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Sensible Things that Communicate

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Real-time optical position sensing on FPGA

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Machine vision systems are becoming increasingly popular in automated surveillance, the process control industry and in robotic navigation. The advancements in the machine vision system are due to technological developments in optical engineering and processing platforms. Time critical and battery operated machine vision systems should have low power consumption and a short response time to external events, which demands robust and efficient hardware architectures.

The focus of this thesis is a presentation of a real-time machine vision system for optical positioning. Optical positioning has capture4d the interest of many researchers due to the rapid development in optical engineering and the advancement in real-time processing platform. Real-time optical positioning has become more significant, particularly in environments there Global Navigation Satellite System (GNSS) signals are attenuated and their accuracy is low. Real-time optical positioning is well suited to the mobile robotic application such as logistics and transport application in large warehouses and robotic inspection in harsh environments such as in nuclear and biological plats. Real-time optical positioning requires a good reference structure, an image sensor and a processing architecture. The reference symbol was designed, with the focus on the hardware computation platform.

Firstly, there is a presentation of the hardware architecture for the connected image component labeling and feature extraction. The targeted application area involves light spots or reference symbols which are uses as references for robotic navigation. The developed architecture has a high frame speed and a low latency. The developed architecture contains basic image component features such as Centre of Gravity (COG), area and bounding box. The architecture can be further extended with additional components as per an application requirement. The synthesis results show that it is possible to process up to 390 frames per second of size 640x480 pixels. The developed architecture suits the smart camera application where only processed and refined information is used for decision making or transmission to the base station. Three smart camera architectures are also evaluated and recommendations are provided in relation to their usage depending on the performance requirement. The three smart camera architectures chosen for evaluation are: commercially available software base smart camera, smart camera system using single Field Programmable Gate Arrays (FPGA) chip having hardware modules and soft-core processor and a smart camera system using hardware modules on a FPGA and an external microcontroller.

Secondly, the designing of a reference symbol is presented, which is suitable for optical navigation. The selection of foreground and background colors used to print the reference symbols was optimized. Experiments show a slightly smaller SNR for the color symbols as compared to those obtained then using a monochrome technique. However, the number of segmented image components is significantly reduced by up to as much as 79 percent as compared to the case when using a monochrome technique. The designed symbol is circular in shape and contains eight bit information. The experimental results show the symbol is rotationally independent and can be decoded correctly up to a distance of 10,7 meter at a 90º angle of the image sensor to the reference symbol. Camera calibration is also performed when known symbol position. The camera can be positioned in a corridor with an absolute error of 3 cm with regard to position and an 8º in rotation along the z-axis.

Finally, the real-time decoding of the designed reference symbol based on hardware-software co-designed platform will be presented. The data component labeling, feature extraction and Region Of Interest (ROI) in a segmented image have been captured at the register transfer level. The less data intensive processing is handled by a 32 bit micro-controller.