Lappeenranta University of Technology
Faculty of Technology Management
Degree Program in Information Technology

Master's Thesis

Pekka Paalanen

REAL-TIME IMAGING AND MOSAICKING OF PLANAR SURFACES

Examiners:	Professor Heikki Kälviäinen
	Lasse Lensu D.Sc. (Tech.)
Supervisor:	Joni Kamarainen D.Sc. (Tech.)

ABSTRACT

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Real-time Imaging and Mosaicking of Planar Surfaces

Master's Thesis

2000

21 pages, 64 figures, 1 table, and 2 appendices.

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Keywords: mosaicing, real-time, tracking, visual inspection, computer vision

Notice that the page, figure, table and appendix counts are for the whole work, including title page, appendices, figures in appendices, etc. You have to count the numbers yourself, except for pages. Lorem ipsum dolor sit amet, consectetur adipisicing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

TIIVISTELMÄ

Lappeenrannan teknillinen yliopisto
Teknistaloudellinen tiedekunta
Tietotekniikan koulutusohjelma

Pekka Paalanen

Tasopintojen reaaliaikainen kuvantaminen ja mosaiikkaus

Diplomityö

2000

21 sivua, 64 kuvaa, 1 taulukko ja 2 liitettä.

Tarkastajat:	Professori Heikki Kälviäinen
	TkT Lasse Lensu

Hakusanat: mosaiikki, tosiaikainen, seuranta, visuaalinen tarkastus, tietokonenäkö
Keywords: mosaicing, real-time, tracking, visual inspection, computer vision

Laajojen pintojen kuvaaminen rajoitetussa työskentelytilassa riittävällä kuvatarkkuudella voi olla vaikeaa. Kuvaaminen on suoritettava osissa ja osat koottava saumattomaksi kokonaisnäkymäksi eli mosaiikkikuvaksi. Lorem ipsum dolor sit amet, consectetur adipisicing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

PREFACE

I wish to thank my supervisor

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Finally, thank you to

Lappeenranta, October 19th, 2006

Pekka Paalanen

CONTENTS

ABBREVIATIONS AND SYMBOLS

AMD	Advanced Micro Devices, Inc.
API	application programming interface
${}^{\mathrm{A}}\boldsymbol{x}$	vector $\boldsymbol{x}$ given in coordinate frame A.
$\boldsymbol{X}$	a matrix

1 INTRODUCTION

1.1 Background

This template has been updated to the Master's thesis guidelines effective from August 1st, 2010.

The need to take digital images is ubiquitous. Whether it is for taking photographs on vacation, environmental images from a satellite, or scanning a paper document into a digital form, digital imaging is everywhere. Digital imaging is especially useful in automatic visual inspection, which is used in almost every field in industry, creating a demand for specialized and accurate imaging technologies.

1.2 Objectives and Restrictions

The objective of this thesis is to construct a device that can be used to image (scan) relatively large surfaces in small pieces, and to develop a method to automatically create a rough mosaic image on-line, in real-time. The mosaic is a color image.

1.3 Structure of the Thesis

This thesis concerns hardware, theory and software implementation required for a functional proof-of-concept level system for real-time mosaicking from a live video stream. Section 2 takes a look at existing real-time mosaicking applications.

2 PREVIOUS WORK ON REAL-TIME MOSAICKING

This should be about real-time mosaicking, but lets just throw one reference to radiometric CCD calibration [1].

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And here is a nice graph in Figure **??**. Notice, that the figure is not stored in EPS in the CVS, but generated from a CSV-file with Gnuplot. See the Makefile and luxeonspectra.gp.

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2.1 Examples of Equations

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First the derivative images[2]

$$
\begin{aligned}
I_x = \frac{\partial I}{\partial x} &= I * \begin{bmatrix} -1 & 0 & 1 \end{bmatrix} \\
I_y = \frac{\partial I}{\partial y} &= I * \begin{bmatrix} -1 \\ 0 \\ 1 \end{bmatrix}
\end{aligned} \tag{1}
$$

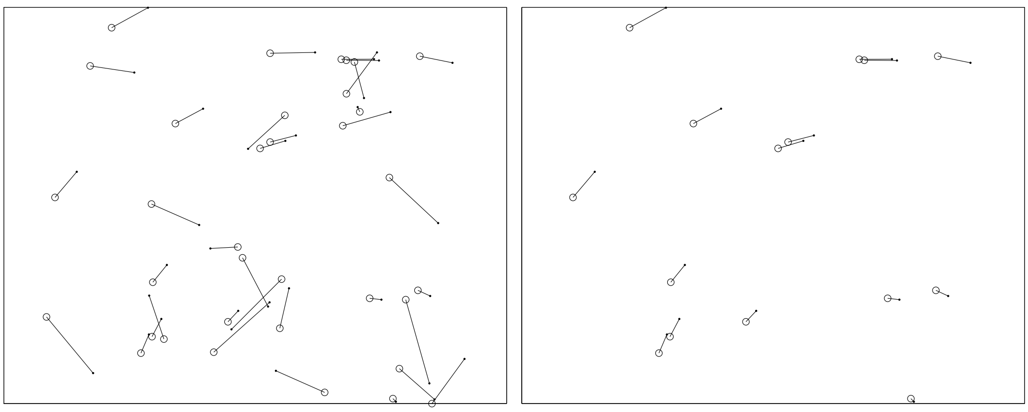
of the input image $I(x, y)$ are computed, where $*$ denotes convolution. The sum of squared errors generated by a small dislocation $\Delta x, \Delta y$ can be written as

$$E(\Delta x, \Delta y) = A(\Delta x)^2 + 2C\Delta x\Delta y + B(\Delta y)^2 \tag{2}$$

where

$$
\begin{aligned}
A &= I_x^2 * w \\
B &= I_y^2 * w \qquad . \\
C &= (I_x I_y) * w
\end{aligned} \tag{3}
$$

And a demonstration of subfigures in Figure 1. We can also reference a single subfigure Figure 1b. And an equation, like Eq. 2.



