

THE 13TH CONFERENCE OF PHD STUDENTS IN COMPUTER SCIENCE

Volume of short papers

CS²

Organized by the Institute of Informatics of the University of Szeged



June 29 – July 1, 2022
Szeged, Hungary

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Preface

This conference is the 13th in a series. The organizers aimed to bring together PhD students working on any field of computer science and its applications to help them publishing one of their first papers, and provide an opportunity to hold a scientific talk. As far as we know, this is one of the few such conferences. The aims of the scientific meeting were determined on the council meeting of the Hungarian PhD Schools in Informatics: it should

- provide a forum for PhD students in computer science to discuss their ideas and research results;
- give a possibility to have constructive criticism before they present the results at professional conferences;
- promote the publication of their results in the form of fully refereed journal articles; and finally,
- promote hopefully fruitful research collaboration among the participants.

The papers emerging from the presented talks will be invited to be considered for full paper publication the *Acta Cybernetica* journal.

Szeged, June 2022

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Measurement Automation of MOSFETs and Other Electronical Components Using Artificial Intelligence, Neural Networks and Computer Vision

Gergő Bendegúz Békési, Péter Ekler, Ágnes Urbin and Szilárd Szőke

Abstract: T3Ster provides an opportunity for thermal examination and identification in field of automotive electronics. T3Ster measurements can be performed more economically and competitively with robotization, which requires a vision system. This paper presents the hardware selection and the artificial intelligence (AI) based software development of the vision system using fully convolutional networks (FCN) and machine learning (ML) algorithms.

Keywords: artificial intelligence, machine learning, fully convolutional neural network, computer vision, image processing, optics, T3Ster, MOSFET

Introduction

Due to global trends such as electrification, proliferation of smart devices, increasing electrical energy consumption, the expansion of electronics and automotive electronics, and the growing popularity of electric cars, special emphasis is being placed on the electronics industry, including the power transistor industry. These electronic devices must deal with more and more heat power, because of their increasing electrical energy consumption, although their surfaces are getting smaller and smaller by the time. This trend is a serious technical challenge, because too high temperature is the leading cause of failure. Thus, thermal examination and identification is extremely important, which can be performed by T3Ster equipment [1]. We with the ThID team at Robert Bosch Kft. participated in a project that automated and accelerated T3Ster measurements.

We developed a vision system as a complex electronic device for a robot made of CNC 3018 Pro, controlled in a LabVIEW environment. As a result, our system can help the robot to detect the MOSFETs and other electronic components. After that, the robot can automatically measure them. We also developed the hardware and software for the system. We selected a camera with appropriate sensor (Sony IMX477) and optics (Waveshare Electronics 8-50mm Zoom Lens), and implemented a server platform capable of serving several computers that would control or monitor the measurement at the same time with the help of a Raspberry Pi 4 Model B. In Autodesk Inventor Professional 2022, we designed the tool that supports mechanical integration and then created a prototype with a 3D printer. In the most emphatic part of our work, we performed semantic segmentation and keypoint detection for robot navigation using artificial intelligence, fully convolutional neural networks, and computer vision algorithms. We implemented the fully convolutional neural networks and created the dataset necessary for the teaching. That dataset was made with the camera and optics that are used in real measurements and annotation happened manually. We have studied neural networks comprehensively. Using automated runs, we taught and evaluated networks, modifying depth, number of channels, resolution, and batch size. We did these in the open-source Python 3 programming language primarily using the OpenCV [2], Pytorch [3] and Torchvision [4] libraries.

The following sections of this paper focus on the image processing part of the described project which consists of two parts. The first part is the selection of the optics and sensor that is detailed in Section 2. The second part is the software development which is presented in Section 3. Finally, Section 4 summarizes the results and tells the conclusions.

Selection of the camera system

In this section, we describe the selection of the optics and sensors for the system to achieve the 100 μm accuracy required to navigate the robot properly.

Calculation of the range of the focal length to select the lens

The accuracy requirement mentioned in Section 2 can be fulfilled in two steps. In the first step, the adequate range of the focal length has to be estimated. It is an estimation because in the first step the difference between the object distance and the object distance measured from the lens is unknown. Thus, these are taken to be the same and clarified in the second step.

