarding path accuracy by an order of magnitude (PF accuracy-loss, noise-level 2dB: 107%, 4dB: 67%, 8dB: 42%, 16dB: 68%) and also performs significantly better in finding the current position (PF accuracy-loss, noise-level 2dB: 10%, 4dB: 36%, 8dB: 40%, 16dB 30%). Using real-world measurements, HMM computes the user's path 23% more accurately compared to PF while PF localizes a user 5% more accurately. Our evaluation further shows that a low-effort 3D model of a building using only five different materials for walls and doors is sufficient to achieve an average localization error below 2m.

We provide a self-contained tool to establish and combine 3D Wi-Fi models, and according EP, TP, and HMM-based path-matching and localization algorithms and show that they perform equally or better compared to existing approaches in real-world and simulation. Our HMM-based approach provides accurate Wi-Fi localization in real-time using commodity hardware and performs especially well in path-matching. This makes it also a viable tool for offline analysis to identify error-prone locations and measurements to improve localization accuracy.

**KEYWORDS**: Hidden Markov Model, Raytracing, Wi-Fi, Path-matching, Indoor localization