MAV Relative Localization Using a Particle Filter and an Euclidean Signed Distance Field

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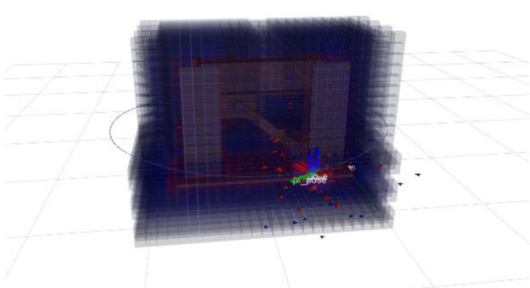
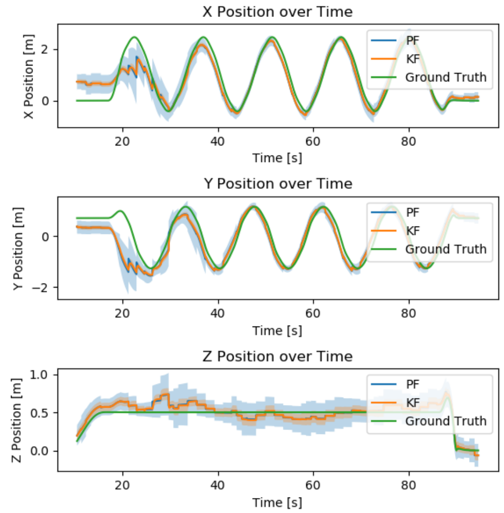
Advances in MAV (Micro Aerial Vehicle) technology have offered drastically better performance at reduced cost, opening up new fields of application for these platforms. The inspection of civil infrastructure is one such application that can benefit significantly from automation, using MAVs as sensor platforms that can safely and economically move through the environment around even hard-to-reach structures. To be able to perform many automated inspection tasks, an MAV must be able to localize itself with respect to the structure it is inspecting. For this purpose, I integrated a Euclidean distance field (EDF) based depth alignment scheme with a particle filter to perform computationally efficient relative localization using depth information captured by an on-board front-facing time of flight (TOF) depth camera.



EDF representation of a structure segment

The EDF-based particle filter localization system leverages the known geometry of most structures that are to be inspected to construct an EDF representation of the structure a priori. This is then used by the MAV to localize itself with respect to the structure as it transits the environment around it. The EDF is a voxel-grid based map representation that stores the distance to the surface of the structure from the center of each of the set of discrete volumes stored in the map. It is built out from the surface of the structure to economize storage by containing information only of areas around the surface that are most useful for localization using depth observations.

The EDF map is used to evaluate depth observations of the structure surface captured by a TOF depth sensor in terms of their alignment with the actual surface for a supposed pose of the MAV. In short, the EDF allows us to determine the probability that the MAV was in a certain pose when it took a scan of the structure. This is necessary for the particle filter generating the estimated pose of the MAV over time. The advantage of the EDF in this application is a fast and computationally efficient calculation of the probability that a depth scan originates from a hypothetical pose.



Estimated MAV position for tracking trial

Testing in simulation demonstrated the performance of the relative localization system using the EDF. Tracking of a simulated MAV orbiting a structure was qualitatively good, and depth scans were integrated into the pose estimate at a rate of approximately 1 Hz, as opposed to a rate of 0.1 Hz for an existing interim depth evaluation method. The success of the particle filter integrated with the EDF map representation paves the way for the development of a global localization system for the MAV and the integration of more advanced inspection features.