Real-time dense 3D reconstruction of indoor environments has been a popular research field due to its wide application, such as inspection, virtual / augmented reality (VR/AR), and service robotics. While many state-of-the-art algorithms are capable of reconstructing accurate 3D dense models in general indoor scenes, robustness is still an unsolved problem for all of them.

The robustness of indoor 3D reconstruction relies heavily on the success of localization, or state estimation to be more general. Typical challenges to successful localization include dynamic environments, loop closure ambiguities, repeated patterns, and textureless scenes, which can result in either tracking failure locally or distortion of the model globally. Even though some of the existing algorithms apply robust estimator or RANSAC to achieve better robustness, none of them has a thorough and systematic solution to deal with all of the challenges. As a result, in this talk, we will focus on solving these ambiguity problems from three aspects: front-end tracking, back-end optimization, and active perception for SLAM, which can be summarized into two proposed works as follows.

The first work is to solve the robustness problem of real-time dense 3D reconstruction in indoor environments efficiently through an ambiguity-aware SLAM framework with both front-end and back-end being capable of handling multiple hypotheses. To be more specific, a multi-hypothesis nonlinear incremental optimizer is developed to handle ambiguous measurements and output multiple possible solutions, which will be integrated with an efficient front-end visual-inertial odometry method with ambiguity detection and a submap and plane-based mapping framework to construct a simultaneous localization and mapping (SLAM) system for robust dense 3D reconstruction in real-time. The resulting robust SLAM system is expected to keep track of multiple possible solutions of the states and maps when the ambiguities are unsolvable, and output only one hypothesis when sufficient information is observed.

The second work is to develop an exploration algorithm and an active loop closing algorithm that both make use of the multi-hypothesis estimates of the states and maps from the robust SLAM system to achieve better robustness. The resulting robust active SLAM solution is expected to help human users navigate through large-scale environments and reconstruct dense 3D models even under ambiguities.