Opponent Report
For the PhD's dissertation of Ing. Jiří Kula

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This is an evaluation report for the PhD dissertation submitted by Ing. Jiří Kula (henceforth: "the author") and entitled "Automatic Visual Control System For Textile Processes" at the Technical University of Liberec, Liberec, Czech Republic. This report is a response to the request of the dean of the Faculty of Textiles Ing. Jana Drašarová, Ph.D. (Č.j. TUL-16/4814/027828) and to fulfill the partial requirements of the defense committee chaired by Prof. Ing. Jiří Militký, CSc. (Č.j. TUL-16/4814/005710).

The report is organized in *four* separate sections that start with a description of the dissertation, then a "discussion and evaluation" of its components are given in section 2 where a detailed reasoning is provided for our final recommendations (given in section 4). General comments on the dissertation layout and the use of language are also included in section 3 of this report.

1 Description

I received a printed copy of the dissertation as well as a compacted disk (CD) that contains a digital copy of the dissertation and the source files for the presented work. The dissertation consists of a *front-matter* (that includes: abbreviations, contents, and abstract), and 101 pages that present a *body* of six chapters (introduction, objectives, pinhole and line scan camera models, image processing, experiment, and conclusion), as well as a *back-matter* (four appendices, references, and the author's publications).

The *first* chapter introduced the investigated problem of this research (the manual evaluation of fabric's quality parameters), and some of the methods introduced in the literature to handle this problem based on fabric's image analysis. The author suggested the use of Gabor filters as an effective tool for extracting the textural descriptors of the fabric. This chapter was concluded by presenting the organization of the dissertation.

The *second* chapter highlighted the main procedures of the work, and described the hardware and the software implemented in this dissertation. This hardware section includes figures for the prototype inspection machine, and the software was presented as a modular platform that allows addition/omission of modules without affecting the total performance of the system.

The *third* chapter described the image acquisition model in a pinhole and a line-scan camera with a mathematical description of the image representation and the algorithms for calibrating, correcting and reconstructing panoramic images of the acquired object based on two (or more) cameras.

The *forth* chapter presented the methodology suggested by the author to handle the investigated problem. A description of Gabor filters and their affecting parameters was given, then the algorithm for identifying the textural descriptors and their extraction from the fabric images. This chapter presented also the method for discriminating between defected and defect-free samples, the thresholding technique, and the detection performance based on some quantitative measures.

The *fifth* chapter presented the results of applying the suggested technique with case studies for some common fabric faults and the detection performance in each case.

The dissertation *closes* with a conclusion followed by appendices for matrix decomposition, homogeneous coordinates, windowing algorithm, and software's component interface. The references of the dissertation were given, then a list of the author's publication was provided.

2 Discussion and Evaluation

The topic of this dissertation is very important in the fields of fabric production and its evaluation. The success of achieving an "automatic visual control system for textile processes" should lead to a consistent fabric production that does not depend on the human intervention and makes the process economically efficient. This research topic is still active with many challenges that need to be solved through a continuous research, and the work presented in this dissertation shall be considered in that context. **The following paragraphs** summarize my comments and evaluation on the topics, *in the same order* of their presentation through the thesis.

The *title* of the dissertation has a broad range, especially when it refers to "textile processes". If changing the title is allowed at this stage, it would be preferred to use more specific title that reflects the presented work and its main scope.

The *first chapter* for introduction has a *fragmented structure*, where the ideas are not presented in a *logical* order. For example, the *contribution* of the work is presented at the first page of the chapter, then the *motivation* behind the work was introduced. Similarly, towards the end of the chapter, the author *distinguished* his work from the available literature, *then* introduced more work from the literature. **To fix this problem**, it is recommended to avoid the *long mixed* paragraphs and present each main idea in a *separate* paragraph, then combine these paragraphs to cover a specific element of the work. I recommend this chapter to present the upcoming elements in the following *suggested* order: *definition* of the problem, its *importance* and the *motivations* behind its solution, *available methods* of solution, *shortcomings* of the available methods, *suggested hypothesis* by the author to deal with these shortcomings, *uniqueness* of the suggested approach, and an overview of the suggested *procedures* to test the *validity* of the hypothesis. These elements already exist, *to some extent*, in the current manuscript and the author can use the suggested order to restructure this chapter. It should be clear that, this comment is provided *as an example* in this chapter, and an *analogy* should be utilized for *the other chapters*.

