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La Rochelle, October 6, 2018

Review Report on PhD Thesis of Radek Richtr

entitled

"Dynamic Texture Modeling"

prepared based on an invitation letter from the dean of Faculty of Information Technology CTU Prague - Dr. Ing. Marcel Jiřina, Ph.D.

Supervisor: Prof. Ing. Michal Haindl

The submitted dissertation presents a new method for modeling Dynamic Textures (DT) in videos. Several different applications are presented, and many results are exposed.

Formal structure and organization of the dissertation

The dissertation consists of 10 chapters (including an introduction and a conclusion) and 4 annexes. The problematic of the thesis is first presented in ***chapter 1***, introducing all the different contributions that will be exposed in the next chapters (a DT synthesis model, DT editing, DT inpainting, a DT perceptual similarity measure and a DT model using a Bidirectional Textural Function).

Chapter 2 exposes the theoretical background of the thesis and a brief state of the art on synthesis and inpainting of DT. The major theoretical contribution of the thesis is a toroidal patch based model for dynamic textures which is described in details in ***Chapter 3***. The next chapters are applications of this DT model to different challenging and interesting areas. In ***Chapter 4,*** a set of methods for editing DT is presented (spatial or/and temporal enlargement of DT, DT mixing and transition between DT). The DT toroidal patch model is adapted in ***chapter 5*** to do video inpainting where the area to be processed can be found automatically by the proposed method. A similarity criterion for comparing DT and based on frequency analysis is proposed in ***chapter 6***, and is assessed by psycho-visual tests. In a short chapter (***chapter 7***) the

Bidirectional Textural Function is combined with the developed DT model for realistic illumination rendering.

Chapter 8 and ***chapter 9*** constitute the experimental parts of the thesis. Datasets used are introduced and different results and psycho-visual tests of the proposed approach are exposed: similarity criterion for comparing DT, synthesis, editing and inpainting of DT.

Last chapter ***(chapter 10)*** concludes on the main contributions of the thesis and presents some prospects for future works.

Evaluation

Even if the core of the presented method is built on an existing work for 2D texture synthesis [Haindl and Hatka, 2005], its extension to dynamic textures was not straightforward at all, due to the specificity of the added time variable. This point has been extensively detailed and discussed in the dissertation, and the new proposed model is one of the main contribution of this thesis.

This model is powerful and can capture the "gist"" of dynamic textures. Its versatility enables a wide range of applications, and the large scope of hot topics on Dynamic Textures tackled in this work is impressive.

Results obtained on different applications are original and convincing. It can be stressed that an important effort has been made to assess presented results using psycho-visual tests with a panel of more than 150 participants.

The bibliography is up-to-date and has nearly 150 references.

For all that reasons, it can be claimed that all the dissertation objectives have been achieved.

Recommendations

The manuscript has spelling, typos and English grammatical issues that unfortunately make sometimes difficult to follow some descriptions or stated arguments. I strongly advise a complete proofread.

There is a very high number of variables in the different equations, many of them having several subscripts and exponents. Although it has to be noted that a list of notations used is provided (more than 6 pages), I would recommend to lighten them as much as possible. The use of variables in functions instead of subscripts and putting all vectors in bold case can also ease the reader's task. The use of pseudo-codes can also greatly improve the comprehension of proposed algorithms.

With the same idea, the use of larger figures, with used variables and more detailed legends can also ease the understanding of notations and formulas.

The number of chapters is pretty high, with unbalanced number of pages. Some of them could maybe be merged (for instance chapter 6 and 8, chapter 7 and 9). In the conclusion chapter, prospects section is a bit short, please give more insights on the questions opened by the method and possible further works.

The above remarks do not alter the intrinsic quality of the presented work, and their aim is to improve the overall quality of the manuscript.

Open questions

I am wondering what is the method used for estimating the Optical Flow (page 41) and how important is this choice in the rest of the process: some technics of Optical Flow estimation have assumptions of mass conservation that may be more suitable for many DT classes (particularly fluids). Please give some comments on this point.

In chapter 4, is it possible to formalize a mathematical model for transition patches, with a possible choice on the underlying interpolation? With the same idea, could a transition between two dynamic textures be seen as a smooth path in a model parameters manifold?

