

A NEW RADAR SENSOR FOR MOBILE ROBOT LOCALIZATION AND MAPPING IN EXTENSIVE OUTDOOR ENVIRONMENT. FIRST RESULTS

R ROUVEURE¹, P FAURE¹, MO MONOD¹

(1) Cemagref - TSCF Reseach Unit, Aubière, France.

In this paper we present a new sensor for mobile robot dedicated to obstacle detection, localization and mapping in extensive outdoor environments.

Radar scanner principle. The sensor is based on microwave radar technology. Laser and video based sensors are common visually based sensors, particularly well adapted in indoor environments. But these systems are affected by visibility conditions that are often poor in outdoor environments: day/ night cycles change illumination; weather phenomena (fog, rain, etc.); dust clouds; etc. Sonar is an other common sensor not affected by visibility restrictions, but it is mainly affected by a limited maximum range and a poor angular resolution due to its beamwidth. Faced with these limitations, millimeter wave radar provides an alternative solution for environmental imaging and overcomes the shortcoming of laser, video and sonar sensors.

The developed radar uses a frequency modulation continuous wave (FMCW) principle: the transmit frequency is modulated with a linear law (triangular or sawtooth). If there is a target at a distance R , an echo signal will return after a time delay $t = 2R/c$. The measured beat frequency F_b , which appears at the receiver, represents the difference between the emitted frequency and the frequency received after reflection on the target, and is proportional to R . The radar is equipped with a rotating antenna in order to achieve a complete 360° monitoring around the vehicle, with an angular resolution of 1° , in the range 3-100 m. The antenna angular rate $\omega = 360^\circ/\text{s}$ and allows to construct one radar image each second. Microwave architecture, electronic cards (modulator, filter/amplifier, DC alimentation) and signal processing unit are integrated in the same housing. Data acquisition and signal processing are achieved with a Pentium M processor board. Computed radar data can be visualized directly on the radar (via a display connector), or transmitted for further treatments through an Ethernet link.

Simultaneous Localization And Mapping. Global Positioning System (GPS) is a satellite based localization system, capable of providing a global location estimate at any point on the planet. But an exclusive use of GPS for outdoor localization is hazardous because of different problems: the necessity to have direct line-of-sight between the satellite and the GPS receiver; the level of precision necessary for autonomous navigation (less than one meter) requires simultaneous line-of-sight of at least five satellites; reflection of the satellite signal on objects in the environment can result in multipath errors (with overestimation of distances). When GPS is intermittently available or completely unavailable, alternative localization methods must be used. In this context, Simultaneous Localization And Mapping (SLAM) represents the higher level of complexity in autonomous mobile robot applications. Ideally, SLAM allows to incrementally construct the map of unexplored environments and to achieve localization in the map without human intervention.

In complex outdoor environments, landmarks which are detected by the radar cannot be model as simple geometric primitives, such as points or lines. Computed radar images contain a large amount of information, so detection and tracking of particular landmarks are not simple problems. For that reason we have selected a matching approach based on cross correlation function. This approach is purely radar based, and makes no landmark assumptions, and we avoid the data association problem by storing a detailed map instead of sparse landmarks, thereby subsuming association with localization.

The first presented experimental result concerns radar image construction. Considering N elementary reflectors present within the radar resolution cell (the radar beamwidth in our case), the sum of the phase of the N reflected signals introduces a random amplitude modulation of the measured radar signal, called speckle effect. To decrease this speckle effect and to build a coherent radar image, a solution is to aggregate a series of images, acquired during the displacement of the radar. This phase is achieved over a period of dead reckoning, by integrating estimates of its motion (odometer and compass sensors).

The second experimental result concerns SLAM process. Radar and odometric sensors are mounted on an utility car. The car is driven at a speed up to 4 m/s. The experimental runs are performed in the car park of our institute, with a "rich" environment (buildings, cars, trees, roads, road signs, etc.). For this initial phase, only qualitative results are presented because no other localization system was available for comparison with the map and localization estimates. The estimated map is superimposed on an aerial view of the experimental zone.