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Efficient next-best-scan planning for autonomous 3D surface reconstruction of unknown objects

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Abstract This work focuses on autonomous surface reconstruction of small-scale objects with a robot and a 3D sensor. The aim is a high-quality surface model allowing for robotic applications such as grasping and manipulation. Our approach comprises the generation of next-best-scan (NBS) candidates and selection criteria, error minimization between scan patches and termination criteria. NBS candidates are iteratively determined by a boundary detection and surface trend estimation of the acquired model. To account for both a fast and high-quality model acquisition, that candidate is selected as NBS, which maximizes a utility function that integrates an exploration and a mesh-quality component. The modeling and scan planning methods are evaluated on an industrial robot with a high-precision laser striper system. While performing the new laser scan, data are integrated on-the-fly into both, a triangle mesh and a probabilistic voxel space. The efficiency of the system in fast acquisition of high-quality 3D surface models is proven with different cultural heritage, household and industrial objects.

Keywords 3D modeling · Next-best-view planning · Active vision · Laser scanning

1 Introduction

Acquisition of 3D models is essential in several different applications, such as cultural heritage digitization, rapid prototyping and reverse engineering. Beyond these classics, the demand for high-quality 3D models in robotic applications such as object recognition, grasping and manipulation is growing. Today, 3D models of unknown objects are generated by hand-guided scanner systems, manipulators, for which scans are manually planned [22], or automatic modeling systems. The latter only work for very small, mostly convex objects or require a very large, fixed and expensive setup [14, 42]. Moreover, hand-guided scanning is a very tedious and time-consuming task for the human and the model quality strongly depends on the skill of the operator. A robotic system, which autonomously generates 3D models of unknown objects with an adjustable coverage or quality, would be highly beneficial. Object recognition for example still performs well even if the models are not nearly complete [18]. For grasp planning, models with higher quality and coverage are required [32]. However, autonomous 3D modeling of complex objects with a robotic system requires a coupling of 3D modeling methods with autonomous view planning and collision-free path planning.

In this work, we present an approach for autonomous 3D modeling of unknown objects in real time. The presented approach is not limited to a class of objects, like for example convex shapes. We tackle the problem of arbitrary objects by simultaneous exploration of the unknown environment and surface modeling of the desired object. The gathered information is used to iteratively find suitable scan paths based on the object shape and plan collision-free robot paths for these trajectories, until the desired model quality is reached. This work is mainly focused on the active scan planning aspect; however, the used concepts for modeling and path planning are summarized and important aspects are exposed to give a good overview and show the interaction between the system components. The approach is evaluated on various household, industrial and cultural

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