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ORB-SLAM2 EVALUATION FOR ELECTRICAL POWERED WHEELCHAIR TRAJECTORY ESTIMATION

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ABSTRACT

This work deals with the implementation, tests of a well-known and on-the-shelve visual Simultaneous Localization and Mapping (vSLAM) algorithms: ORB-SLAM2 proposed by Mur-Atal & al. The main objective of this evaluation deals with the implementation of a low-cost trajectory estimation functionality on-board of an electrical powered wheelchair equipped with driving assistance technologies. The benchmark has been carried out with an Intel RealSense D435 camera mounted on top of a robotics electrical powered wheelchair running a ROS platform. The ORB-SLAM2 has been implemented taking into account a monocular, stereo and RGB-D camera. Several experiments have been carried out in a controlled indoor environment at the ESIGELEC's Autonomous Navigation Laboratory. Different motion scenarios have been used to test the SLAM algorithm in various configurations: straight-line, straight-line and back, circular path with loop closure, etc. These experiments have been supported by the use of the VICON motion capture system used as a ground-truth to validate our results.

Keywords Visual SLAM, ORB-SLAM, Trajectory estimation, Localization, Powered wheelchair

1 Introduction

Estimating the camera trajectory while simultaneously reconstructing the environment is a key and well-know problem in robotics and computer vision. This can be achieved by the use of different measuring means (LIDAR, RADAR) and algorithms (particle filter, extended Kalman filter, GraphSLAM). When cameras are used SLAM techniques are named as visual SLAM (vSLAM). vSLAM algorithms have been widely proposed in the field of computer vision and robotics. Taketomi & al. [1] proposes an exhaustive survey of real-time vSLAM algorithms developed from 2010 to 2016.
In this paper we evaluate the vSLAM algorithm ORB-SLAM2 proposed by Mur-Atal & al in 2017 [4] . This evaluation fits within the framework of the ADAPT project ("Assistive Devices for empowering disAbled People through robotic Technologies") for which driving assistance functionalities are implemented on a standard powered wheelchair to ensure the patient a safe driving. One requirement is related to the estimation of the path carried out by the patient during the clinical trials so as to evaluate the driving capabilities or the effect of the driving assistance in relation with an ideal trajectory. This algorithm has been evaluated using an Intel RealSense D435 camera mounted on top of the ESIGELEC's robotics wheelchair which runs the ROS Kinetic middleware. ORB-SLAM2 has been tested for a monocular, stereo and RGB-D camera. Several experiments have been carried out in a controlled indoor environment at the ESIGELEC's Autonomous Navigation Laboratory. These experiments are supported by the use of the VICON motion capture system used as a ground-truth to validate our results. Different motion scenarios have been implemented to test and benchmark the vSLAM algorithm: straight-line, straight-line and back, circular path with loop closure.
The paper is organized as follows: a bibliographic review of SLAM is proposed in section 2. Section 3 presents the experimental setup. Section 4 gives an overview of ORB-SLAM2. Section 5 illustrates preliminary results. The last section 6 gives a conclusion and perspectives.

2 Related Works

In robotics, Simultaneous Localization and Mapping (SLAM) is the computational problem of constructing or updating a map of an unknown environment while simultaneously keeping track of an agent's location within it. While this initially appears to be a chicken-and-egg problem there are several algorithms known for solving it, at least approximately, in tractable time for certain environments.
One possible classification of SLAM algorithms relies on how the SLAM algorithms use the information from the received image [16]. On a one hand, the SLAM indirect algorithms extract features from the images and use them to estimate the pose of the camera and build the map. The features can be edges or corners or more sophisticated ones obtained by specific feature descriptors such as ORB, FAST, SIFT. Since the indirect methods use only a subset of the image information, they lead to sparse representation of the map. A pioneering method is MonoSLAM presented in 2007, allowing to simultaneously estimate the pose of the camera and the 3D structure of an unknown environment using an Extended Kalman filter (EKF) [14]. The 3D camera movement (6 DOF) and the 3D positions of the features are represented by a state vector of EKF. PTAM offers an improvement by separating tracking and mapping in different threads of the CPU [15]. PTAM also introduced the use of keyframes for mapping as well as a feature classifier to search for the keyframe closest to the input image. ORB-SLAM can be considered as an extension of PTAM including features such as separate threads and keyframes, the detection of loop closures and the optimization of the poses graph [3]. ORB-SLAM [3], introduced in 2015, is the most complete indirect monocular vSLAM method and has been extended for stereo systems and RGB-D systems in ORB-SLAM2 in 2017 [4].
On the other hand, direct methods use the pixel intensity based on a photometric error estimation to locate the camera and build the map. The direct methods use the information from the entire images and provide a dense representation of the map. A completely direct method is DTAM which, like PTAM, has two distinct parts: pose tracking and mapping [5]. However, PTAM tracks a set of 3D points while DTAM maintains dense depth maps for a selection of keyframes. The most representative method in the category of direct methods is LSD-SLAM (Large-Scale Direct SLAM) which is a monocular SLAM algorithm [6]. The map is constructed based on keyframes composed of camera image, a map of the inverse depths (inverse depth map) and the variance of the inverse of depths.