The proposed similarity criterion for comparing DT (chapter 6) is based on the harmonics of time series of spatial frequencies extracted from a (spatial) Fourier transform. Please discuss this choice compared to other transforms such as the windowed Fourier Transform, or multiscale transforms such as wavelets or even directional wavelets (X-lets)? Similarly, why not performing directly a fully spatio-temporal frequential analysis of the DT sequence?

Deep learning approaches are quickly put aside in the manuscript. To what extent could the proposed method use a hybrid approach and incorporate deep learning to improve patch and model selection?

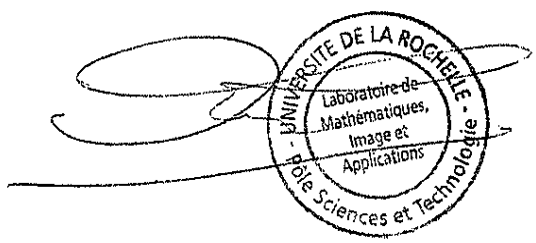
Conclusion

As stated previously, this dissertation has significant contributions to the domain and objectives have been achieved. The dissertation results were published in three international conference proceedings and submitted to an international journal. The author of the dissertation has proved the ability to conduct research and achieve scientific results. In accordance with par. 47, letter (4) of the Law Nr. 111/1998 (The Higher Education Act) I do recommend the thesis for the presentation and defense with the aim of receiving the Ph.D. degree to Mr Radek Richtr.

In La Rochelle, October 6, 2018

Signature of the reviewer

Dr Renaud PETERI
Associate Professor



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Review of the Dissertation Thesis

Dynamic Texture Modeling

Submitted by **Radek Richtr**, Faculty of Information Technology, Czech Technical University in Prague, Czech Republic

reviewer: prof. RNDr. Roman Ďurikovič, PhD, DE, Faculty of Mathematics, Physics and Informatics, Comenius University in Bratislava, Slovakia

Up-to-dateness of the dissertation

In his dissertation thesis, Radek Richtr concerns himself with a dynamic texture inpainting problem, especially inpainting with a dynamic background which is generally recognized as a challenging problem. The topic and its partial problems are not new the computer graphics community nevertheless it is up to date as methods dealing with dynamic textures have wide applications in material editing, design and production as bidirectional texture function, also in light source design as dynamic irradiance capturing textures. Thus, each incremental technique which successfully strives to push the state of the art either towards quality or towards lower computational demands is worthwhile.

Formal structure and organization of the dissertation

The thesis is structured into 9 chapters 3 appendices having 198 pages including the list of references consisting of 149 items that are adequate including new scientific papers from 2017.

After the Introduction with nice definitions and the problem statement, a Background and State-of-the-Art introducing the necessary theoretical background and the current state-of-the-art follows. This is the author contribution of the thesis where the author summarizes large body material. Unfortunately, limitations of the surveyed methods and the relation to the author's contribution work remain often unclear. Chapter 3 Introduces the general textural model capable to model vast amount of possible dynamic texture realization.

Chapter 4 Dynamic Texture Editing: Demonstrate the ability of a proposed dynamic textural model to the dynamic texture editing problem and provides a description of model enhancements depending on DT editing issues. Chapter 5 introduces a dynamic texture inpainting problem and a proposed dynamic textural model to deal with it. Chapter 6 presents a novel Fourier transformation criterion for texture comparison and ranking of synthesis and inpainting results. Chapter 7 demonstrates the

combination of two concepts Dynamic texture and BTF model to introduce DBTF. Chapter 8 describes the dynamic texture database that is used for experiments to verify our approach. Chapter 9 contains many comprehensive examples of the results of the presented methods and their limitations. Chapter 10 is a summary and suggests possible topics for further research.

Assessment of the methods used in the dissertation

The basic idea behind the triple toroid-shaped patch based dynamic texture model is rather straightforward extension of the texture space in each spatial (horizontal and vertical) and temporal dimensions nevertheless, the mathematical definition is clear and correct. Final texture is divided into logically consistent patches by spatial similarity and similarity in dynamics. Final model is quite complex with multiple indices and the searching space is large. I wonder if the GPU implementation is possible. The model is adequate, but it was not evaluated/designed from the data structure vs. algorithm complexity point of view. I think the average PhD student will not be able to reimplement the model.