Regarding the used references for this work; while it is important to focus on the *textural methods* and their *performance* in the introduction (as they are more related to the topic of the thesis), the *scope* of coverage should be *wider* to extend for *other methods* and efforts in the field. Also, the majority of references used in the presented survey are *outdated* and do not catch up with the recent advances on the topic. According to these two comments, the author should be very *conservative* in giving *general opinions*, such as saying "No scientific work has been published....". In fact, such statements arise from *mixing* the *absence of evidence* with the *evidence of absence*, which is a major *trap* for generalization.

The *second* chapter carries the title of "objectives", which is *misleading* and does not reflect the materials that were presented in the chapter. Hence, a *change* of the chapter's title will be useful. Although the chapter presents a detailed structure of the hardware and software, there was no definitive answer to questions such as: what is the linear speed of the prototype machine (the text only refers to 0.87 m/s as a *camera limit*)? Or, whether the system performs *online* or *offline* analysis? The author argues that *it is both*, but it will be more useful to give a *specific definition* for the analysis type *then* identify the system *according to* this definition. Also, it is not convincing for the reader to *list* some advantages of a line-scan camera, while the presented work *does not utilize* these advantages in the given analysis.

For the *software utilization* in this chapter; The author argues in different places of the thesis that, the main contribution of this *whole work* to the current state of knowledge is the algorithm for *correcting* the captured image and projecting the *actual* camera image to the *ideal* camera image. Regardless of the *accuracy* of this statement and the *existence* of similar calibration and correction methods in the literature, the introduced software structure utilized the CameraLink and the Multiplexor to capture the images and stitch them together to form the final image of analysis. Both of these modules (as well as the other used modules) are standard "filters" of the DirectShow software, and it is not clear how these *standard* algorithms utilize the "*new*" correction algorithm described in Chapter 3? Therefore, it is of a special importance to clearly identify the *actual contributions* by the author to build the analysis software and the parts he *developed* versus the *ready-made* ones.

This question leads to a description for the CD attached with the thesis. There is neither *organization* nor *instruction* on using the files on the CD. Most of the files are not usable, even the simple Matlab script files do not function properly and depend on certain files and commands that are not included. Since the author decided to attach the software part to the thesis, it should be presented in a way suitable for the PhD dissertation. As a general rule, if an item (sentence, paragraph, computer file,...etc.) does not *add* to the work, it will automatically *subtract* from its value. That means, the author should be *more careful* in presenting the work in the written form *as well as* in the accompanied digital form.

Progress of ideas and derivations in chapter *three* is relatively clear to follow. However, the introduction of matrix **A** and **B** after Equation (29) is not obvious whether they refer to the ideal (non-rotated) camera image (i.e. $\mathbf{A} = y_a = U_A X$ and $\mathbf{B} = y_b = U_B X$) or not? Especially that, the symbol **A** was used in a different context with Equation (2).

The idea of "*automation*" does not have *enough evidence* and *might collapse* based on the given work in *chapter 4* (and in *chapter 5*). For example, to show the effect of Gabor filter on the periodic structure, the author demonstrated the results in Figures 21-23; nevertheless, these figures were produced under *selected* and *optimized* conditions (the same applies to results of *chapter 5*). This means that, a *prior knowledge* about the samples is required *for a proper adjustment* of the values of parameters Θ and Ω that create the set (or the bank) of filters. Also, picking "element No. seven" (which represents the mean μ and standard deviation σ at a specific filter *distance* and *orientation*), as a representative for all texture descriptor is another evidence of this *selectivity* and *bias* regarding the performance of the system with each sample. This *prior knowledge* poses questions about the *credibility* of the "automatic system" and its *validity*, while the author admitting in chapter 5 that: *"...It is never known in advance, which kind of defect is going to appear during production"*.

