Contributions

In order to track and estimate the pose of rigid objects with high accuracy in unconstrained environments, we propose a framework that combines 3D particle filter with algebraic pose optimization in a closed loop. The contributions include:

1. A new Particle Filter observation model based on the proximity in 3D space;
2. Coupled tracking and algebraic pose optimization in Particle Filter framework;
3. A dynamic ROI is developed which reduces the line detection and search space for real-time application.

Particle Filter Model

Dynamic Model

As we focus on freely tumbling objects, the random walk [1] model is adapted, i.e.

\[ p(X_k|X_{k-1}) = U(X_{k-1} - v, X_{k-1} + v) \]

where \( U \) denotes uniform distribution and \( v \) is the uncertainty about the incremental movement.

Observation Model

The observation model proposed in [1]:

\[ p(y_k|X_k, Z) = \exp\{-\sum_{i=1}^S \sum_{j=1}^m \rho(\bar{N}_i \cdot F(L_j, X_k))\} \]

\[ \rho(\bar{N}_i, L_j, X_k) = \begin{cases} 1 & \text{if } \bar{N}_i \cdot F(L_j, X_k) < \varepsilon \\ 0 & \text{otherwise} \end{cases} \]

Instead of assigning only 1 or 0 to each particle, our proposed soft-assignment observation model for particle filter which is more accurate:

\[ \rho(\bar{N}_i, L_j, X_k) = \begin{cases} \exp\{-(\lambda_1 \frac{\theta}{\varepsilon_\theta} + \lambda_2 \frac{d}{\varepsilon_d})\} & \text{if } \theta < \varepsilon_\theta \text{ and } d < \varepsilon_d \\ 0 & \text{otherwise} \end{cases} \]

where \( d = (d_1 + d_2)/(P^2 + P'^2)/2 \) and \( \lambda_1 \) and \( \lambda_2 \) are designed to balance the relative importance of the angle and distance information.

Results

Experiments of tracking freely moving objects in complex environments with occlusion, light disturbances, etc. ROI: In our experiments the average FPS with and without dynamic ROI (blue rectangles) is respectively 16.2 and 5.3.

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References