In the dynamic texture editing author introduces how to apply the textural operators to tone colors, change dynamics or differs texture itself without the possibility to an affect the homogeneity of the whole dynamic texture. Authors proposed the principle of transition patches between toroidal patches considering the algorithm complexity, too. It is no clear from Fig.4.12 how the different local (arrows) optical arrow are used in DT shifting method.

The authors most valuable results are summarized in dynamic texture inpainting method addressing many particular problems from previous chapters including the similarity criterion. I was convinced that the theoretical contribution of this thesis i.e. the concept of the toroid-shaped patches of a suitable size, naturally respect and reproduce the lost frequencies without loss of structural information. Probably I was reading carefully, but here I have a question why the method works? Several error metrices has been introduced and combined with weight equal to 1 (Eq.4.13). How to set the error weights to find the good results easily?

"Y is basically sum of area-to-area measures from original to every another area" above Eq.5.13 -> definition of Y is missing. Y is dynamic texture some mismatch.

Eq. 5.14 dissimilarity measure Gamma - > is it really the measure?

Method based on Fourier analysis presented in dynamic texture similarity criterion lucks the comparison to well established Image metric [A], also the reference is missing to this pioneering work in the thesis.

Eq. 6.2 has errors, function f(x1,x2,x3) is then used with only 2 parameters in the form f(x2,x2) and it

needs to the double integral. It is not a 3D transformation but 2D. See correct definition at Wolfram Eq.67 http://mathworld.wolfram.com/FourierTransform.html

I must truly say that I didn't understand how the author can pack DBTF into the triple toroid-shaped patch based dynamic texture model. Can you draw a simple image like those in chapter 3 and make arrows to what is stored to what part? The persisting problem with BTF and with DBTF is the texture mapping.

Evaluation of the results and the contribution of the dissertation

The main author's contribution - author suggested several improvements of Dynamic texture synthesis model [A.5, A2], Dynamic texture editing [A.3], Inpainting and error concealment [A.4], Dynamic texture perceptual similarity [A.1], Dynamic bidirectional texture function are published in three conference papers (1 Scopus, 2 ACM) and in one journal paper (WoS) currently under review and are summarized in Chapters 4-6 of the thesis. Concept of Dynamic bidirectional texture function was not published yet.

Publication activity

Most of the authors publications are presented on international conferences. According to my knowledge **author didn't publish a single journal article!** Nevertheless, international community had enough chances to adequately evaluate the authors contribution and results.

The overall evaluation of the dissertation

I really appreciate the written style of the thesis with list of acronyms, notations the detailed equations describing the complex relations between image areas. The my understanding the Fournier transformation is a basic knowledge and the equation should be correctly written what is not the case of this thesis. Sometimes the details of the equations their parameters are not clear because the text does not explain the idea corresponding to equation. Some equations cannot be used in my opinion in the parallel implementation. How to cope with this problem in the future?

Missing references:

[A] Petr Kellnhofer, Tobias Ritschel, Karol Myszkowski, Hans-Peter Seidel:
A transformation-aware perceptual image metric. Human Vision and Electronic Imaging 2015: 939408

Questions

1. Not only the size of inpainted part should be considered but also the pixel size or the actual area

viewed by the pixel. In other words when inpainting the water waves (in perspective view) with the waves that are very far we get the smaller waves. There are other examples in special space, too. Is the similarity of the pixel resolution guaranteed by the toroid patch DT synthesis?

2. Can you comment more on the parallel implementation? What will be the main idea behind the parallelization and memory handling? I'm curious to understand how to convert the toroidal DT structure into a CUDA code on a simple example.

Conclusion

The scientific novelty is the triple toroid-shaped patch based dynamic texture model and contribution of presented content is mostly in implementation of inpainting algorithm. The novel results are not presented in journals, yet, hopefully it will be done before the defense. The thesis and the results fulfil the high-quality international standards required for doctoral thesis.

Statement

Regarding these shortcomings, author proved the ability to do the highly scientific research and achieve scientific results. In accordance with par. 47, letter 4 of the Law Nr. 111/1998 – The Higher Education ACT. I **do recommend** the thesis for the presentation and defense and honor **Radek Richtr** the Ph.D. degree.

