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# 摘 要

同步定位与地图构建（Simultaneous Localization And Mapping，SLAM）是人工智能领域的热门研究话题。SLAM即智能体借助自身传感器所测量的环境信息，确定自身位置和姿态，以及周围环境的三维地图的过程。SLAM技术广泛应用在自动驾驶、自主移动机器人、虚拟现实、增强现实等领域。例如，智能车通过测量周围场景信息，基于SLAM进行自身定位以及对场景的建模分析，从而及时、准确避障和规划行驶路径。家庭服务机器人借助SLAM技术确定自身位置并构建三维环境地图，以规划路径并与环境进行交互。视觉SLAM是SLAM的分支，其输入为连续的场景序列图像，输出为相机位姿和环境的三维地图。

目前，视觉SLAM 算法已取得较大进展，但仍存在诸多不足，具体问题包括：

1. 现有SLAM 算法在进行捆绑优化时，对从图像序列帧中检测到的所有特征数据，包括特征点和特征线等，不加区分地统一处理。然而，所检测特征往往包含众多噪声，干扰SLAM计算过程，导致定位精度下降。

2. 现有SLAM 算法多以定位为主，在地图构建方面的表现差强人意。比如基于直线的SLAM 算法，所重建地图质量普遍较低，存在线条不完整、杂乱等情况。

3. 不少学者将点、线等多种特征融入SLAM 框架中，以应对挑战性场景，然而这些方法在定位和建图过程中，依然将每类特征作为独立的个体，忽略了特征之间的关联，地图重建质量受限。

在综合分析前述问题的基础上，本文构建了一种基于多视角互补的SLAM技术框架。相比传统SLAM 框架，所提出框架充分利用了二维观测之间的时序关联和几何对应关系，从而有效解决前述问题。基于此框架，所开展的具体工作如下：

1. 针对现有SLAM 算法无法有效抑制不可靠特征的问题，提出利用多视角信息对三维特征进行可信度量，从而抑制不可靠数据带来的误差影响。通过实验验证了所提出的基于可信度度量的SLAM算法能够有效提升定位准确度。

2. 针对现有SLAM 算法的三维地图重建效果不佳的问题，提出构建线条序列，在位姿优化后，对序列进行端点优化，以提升端点准确度，从而提升重建地图中三维线条的完整度。通过在多个场景上的重建实验验证了所提出的融合线条序列优化模块的SLAM算法在提升建图效果方面的有效性。

3. 针对现有SLAM 算法忽略不同类型特征之间关联的问题，提出在多视角互补框架下，根据特征之间的结构关系建立复合特征。在捆绑优化时，利用复合特征优化三维地图。实验证明：所提出的融合复合特征优化模块的SLAM算法能够进一步提升地图重建质量。

关键字：同步定位与地图构建；多视角互补；捆绑优化；线条优化；复合特征优化

# **Abstract**

Simultaneous Localization And Mapping (SLAM) has become a hot topic in the field of Artificial Intelligence. SLAM is the process that intelligent agents compute their own poses and the 3D maps of surrounding environments, based on the data acquired through the sensors mounted on the agents. SLAM is widely used in automatic driving, autonomous mobile robots, virtual reality, augmented reality and other fields. For example, autonomous driving cars can locate and construct the surrounding scenes based on SLAM, to avoid obstacles and plan routes. Domestic service robots need to localize themselves and reconstruct scene maps, in order to plan the path and interact with the environments. As a branch of SLAM, Visual SLAM takes sequential images of scenes as input and outputs the camera pose at each frame and the 3D map of the sensed environment.

At present, visual SLAM technologies have been widely studied. However, there are still some shortcomings as follows:

1. Existing SLAM algorithms directly utilized features extracted from sequential images in bundle adjustment. However, the detections often contain noises, which will interfere with the optimization and deduce the accuracy in localization.

2. Most SLAM algorithms paid more attention to the localization accuracy, but their performance in mapping is limited. For example, the line-based SLAM algorithms generally reconstruct 3D maps with incomplete and unstructured lines.

3. Many scholars integrated different features, e.g. line and points, into SLAM systems, to deal with challenging scenes. However, these systems still treat each type of features separately, while neglecting the relation between them.

After comprehensive analyses on the above issues, we develop a SLAM framework supporting multi-view complementarity. Compared with the traditional SLAM framework, this framework makes full use of the temporal information and geometric relationship between 2D observations. Based on this framework, we carry out works as follows:

1. Aiming at solving the problem that existing SLAM algorithms cannot effectively suppress unreliable features, we propose to use multi-view information to measure the credibility of 3D features and suppress the negative impact from unreliable data. Experimental results show that the credibility-based SLAM obtains higher accuracy than the state-of-the-arts.

2. Aiming at solving the problem of low quality of 3D line maps, we propose to construct the matched line features into a sequence, and optimize the end points of the sequence after pose optimization. This helps improve the accuracy of the end points, and thereby improving the integrity of the 3D maps. Through the reconstruction results of multiple scenes, we demonstrate the proposed SLAM algorithm with sequential line optimization is effective in improving mapping quality.

3. Aiming at solving the problem that the relation between hybrid features was ignored, upon our framework of multi-view complementarity, we establish the structural connection between hybrid features. In bundle adjustment, the hybrid features with structural connection are used to optimize the 3D maps. Experiments show that the quality of reconstructed maps has been further improved.

**Key Words**: simultaneous localization and mapping; multi-view complementarity; bundle adjustment; line sequence optimization; complex feature optimization