3 Experimental Setup

3.1 ESIGELEC's robotics wheelchair

The robotics electrical powered wheelchair from the ESIGELEC's lab is an Invacare Bora wheelchair from which all the proprietary electronics has been removed and replaced by an embedded PC running Ubuntu 16.04 LTS, a motor driver from Roboteq and a wireless Xbox joystick. The wheelchair software is based on ROS. Figures 1 and 2 give an overview of the different parts of the wheelchair and its hardware architecture.

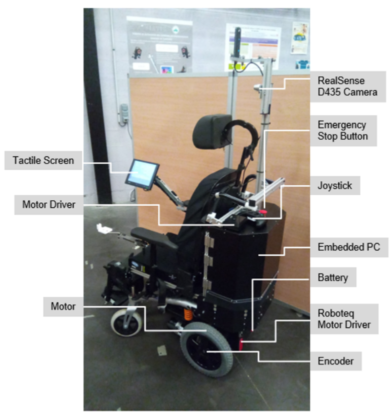

Figure 1: ESIGELEC's robotics wheelchair overview

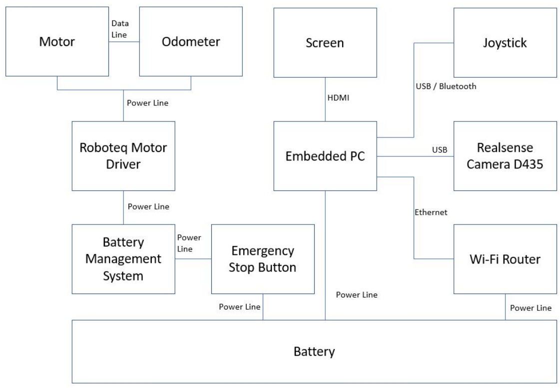

Figure 2: Hardware architecture of the wheelchair

3.2 ESIGELEC's autonomous navigation laboratory

The ESIGELEC's autonomous navigation laboratory (Laboratoire de Navigation Autonome - LNA) is a 10 x 15 x 5 m^3 space located in the CISE building at ESIGELEC (see figure 3). It is equipped with different technologies of sensors to conduct and validate robotics-based experiments. A VICON motion capture system using 20 cameras T40S is installed in the lab to cover the entire space for marker position tracking. As discussed by Merriaux & al. [2], the VICON positioning error is lower than 2mm in dynamic. This system will be used as the ground truth to evaluate the distance measurement estimated by the SLAM algorithms.

Figure 3: Autonomous navigation laboratory (LNA) at ESIGELEC

4 ORB-SLAM2 Overview

ORB-SLAM2 is a real-time SLAM library for monocular, stereo and RGB-D cameras that computes the camera trajectory and a sparse 3D reconstruction. It is able to detect loops and re-localize the camera in real time. The system works in real-time on standard CPUs in a wide variety of environments from small hand-held indoors sequences, to drones flying in industrial environments and cars driving around a city. The back-end based on bundle adjustment with monocular and stereo observations allows for accurate trajectory estimation with metric scale. The system includes a lightweight localization mode that leverages visual odometry tracks for unmapped regions and matches to map points that allow for zero-drift localization. The main functionalities of ORB SLAM are: feature tracking, mapping, loop closure and localization.

5 Results

The tests were carried out into the LNA for the indoor scenarios and in the ESIGELEC's car park for the outdoor ones. The evaluation criterion is based on a distance measurement. Different scenarios have been conducted to evaluate the algorithm: from strait line to circular trajectories so as to test SLAM techniques in different configurations. Figure 4 illustrates paths carried out in the LNA (indoor scenarios) and in outdoor for trajectories carried out in the ESIGELEC's car park. The ground truth has been provided by the VICON system for the indoor scenarios. A measuring tape has been used for getting the ground truth for the outdoor tests.

The Table 1 below summaries the distance measurements for the various paths carried out in indoor and outdoor.

