I. IDENTIFIKAČNÍ ÚDAJE

Název práce: Automatic Optical Inspection of Printed Circuit Boards	
Jméno autora: Bc. Ondřej Kunte	
Typ práce: Diploma thesis	
Fakulta/ústav: Faculty of Electrical Engineering,	
Katedra/ústav: Department of Cybernetics	
Oponent práce: RNDr. Zuzana Berger Haladová PhD.	
Pracoviště oponenta práce: Faculty of Mathematics, Physics and Informatics, Comenius University in Bratislava, Slovakia	

II. HODNOCENÍ JEDNOTLIVÝCH KRITÉRIÍ

Zadání

Assignment of the thesis seems to be very ambitious. Automatic visual inspections systems of non-trivial products (such as PCB) usually require very complex solutions combining both computer vision algorithms and hardware (cameras, lighting, coating...). The goal of analysing both plain and assembled boards also resulted in not doing any of these accurate enough.

Splnění zadání

Posuďte, zda předložená závěrečná práce splňuje zadání. V komentáři případně uveďte body zadání, které nebyly zcela splněny, nebo zda je práce oproti zadání rozšířena. Nebylo-li zadání zcela splněno, pokuste se posoudit závažnost, dopady a případně i příčiny jednotlivých nedostatků.

As I already mentioned in the previous section, assignment seems to be very ambitious and therefore was hard to achieve. Author himself stated that his system is not precise enough to detect less than 10 mil wide errors which are common in production of plain PCB's. He also claimed Assembled Board inspection success rate of 93% as inaccurate for real production. On the other hand, author designed and constructed functional low cost setup for image acquisition and proposed and tested several methods for visual inspection.

Zvolený postup řešení

Posuďte, zda student zvolil správný postup nebo metody řešení.

I will comment separately on hardware and computer vision part.
Hardware: Author reviewed several State of the art industry and low cost solutions, studied the illumination techniques and designed and constructed hardware setup including lightning and coating. I appreciate the usage of 2 different cameras and the design of hardware for color contrast enhancement controlled by the light illumination, which was unfortunately not used during testing.
Computer Vision: In the first part of the thesis author reviewed the previous works. I think more time spent in this phase would help him with his visual inspection solution (I comment more on this in bibliography section). In the methodology section author provided a list of possibly useful computer vision algorithms. Then he proposed some solutions on two problems: Plain PCB and Assembled PCB automatic visual inspection. Afterwords author acquired dataset and provided some testing. I personally lack the division on the database on training/validation/testing and comparison of his solution to other solutions.

Odborná úroveň

Posuďte úroveň odbornosti závěrečné práce, využití znalostí získaných studiem a z odborné literatury, využití podkladů a dat získaných z praxe.

In the thesis author describes his approach for both plain and assembled board inspection. He has proposed and tested several approaches to compare the test board against the golden (benchmark) board.
However it is often not clear why the methods were chosen and what benefit they provide. Author writes "*Threshold limits were taken from the color library which had been estimated in advance experimentally. The final operation of threshold process is a combination of results from all color spaces. Experimentally, it was discovered that the logical combination of....*" but does not provide any details on what kind of experiments were carried out. Another issue of this thesis is the validation step. Proposed (hardware or software) solution was not compared to any other existing solutions. It will be beneficial to compare (at least theoretically) the parameters and the performance of proposed solution with low-cost and industry solutions (at least to those) mentioned in the paper. Some (minor) formal issues:
 "*The base colors are L* (light)...*" **channels**
"*Significant improvement can be achieved with opening or closing operations. The desired effect is sometimes obtained with several iterations.*" **this is not true as these operations are idempotent**

"*The tested image is calibrated against camera distortion*," **image is undistorted using camera parameters?**

Formální a jazyková úroveň, rozsah práce

Posuďte správnost používání formálních zápisů obsažených v práci. Posuďte typografickou a jazykovou stránku.

Although the thesis was nicely formatted and quite well readable,
there were some language problems: ...*towards a area...*, *...caused mainly because of...*, *This fact had to taken in consideration...*,**...**
I appreciate the vignetting adjustment of photographs illustrating the final setup.

Výběr zdrojů, korektnost citací

Vyjádřete se k aktivitě studenta při získávání a využívání studijních materiálů k řešení závěrečné práce. Charakterizujte výběr pramenů. Posuďte, zda student využil všechny relevantní zdroje. Ověřte, zda jsou všechny převzaté prvky řádně odlišeny od vlastních výsledků a úvah, zda nedošlo k porušení citační etiky a zda jsou bibliografické citace úplné a v souladu s citačními zvyklostmi a normami.

Author cited only 3 works on Visual inspection of PCB, however after 10 minutes of search on google scholar I myself found several papers which will be (even more) relevant for the work, and haven't been taken into consideration:
GANAVI, V. M.; RAO, Mahesh. Printed Circuit Board Assembly Defects Detection Using Image Processing Techniques. International Journal of Engineering Science, 2016, 7824.
IBRAHIM, Zuwairie; AL-ATTAS, Syed Abdul Rahman. Wavelet-based printed circuit board inspection system. International Journal of signal processing, 2004, 1.1: 73-79.
CHO, Han-Jin; PARK, Tae-Hyoung. Wavelet transform based image template matching for automatic component inspection. The International Journal of Advanced Manufacturing Technology, 2010, 50.9: 1033-1039….
Citations of websites (for reference of used hardware) and books/papers (for reference on image processing techniques) where done correctly.

Další komentáře a hodnocení

Vyjádřete se k úrovni dosažených hlavních výsledků závěrečné práce, např. k úrovni teoretických výsledků, nebo k úrovni a funkčnosti technického nebo programového vytvořeného řešení, publikačním výstupům, experimentální zručnosti apod.

I would expect the database of all used input and processed images (ideally with marked errors) to be included in the materials.

III. CELKOVÉ HODNOCENÍ, OTÁZKY K OBHAJOBĚ, NÁVRH KLASIFIKACE

Shrňte aspekty závěrečné práce, které nejvíce ovlivnily Vaše celkové hodnocení. Uveďte případné otázky, které by měl student zodpovědět při obhajobě závěrečné práce před komisí.

As I started to read the thesis I was excited about very ambitious assignment. The introduction as well seems to belong to the thesis of very motivated student. The hardware was thoughtfully designed and the setup precisely assembled. On the other hand it seems that student didn't spend enough time studying the state of the art of the PCB's visual inspection. The algorithms where chosen or excluded without broader explanation or discussion. I lack the comparison of author's solution to the existing solutions in the papers/on the market. Author himself also stated that the performance of his solutions for both plain and assembled board inspection is not precise enough to be used in production.
On the other hand I have to say that I appreciate the hardware-software nature of the work, the fact that the lights were designed and adjusted to enable capturing of images without specular reflections in metal parts. The GUI was also clearly designed and thesis is readable and nicely formatted.

Questions:
1. On the page 41 you propose an aligning method of a board based on segmentation from white background and rotating of bounding box. Comment on whether the registration can be improved using Hough transform to detect the board frame and resampling of the images.
2. On the page 29 you stated:"*With knowledge of a correct position and rotation, based on the position of pads from Golden board, the error of absolute rotation can be estimated as well as position error. Position error is calculated as euclidean distance of center of a part and a pad. Defect is reported when some of these values exceed the given limit.***"**
explain how you compute the rotation error.

Předloženou závěrečnou práci hodnotím klasifikačním stupněm **D**

Datum: Podpis: