基于多传感器融合的林区非结构化道路检测

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摘 要:【目的】林业工程车辆的智能化研究是进一步提高林业工程装备工作效率的有效途径和必然趋势。而林区无人作业车辆在林区复杂环境下的动态感知是实现林区无人驾驶的最大瓶颈。林区道路缺乏参照物和地图标识，受自然环境(地面障碍、地表条件、气候条件)的影响较大，这对实现林区无人车辆的自主作业提出了极大挑战。这项研究为解决林区复杂路况下无人驾驶车辆环境感知的科学问题提供了依据。【方法】本文提出了一种基于二维激光雷达和单目相机的多传感器融合检测方法用于实现林区非结构化道路识别。首先，基于单目视觉相机采集的图像信息，本研究采用了“改进 SEEDS+支持向量机（SVM）”的策略用于对道路区域的快速识别。在图像实施超像素分割的基础上，结合支持向量机对每个子区域进行分类与合并得到可行驶区域。然后，将二维激光雷达采集的点云信息，通过重投影的方式实现与图像信息的匹配与融合。通过坐标变换与 B 样条曲线拟合得到机器人坐标系下的道路模型。【结果】实验中，我们搭建了林区自主智能导航平台，并通过“公开数据集+自采集数据集”的形式构建了数据库。对本研究提出的基于多传感器环境识别策略进行了训练与测试。在北京林业大学聊城林场与鹫峰国家森林公园选取了多段林区道路进行野外实验。实验结果显示，系统处理单帧图像的平均时间可以达到 89.3ms。这表示系统能够达到 10 帧/秒的信息处理速度。同时，人工标定与程序运行结果对比也表明，图像道路区域的召回率和精确度都达到 90%以上。【结论】本研究能够满足在林区环境下自主导航平台在低速条件下的实时性需求与精度需求。为林区无人作业车辆的环境动态感知与实时监测提供了重要依据。并且，该技术对林区无人作业车辆在自主巡检，自主喷药、无人集材和运输等方面具有重要的应用价值。

关键词: 林区非结构化道路；多传感器融合；自主导航；环境感知；道路识别

Detection of unstructured roads in forest areas based on multi-sensor fusion

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Abstract:【Objective】The intelligent research of forestry engineering vehicles is an effective way and an inevitable trend to further improve the efficiency of forestry engineering equipment. The dynamic perception of unmanned vehicles in the complex environment of forest areas is the biggest bottleneck to realize unmanned driving in forest areas. Roads in forest areas lack reference objects and map signs, and are greatly affected by the natural environment (ground obstacles, surface conditions, and climatic conditions). This poses a great challenge to the autonomous operation of unmanned vehicles in forest areas. This research provides a basis for solving the scientific problem of environment perception of unmanned vehicles under complex road conditions in forest areas.【Method】This paper proposes a multi-sensor fusion detection method based on two-dimensional lidar and monocular camera to realize unstructured road recognition in forest areas. First, based on the image information collected by the monocular vision camera, this study adopts the strategy of "improved SEEDS + support vector machine (SVM)" to quickly identify the road area.On the basis of image superpixel segmentation, thesupport vector machine is used to classify and merge each sub-area to obtain the drivable area. Then, the point cloud information collected by the two-dimensional lidar is matched and fused with the image information through remapping. The road model in the robot coordinate system can be obtained by coordinate transformation and B-spline curve fitting.【Result】In the

experiment, an autonomous intelligent platform is built for forest areas navigation, and a database is constructed in the form of "public dataset + self-collected data set". The multi-sensor environment recognition strategy proposed in this study was trained and tested. In the Liaocheng Forest Farm of Beijing Forestry University and Jiufeng National Forest Park, several forest roads were selected for field experiments. The experimental results show that the average time for the system to process a single frame of image can reach 89.3ms. This means that the system can reach an information processing speed of 10 frames/s. In addition, the comparison between the manual calibration and the program running results also shows that the recall rate and accuracy of the image road area have reached more than 90%.【Conclusion】This research can meet the real-time requirements and accuracy requirements of the autonomous navigation platform in the forest environment at low speeds. It provides an important basis for environmental dynamic perception and real-time monitoring of unmanned operating vehicles in forest areas. This technology also has important application value for forestry engineering vehicles in autonomous inspection and spraying, nursery stock harvesting, skidding, and transportation.

Key words: Unstructured road in forest area; multi-sensor fusion; autonomous navigation; environment perception; road recognition.