論 文 の 内 容 の 要 旨

論文題目　Dense 3D SLAM Using Multi-Resolution Volumetric Mapping and Real-Time Agile Tracking（多解像度立体地図生成と実時間敏捷追跡による稠密 3D SLAM）

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Simultaneous Localization and Mapping lies at the heart of fully autonomous mobile robotic systems. Last years have seen a prominent number of contributions to the field backed by the recent advent of cheap yet reliable commodity sensors. Successful SLAM systems lay a solid ground for achieving challenging tasks such as disaster area exploration where network latencies, non availability of previously acquired maps of any sort, severe viewing conditions ask for robots to show high degrees of autonomy and less reliability on a remote human agent. Key aspects of such SLAM systems include high speed robust tracking, online volumetric map construction, dynamic obstacles handling and reliability in challenging environments which can exhibit geometrical or photometric features scarceness. If the 2D SLAM problem has widely been tackled during the past decade, 3D SLAM and its increased load of information brings in additional challenges where memory consumption can quickly grow out of the system boundaries and straightforward tracking methods fail to keep up with real-time needs.

In the present work, we derive a solution to the full 3D SLAM problem which complies with mobile robotic systems and their tight requirements. First, we proposed a map representation with associated stepping and traversal iterators. The map bases on a limited depth octree data structure which allocates all necessary memory beforehand to avoid online data allocation latencies and guarantee memory contiguity. Memory is managed internally and allows concurrent reading and modification on multi-core hardware. Our map representation allows us to derive fast insertion, freeing, raycasting and

neighbor search algorithms. The enhanced speed we obtain is crucial to be able to build highly detailed maps online and in real-time. The memory compression is also such that large workspaces and maps can be handled. The map is essentially multiscale. The multiscale property is used by all algorithms for speed-ups but also as different points have different noise amplitude, mapping proceeds by inserting each point at the correct scale hence avoiding corruptions of more precise voxels with less precise data. Then, we proposed a real-time agile tracker which builds on the association of a direct optimization based dense photometric tracker and a model based geometric tracker. The geometric tracker builds on our map iterators to extract at high speed the exact nearest neighbor in a 3D neighborhood around candidate points and run subsequent ICP optimization. This tracker shows large basin of attraction to the minimum cost solution with a marked convexity and hence converges in few iterations only. The geometrical tracker can recover from relatively large six dimensional sensor displacements and return results at high speed. These two conditions guarantee convergence under fast and dexterous sensor motions. The photometric tracker complements the geometric tracker's behavior and adds more stability and robustness against environments with poor geometric features. The photometric tracker show tighter basin of attraction but, with good initialization from the geometrical tracker counterpart, can yield subpixel motion estimates in few iterations only. A sensor model associates each point at the input stage with a proper variance derived from a normal distribution approximation. The point noisiness is taken into account during the tracking stage to yield more noise resilient estimates. Our front-end methods are used in association with a back-end routine with runs loop closure detection and optimization and hence allows to scale up the system for large environments. Finally, all system components are blended in an architecture which solves the full 3D SLAM problem at high speed. The architecture blends tracking, sensing, map insertions, map freeing, drawing, loop detection and optimization in a concurrent way and such that, at each moment, distinct threads request different computational resources on the CPU or the GPU side. The architecture as it has been designed allows solving the full 3D SLAM problem and rendering highly detailed 3D maps in real-time without enforcing any high-end computing power requirements. Experimental results show how our framework provides with a fast and reliable solution to the 3D SLAM problem and can be used as a backbone for mobile robots operating under the most challenging conditions.