Please contact me in case of any further questions.

Jul 22, 2018

prof. RNDr. Roman Ďurikovič, PhD, DE
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Typos

Chapater 3:

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Some statements are not evidenced "Note that the triple toroidal patch should be extended this way (see Figure 3.17)".

Fig.3.2 The bottom three images suggest the computational difficulty of the methods. I do not see it on figure.

The corder areas -> corner

The diagonal area part must be taken into account. <- Why, show the image?

Eq.3.15 eps_circ not defined.

Eq. 3.19 eps_x not defined

cut lines shat starts ->correct

series fun in the reversed -> correct

is it is not->

TThis can be->

Chapter 4:

It is no clear from Fig.4.12 how the different local (arrows) optical arrow are used in DT shifting method.

Chapter 5:

Dynamic Texture Inpaining->

The 5.16 then becomes: -> numbering

Chapter 6:

It is oblivious ->

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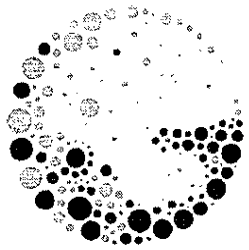

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To whom it may concern

This document presents a review of the dissertation thesis of Mr. Radek Richtr entitled "Dynamic Texture Modelling". The thesis presents a summary of research on modeling, synthesis, editing, and inpainting of dynamic (moving) textures. The fundamental idea is the representation of the texture by a set of toroidal (i.e. repeating) patches that can then be seamlessly arranged to create a larger texture, combine different textures together, fill in missing parts of texture or image, etc. While the goals of the thesis are, without any doubt, valuable, I have some doubts about the quality of the presented work in several respects, which I list below.

Originality/novelty

The basic underlying idea of representing a texture using patches with optimized boundaries has been around for some time, at least since the famed work:

Alexei A. Efros and William T. Freeman. 2001. Image quilting for texture synthesis and transfer. In *Proceedings of the 28th annual conference on Computer graphics and interactive techniques* (SIGGRAPH '01). ACM, New York, NY, USA, 341-346.

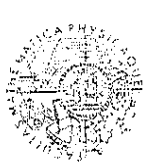
This seminal paper sparked numerous follow-up works so the body of texture analysis and synthesis research that relies on image quilting (i.e. texture patches with optimized boundaries) is quite large by now. Unfortunately, the thesis makes it very difficult to understand the nature of the difference between the presented method and the existing research (this may perhaps be partially be attributed to the unclear writing, see below). Since novelty is an important aspect for assessing the quality of any research, I consider is a serious shortcoming.

Evaluation/comparison

Related to the previous point is the lack of evaluation of the presented methods with respect to the existing work, or at least the most significant papers. What are the advantages of the proposed methods, if any? Why would one want to prefer the proposed methods over the state-of-the-art?

Writing

Writing quality is generally unsatisfactory for several reasons. First, the text contains such a high number of typos, grammatical, and stylistic errors, that it becomes essentially impossible to comprehend. Furthermore, writing is overly verbose – simple concepts are explained in long paragraphs using language and notation that obfuscates the essence of the presented ideas, rather



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than helping to grasp them. The mathematical notation suffers from similar problems: simple concepts use complex formulas, notation with numerous subscript and superscript symbols make it very difficult to parse even the simplest of the formulas.

Author's publications:

The published material of the authors includes two SCCG publications. With all due respect to the SCCG conference, it can hardly be considered an indicator of a high quality of the published works. There is also one paper published at IEEE ICPR, which is certainly a higher-quality conference, but I would expect the work to be backed up by at least one journal publication for it to be acceptable. Furthermore, it was not clear how the individual chapters of the thesis relate to the published papers.

In summary, I believe the work is not yet ready to be defended. I would suggest addressing the above comments in a revised manuscript and running through a sufficient number of feedback and revisions cycles before resubmitting the work again (I have annotated the hard copy of the thesis with some comment that could help in that effort). By that time, the work will hopefully be backed by an accepted journal publication [A.4] which will provide an additional degree of credibility.

To conclude, **I cannot recommend the presented dissertation of Mr. Radek Richtr for a defense**.

In Prague, 2. 8. 2018

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