Another *major issue* of results in chapters 4 and 5 is the *lack of distinction* between the *detection* and the *classification* processes. Generally, there is only a "*defect detection*" system in this work and "*no classifiers*" are presented. The system can be called "classifier" if it has the ability to deal with *multiple fabric faults* under the same condition (i.e. same analysis algorithm with the same settings for Gabor filters), and having the ability to distinguish (i.e. *classify*) each fault type. However, in this work, each fault type was treated with a different set of Gabor filters (with *optimized* and *a priori known parameters*) which allowed it to "detect" the fabric fault, not to "classify" it. For the distinction between *classifiers* and *detectors*, the author might check a previous work by Eldessouki *et al.* in *FIBRES & TEXTILES in Eastern Europe* 2014; 22, 4(106): 51-57.

Related to the previous point: the efficiency of detection *for the system* is misleading, because it is calculated based on a single defect type. It should be more informative about the system's performance if the efficiency of the same *detector* is measured with samples of different defect types. As a matter of fact, it will be really surprising if the performance of the given *supervised* and *optimized* system is less than 90%. In other words, and just to give *one* example: what will be the performance of detectors in sections 5.3 and 5.5, which have filters with (Θ, Ω) = (24,0), (24,30) and (24,90), if they were used in detecting fabric faults of sections 5.1, 5.4, 5.6 and 5.7 which *also* use the same set of filters?

In a similar fashion that demonstrates the *biased* efficiency of the detection systems and how they are *tailored* to specific samples, the author stated in section 5.2 that "Much of what has been described for the thin place defect also applies for irregular weft density". If these defects (5.1 and 5.2) are similar, why only *two* filters were used in the first defect, while *computationally demanding eleven* filters were required in the second case? The same logic applies to faults in sections 5.3 and 5.5 that were described as "similar" because they show "vertical strips along the material". Since both faults are *visually similar*, why using different filter sets in each case? From the analytical point of view, these questions are understandable and can easily be answered; however, these questions are given here to indicate the importance of avoiding the *misguidance* to the readers, and the need to *clarify the facts* while documenting the results.

Regarding the *definitions* and the *categorization* of fabric faults; the "thin places" (in section 5.1) are well known defects in the *spinning* industry (i.e. *yarn* defects), while its use in the thesis refers to *a variation of the weft density* is not accurate. Technologically, this defect occurs due to a stop/start of the weaving machine and that is why it is usually called a "stop-mark". Similarly, it might be more suitable to categorize fabric faults according to the *orientation* of their occurrence in warp, weft, or areal directions (please refer to the above reference for details), especially that Gabor filters are also sensitive to their orientation.

There is a great *ambiguity* about the *samples size* in this work. If I understood it correctly, the total number of points plotted in the results for each fault type represents the number of sub-windows within the detected sample. In other words, it seems like, the whole system is based on a *single image for each type* of fabric faults, and this image is used for calculating the control limits of the system (i.e. its training), as well as its testing and validation. *If this interpretation is true* (as I said, it is really ambiguous), the *credibility* of the suggested system will be *questionable*; because no system can be built and *generalized* based on a *single observation* (regardless of the number of sub-readings obtained *within* that observation).

In section 5.4, the author highlighted the poor ROC result and attributed it to the effect of "neighboring yarns". Regardless of the discrepancy between that statement and the other statement "the fault can be detected with high confidence" (as tried to be explained in the caption of Figure 48), the size of the sub-window was not given for this particular case (it will be better to give this size than talking about an optical illusion of red and green colors in page 68). Also, it might be useful to show how changing the size of the sub-window may affect the ROC results.

Presenting the results in chapter 5 lacks the *deep discussions* and full of *redundant* figures. For example, if all samples were captured out of the same fabric (with the same structure), then most images given for the "*defect-free*" and their "*power spectra*" (images *a* and *c* in the second figure for each fault type) should be identical and no need to repeat them in each case. It might be useful, however, to indicate the *descriptor values* for the defect-free and the *deviation* from them in each case. This suggestion implies, for a good comparison, the need to use the same size of filters in all cases, and I suggest using a general "classifier" (with a suitable size of filters) at the end of chapter 5 to demonstrate the *performance* of this classifier with the different types of faults.

