ANALYSIS AND IMPLEMENTATION OF LOCALIZATION AND MAPPING ALGORITHMS FOR MOBILE ROBOTS BASED ON RECONFIGURABLE COMPUTING

M. C. SACCHETIN, J. J. LOPES, D. F. WOLF, J. L. SILVA and E. MARQUES

Computer Systems Department, University of São Paulo
Av. Travaihalor São-carlense, 400 – centro - CEP: 13566-970, São Carlos - SP, Brazil
e-mail: {sacchet.joelmir.denis.jsilva.emarques}@icmc.usp.br
http://www.icmc.usp.br

Abstract— Localization and Mapping are fundamental problems in the field of mobile robotics that have been receiving considerable attention of the scientific community in the last ten years. Most of the work in this area is developed using personal computers and it still a challenge to execute these algorithms on embedded systems. This paper describes the analysis and embedded implementation of particle filter and occupancy grid algorithms, used for localization and mapping respectively. Experimental results and performance analysis were obtained using the softcore Altera Nios II running on Stratix II FPGA devices.

Keywords — Embedded Systems, Mobile Robotics, Localization, Mapping.

I. INTRODUCTION

In the last years a considerable amount of research in mobile robotics has been focusing on localization and mapping. Particularly, the problem of simultaneous localization and mapping (SLAM) has been receiving attention from the researchers in the field. A large part of the approaches for these problems are based on probabilistic theory.

Some works describe theoretical proofs of the convergence of the problem (Dissanayake et al., 1999), experimental verification of the adaptation of the robot behavior to improve the precision (Leonard and Feder, 1999) and different implementations for robots in external and internal environment (Leonard and Feder, 1999) (Castellanos et al., 1999). However, those solutions are developed to solve a conceptual problem that in most cases requires a large amount of computation to be executed in real time. As most of these implementations are design to be executed on personal computers, embedded solutions for these problems still pose challenges due to their computation limitations.

This paper presents an embedded implementation for particle filter and occupancy grid algorithms, used respectively for mobile robot localization and mapping. Our approach is based on code originally developed in C language, which was analyzed and modified to be executed on an embedded system based on a field programmable gate array (FPGA) device.

The rest of the paper is organized as follows. Section II presents an introduction for the FPGA technology. Section III describes the particle filter algorithm, used for robot localization. A brief description of the occupancy grid algorithm used for the mapping is presented in the Section IV. Section V describes the implementation of the algorithms in FPGA. Section VI presents the experimental results and Section VII shows the conclusions and proposes some future work.

II. FPGA TECHNOLOGY

With the evolution of the micro-electronics, FPGA becomes an intermediate element among the General Purpose Processors and Application Specific Integrated Circuit (ASIC) (Dehon,1996). A specific application project, in general, is very inefficient or inappropriate for others applications. Due to the possibility of reconfiguration of the circuits, a FPGA can operate as a variety of specific architectures (Cappelletti, 2001).

A FPGA is a digital integrated circuit that contains a regular structure of configurable cells and a programmable interconnection, and can be used to implement arbitrary digital systems, limited for the number of cells and available interconnections. When a FPGAs is configured for some application, it can be viewed like ASICs (Hauck, 2000).

As in general-purpose processors, FPGAs are programmed after the production to solve many computational tasks. However it is possible to explore the parallelism of the application program implementing different parts of the program, inside of the FPGA. As an example, some parts of the program can be executed in a regular general-purpose processor (which can be placed inside the FPGA) and the intensive computational part of the code can be executed on dedicated hardware parts of the FPGA. This can result on a considerable performance gain when compared to traditional software implementations executed on general-purpose processors.

III. PARTICLE FILTER

Particle filter is a sampling-based estimated method derived from the Bayes filter (Dellaert et al., 1999). In the mobile robotics localization context, each particle corresponds to the possibility of the robot being at a specific position. This localization method requires some previous knowledge about the environment, usually represented as a map. Particles propagation (action model) is