Furthermore, the object is assumed to be located along the optical axis for each measurement. So, based on the laws of industrial optics, the required range of focal length (f) can be calculated from the number of the pixels of the smallest part to be observed (a), the pixel size (px), the object distance (s), and from the size of the smallest part to be observed (x).

$$f = \frac{1}{\frac{x}{a \cdot px \cdot |s|} - \frac{1}{s}} \quad (1)$$

Selection of sensor

After having the lens a sensor has to be selected. Based on the technical parameters of the lens, a can be defined as a function of px , and s can be distinguished from the object distance measured from the lens (s_0). In equation (2) d is the total length of the lens.

$$a = \frac{x}{px} \cdot \frac{1}{|s_0 - d + f|} \cdot \frac{1}{\frac{1}{f} + \frac{1}{|s_0 - d + f|}} \quad (2)$$

It is advisable to choose px so, that a remains within the [5; 15] range for every possible f . The value of a is important to be well selected for two reasons. If a is too large, the entire MOSFET will not be detected. And if a is too small, the smallest part is not well detectable.

Software development

After performing the hardware tasks of image processing, the software implementation can take place. It basically consists of configuration, semantic segmentation, and keypoint-based displacement calculation.

Configuration

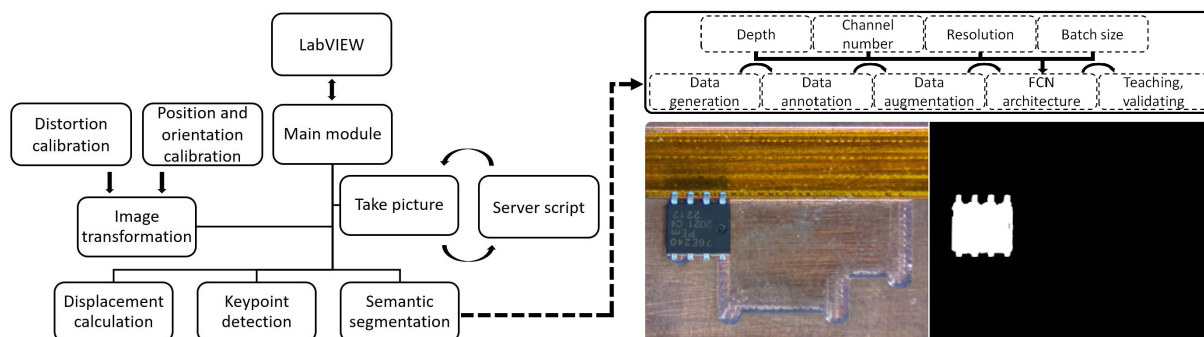
Radial distortion must be eliminated during configuration. In doing so, calibration can be performed based on the conventional distortion approach according to [5]. This is a nonlinear optimization using the Levenberg-Marquardt algorithm. The camera matrix is calculated by SVD decomposition.

Another calibration is the calibration of the position and orientation of the optical system. It can be performed with the built-in functions of OpenCV [2], applying a perspective transformation based on four known points in the calibration image.

Semantic segmentation

After having an undistorted image, semantic segmentation has to be performed to specify the region of interest (RoI), where the keypoints have to be found for navigation. As a result

of a detailed literature search, we found FCNs to be the most suitable for this task because conventional ML algorithms, like k-means clustering did not give an accurate solution [6]. The effectiveness of FCNs is confirmed by both [7], [8] and [9].



Keypoint detection for displacement calculation

probability of their existence, this approach can correct the effect of small semantic segmentation errors on the workflow by using the best 50% of the detections.

Performance and overview

The semantic segmentation was rated with the internationally accepted Intersection over Union (IoU) metric used in OpenCV. With a train-validate-test ratio of 233-111-111, we achieved a validation result of 93.78% and a test result of 94.01%. The best was the 5-depth, 8-channel, 4-batch neural network with the resolution of 576 x 896. The displacement calculation was tested in 50 cases with a calliper and every time the error of the calculation was in the 50 μm - 100 μm range. The error of the rotation calculation was always under 1°. So, the most important requirements were fulfilled.

All in all, we created an electronic system consists of the sensor, the lens and the Raspberry Pi 4 Model B, with a robust implementation of navigation to the components, that are measured. A significant advantage of the developed system is that it is not necessary to perform manual preparation on the components to be measured. This method therefore increases the number of components that can be measured per unit time by more than ten times. We achieved 100 μm and 1° accuracy, which was associated with an IoU value of 94% accuracy for semantic segmentation. We tested our system in the real, original measurement environment. So, our work is absolutely applicable for additional scientific and industrial projects. Furthermore, using the FCNs and SIFT algorithm together, that helped to reach presented results, is a new approach.

Acknowledgements

We wish to thank to Robert Bosch Kft. for supporting this project under the Bosch Engineering Students Team Scholarship.

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