Finally, the conclusion of this study includes a few *alarming* statements that should be *reconsidered* by the author. One statement implies that: the author did not work *solely* on this research, and it came just as a byproduct of another system. The author also described the importance of the work as: the *detailed* discussions for *certain aspects* that usually *overlooked* by researchers in the textile field; however, this should maintain the *balance* with the topics of interest in that field (where the author is seeking a degree). It is not proper to *completely overlook* some important aspects in the presented research such as the fabric defects, technological reasons, and their impact on the quality of the product.

3 General comments

The *substantial* comments on the topic were given in the previous section of this report, however there are some *general* comments that are related to the overall dissertation and its style and formatting. These comments are listed below:

- The author used a reasonable English language in the dissertation. While there are some typos and grammar mistakes, they generally do not affect the meaning of the sentences and the context is still understandable. It is necessary, however, to proofread the dissertation again to correct these mistakes.
- The accuracy of detection is given by Equation (39), however the efficiency of detection is given in terms of TPR and FPR. There should be a consistency in the work, especially that the given "*efficiency*" sums up, in many cases, to values different than 100% (sometimes it is less than 100% and sometimes it is more).
- Since it is difficult for the reader to count all the "red" and "green" windows in each fault case, it will be more useful to add the "*confusion matrix*" next to each figure which will help in getting more grip of the numbers through the given discussions.
- It is understandable that DirectShow refers to its elements as "filters"; however, in this work I prefer to use the word "*module*" or "*node*" to refer to these elements and not to confuse it with the *filtration* process during the image analysis.
- Referring to the "*defect-free*" fabrics should not be with the words "*fine*" samples as noticed in chapter 5.
- The caption of Figure 8 refers to the origin as the point **O**, which should be corrected to the point w as given in the drawing.
- In Equation (37), it is better to use a different symbol other than Σ, just to avoid the confusion that might result from the special meaning of this symbol in mathematics.
- The page number of the "abbreviations" page (in the front-matter) is wrong and should be corrected (shown as page No. 4 then followed by page No. 1 in the introduction).
- All figures should be used in the main text with a referral and some comments. The following figures were not used in the text at all: Figures 22-23, 32, 43-44, 46-48, 51-52, and 55-64.
- All tables should be used in the main text with a referral and some comments. Table 1 should be used in page 52, for example: "...confusion matrix *given in Table* 1".

- All abbreviations should be clearly stated at their first appearance in the text. It is not enough to collect all abbreviations in a table at the beginning of the dissertation and leave them in the text without a clear description.
- The format of the biography should follow a *consistent style* and the names of all authors should appear (*according to the used style*, which also uses the abbreviation "*et al.*" only in the main body of the text).

4 Conclusion and Recommendations

The topic presented in this dissertation is very important for the scientific community and the methods implemented in this work were presented at a reasonable level. The problem solving approach in this work and its presentation were scientifically sound. On the other hand, the results presented in this dissertation are limited in scope and in significance, and the author should clarify some of the comments and questions highlighted in the discussion section of this report. The response for these comments is possible by correcting some sections of the dissertation according to the given guidelines, and therefore:

I RECOMMEND THIS WORK FOR A DEFENSE

Eldessouki

Doc. Ing. Mohamed Eldessouki, PhD
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Liberec. August 25, 2016

Oponentský posudek na disertační práci Ing. Jiřího Kuly

Automatic visual control system for textile processes (Automatická vizuální kontrola textilních procesů)

Předložená disertační práce se zabývá hardwarovou a softwarovou implementací systému pro on-line kontrolu kvality povrchové struktury textilie. Z tohoto hlediska se práce zabývá aktuální problematikou, jejíž řešení není v praktických provozech doposud uspokojivě vyřešeno.