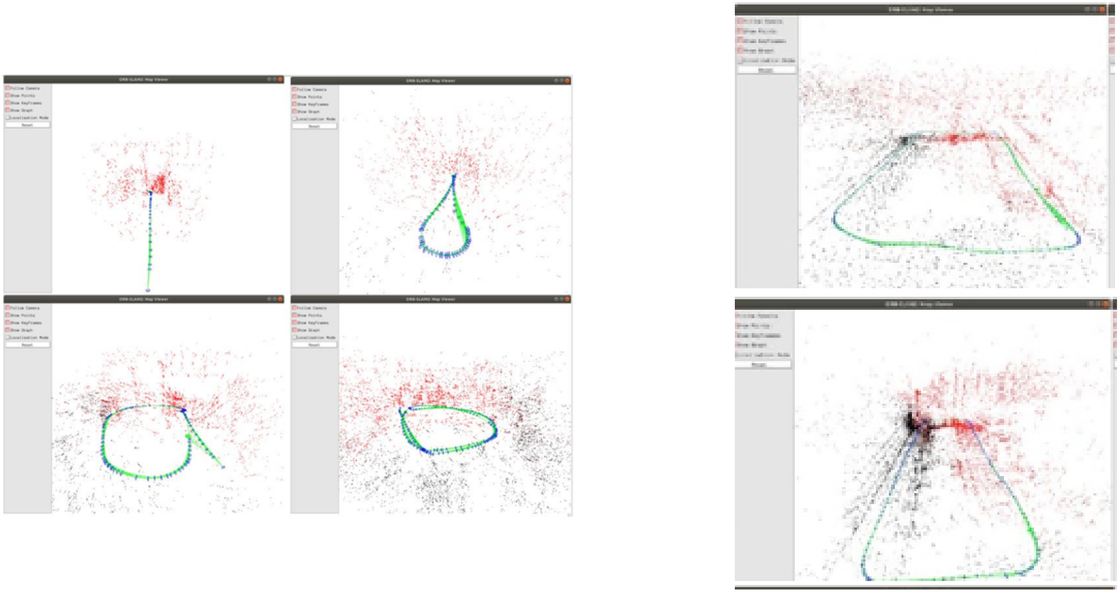

Figure 4: Map and Trajectory estimations given by ORB-SLAM in indoor (left) and outdoor (right) environments

Table 1: Summary of distance measurements obtained with ORB-SLAM in stereo and RGB-D modes. Ground truth is given by the VICON system (all distances are in meter)

Scenarios	Ground Truth	ORB Stereo	ORB RGB-D
Indoor 1	7.82	7.69	7.16
Indoor 2	6.98	7.38	6.81
Indoor 3	15.05	15.49	14.32
Indoor 4	21.75	21.17	21.31
Indoor 5	29.69	21.47	22.13
Indoor 6	37.69	38.84	38.79
Outdoor 1	28	28.85	19.27
Outdoor 2	28	27.29	17.83
Outdoor 3	56	56.63	37.25
Outdoor 4	92	94.55	65.87
Outdoor 5	92	95.8	66.97
Outdoor 6	80	84.38	66.24
Outdoor 7	80	81.9	63.36
Outdoor 8	160	172.6	129.41

Comparisons of trajectories between ORB-SLAM and VICON data have been made to evaluate the relevance of the algorithm. The Figure 5 shows this trajectory comparison.

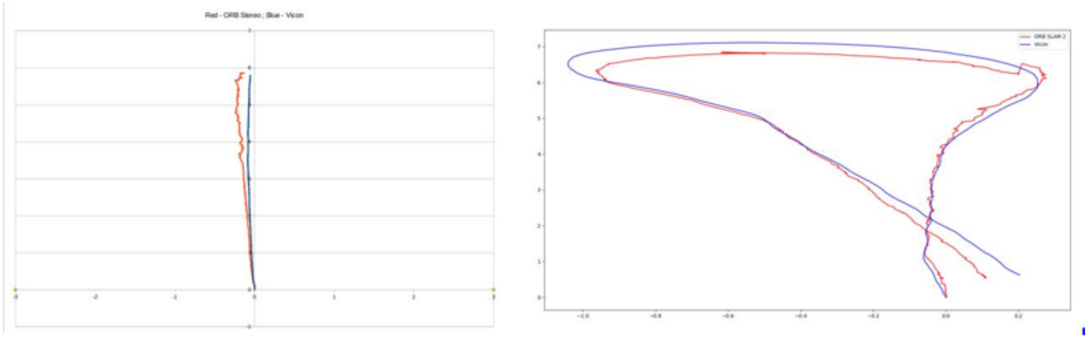

Figure 5: ORB-SLAM and VICON trajectory comparisons for strait line and curved paths

6 Conclusion

In this paper, we have presented a wheelchair localization and mapping-based vSLAM for both indoor and outdoor environments. An evaluation study for the ORB-SLAM2 algorithm has been developed. The whole algorithm has been validated under the ESIGELEC's robotics powered wheelchair platform for indoor and outdoor scenarios. Regarding the indoor scenarios, a VICON motion capture system has been used as the ground truth. The results highlight a good accuracy of ORB-SLAM regarding the criterion of the estimated path distance. Next we propose to continue the evaluation of this algorithm by comparing the estimated poses. We will use the traditional metrics available on the literature, such as the Absolute Trajectory Error (ATE), the Relative Trajectory Error (RTE) as presented by Sturm et al. [17]. An other axis of work will deal with the aggregation of other "on-the-shell" SLAM algorithms so as to build an up-to-date visual SLAM benchmark.

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