Práce je formálně rozdělena do osmi kapitol a čtyř dodatků (které v obsahu na začátku práce nejsou uvedeny). Z věcného hlediska ji lze rozdělit na čtyři tématické části, jejichž popis řešení je uveden v kapitolách 2, 3 a 4. První částí je hardwarová implementace. Obsahuje velmi stručný popis zařízení, zkonstruovaného na katedře hodnocení textilií textilní fakulty TU Liberec (tato informace v textu opět chybí, stejně tak jako informace o autorech tohoto zařízení). Ve druhé části autor řeší problematiku získávání obrazu hodnocené textilie na daném zařízení. Této části je v práci věnována celá jedna kapitola (kapitola 2) a autor se zde zabývá transformací obrazu získaného při aplikaci dvou modelů: modelu centrální projekce (tzv. "pinhole camera") a modelu lineárního snímání (tzv. "line scan camera"). Velká část této teorie je převzata z literatury a autor se zde dopouští řady nepřesností ve vyjadřování (viz otázka 1). V závěru této kapitoly se autor věnuje původnímu řešení problému nezkresleného spojení dvou sousedních obrazů získaných ze dvou kamer, (jejich "narovnání"). Ve třetí části (v kapitole 4) disertant popisuje metodu zpracování získaného obrazu. K tomu používá diskrétní Fourierovu transformaci a Gáborovu filtraci. Na spektrální reprezentaci snímaného obrazu aplikuje sadu Gáborových filtrů, pro každý spočte dvě statistické charakteristiky. Tím dostane tzv. deskriptor daného obrazu. Vlastní detekce potom probíhá tak, že srovnává deskriptory získané při lineárním snímání s referenční hodnotou, získanou z pozorování nedefektní textilie. K tomu používá Hotellingovu T^2 statistiku. Součástí práce je ukázka výsledků této metodologie na různých typech vad textilie (v kapitole 5). Poslední čtvrtou částí je softwarová aplikace. Ta je popsána v kapitole 2 spolu s hardwarovou implementací. Z textu vyplývá, že program byl vyvíjen v jazych C++ s využitím standardních knihoven. Softwarové řešení je modulární a otevřené k dalšímu rozšiřování.

Předložená práce je druhou přepracovanou verzí. Zatímco většině námitek k první verzi autor vyhověl a práce je na lepší úrovni, než byla původní verze, na hlavní otázku autor ani v této verzi jasně neodpověděl. Z práce jsem například nevyčetl, kdo je autorem návrhu zařízení pro snímání textilie, jaký je autorův podíl na konstrukci zařízení, na tvorbě software atd. V práci zůstala řada překlepů, které ovšem nemají vliv na obsah.

Otázky na disertanta:

1) Mohl by autor objasnit svá tvrzení na straně 19 před vzorcem (2)? Není jasné, jak je to s linearitou zobrazení "between three dimensional world points into two dimensional image points"vyjádřené rovnicí (2).

2) V kapitole 6 Conclusion (očekával bych spíše "Conclusions", neboť kapitola obsahuje více závěrů) autor mimo jiné uvádí, že "the weak part of the algorithm is the bank of filters itself"a o několik vět dále lze nalézt větu "Certainly the static bank of Gabor

filters is not the optimal solution". Jako alternativní řešení zde uvádí palikaci neuronových sítí. Mohl by autor vysvětlit výhody a nevýhody použití Gáborovy filtrace ve srovnání s jimými metodami a objasnit, proč použil právě tuto metodu (když – podle jeho vlastních slov – není optimální)?

3) Hotellingova metoda srovnávání vícerozměrného pozorování s referenční hodnotou vyžaduje nějaké předpoklady pro její použití. Toto disertant ve své práci nijak nekomentuje a žádné předpoklady neověřuje. Při obhajobě by měl toto uvést na pravou míru.

4) Co je v této práci původním přínos autora k danému tématu? Přes moji výtku k první verzi této práce jsem ani v této přepracované verzi nenašel jasně vymezené původní výsledky práce disertanta a výsledky přejaté odjinud.

Disertant ve své práci nabízí řešení aktuální problematiky zpracování a analýzy obrazu v aplikaci na kontrolu kvality v textilní výrobě. V práci je použita poměrně složitá metodika pořizování a zpracování obrazové informace, založená na netriviální matematice. Není pochyb, že autor této metodice rozumí a dokáže ji aplikovat. Předloženou práci doporučuji k obhajobě.

Na závěr konstauji, že práce splňuje požadavky kladené na disertační práci a pokud autor uspokojivě zodpoví položené otázky, doporučuji udělení titulu PhD.

V Praze, dne 29. 9. 2016

prof. RNDr. Gejza Dohnal, CSc.