(a) (b)

Figure 1. Apparent motion of a set of point trackers. Positions in frame t are circles and positions in frame $t + 1$ are dots: (a) All trackers; (b) Only coherent trackers.

[1] Testing footnotes.
[2] You should not usually use footnotes.

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And then some nice math:

$$\begin{aligned} L_{\mathrm{o}}({}^{\mathrm{S}}\boldsymbol{x}, \lambda, \boldsymbol{\theta}) &= \iint\limits_{\boldsymbol{\phi}\in\Omega_{\mathrm{i}}} \left[\rho_{\mathrm{d}}({}^{\mathrm{S}}\boldsymbol{x}, \lambda) + \rho_{\mathrm{s}}(\boldsymbol{\theta}, \boldsymbol{\phi})\right] \, L_{\mathrm{i}}({}^{\mathrm{S}}\boldsymbol{x}, \lambda, \boldsymbol{\phi}) \, \cos\boldsymbol{\phi} \, \mathrm{d}\boldsymbol{\phi} \\ &= \iint\limits_{\boldsymbol{\phi}\in\Omega_{\mathrm{i}}} \rho_{\mathrm{d}}({}^{\mathrm{S}}\boldsymbol{x}, \lambda) \, L_{\mathrm{i}}({}^{\mathrm{S}}\boldsymbol{x}, \lambda, \boldsymbol{\phi}) \, \cos\boldsymbol{\phi} \, \mathrm{d}\boldsymbol{\phi} \\ &\quad + \iint\limits_{\boldsymbol{\phi}\in\Omega_{\mathrm{i}}} \rho_{\mathrm{s}}(\boldsymbol{\theta}, \boldsymbol{\phi}) \, L_{\mathrm{i}}({}^{\mathrm{S}}\boldsymbol{x}, \lambda, \boldsymbol{\phi}) \, \cos\boldsymbol{\phi} \, \mathrm{d}\boldsymbol{\phi} \\ &= \rho_{\mathrm{d}}({}^{\mathrm{S}}\boldsymbol{x}, \lambda) \iint\limits_{\boldsymbol{\phi}\in\Omega_{\mathrm{i}}} L_{\mathrm{i}}({}^{\mathrm{S}}\boldsymbol{x}, \lambda, \boldsymbol{\phi}) \, \cos\boldsymbol{\phi} \, \mathrm{d}\boldsymbol{\phi} \\ &\quad + \iint\limits_{\boldsymbol{\phi}\in\Omega_{\mathrm{i}}} \rho_{\mathrm{s}}(\boldsymbol{\theta}, \boldsymbol{\phi}) \, L_{\mathrm{i}}({}^{\mathrm{S}}\boldsymbol{x}, \lambda, \boldsymbol{\phi}) \, \cos\boldsymbol{\phi} \, \mathrm{d}\boldsymbol{\phi} \ . \end{aligned} \tag{4}$$

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$$\begin{bmatrix}\hat{V}^1\\ \hat{V}^2\\ \hat{V}^3\end{bmatrix} \approx \begin{bmatrix} \frac{\langle \tau^1 qL, \tau^1 \rangle}{\|\tau^1 qL\|^2} & \frac{\langle \tau^2 qL, \tau^1 \rangle}{\|\tau^2 qL\|^3} & \frac{\langle \tau^3 qL, \tau^1 \rangle}{\|\tau^3 qL\|^4} \\ \frac{\langle \tau^1 qL, \tau^2 \rangle}{\|\tau^1 qL\|^5} & \frac{\langle \tau^2 qL, \tau^2 \rangle}{\|\tau^2 qL\|^6} & \frac{\langle \tau^3 qL, \tau^2 \rangle}{\|\tau^3 qL\|^7} \\ \frac{\langle \tau^1 qL, \tau^3 \rangle}{\|\tau^1 qL\|^8} & \frac{\langle \tau^2 qL, \tau^3 \rangle}{\|\tau^2 qL\|^9} & \frac{\langle \tau^3 qL, \tau^3 \rangle}{\|\tau^3 qL\|^2} \end{bmatrix} \begin{bmatrix}V^1\\ V^2\\ V^3\end{bmatrix} \quad , \tag{5}$$

Give URL's like this: `http://www.oonumerics.org/blitz/`. That way they may work as links in PDF.

3 EXPERIMENTS

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An example of a table is presented in Table 1.

Table 1. Method parameters for all tests.

minimum distance	10	px
maximum number of point trackers	50	
maximum time between point tracker resurrections	10	fr
minimum number of point trackers until resurrection	20	
template matching RMSE threshold	32	
template size	9 by 9	px
search distance along both axes	7	px
weak corner eigenvalue threshold	0.01	
RANSAC inlier error threshold	1.4	px
RANSAC maximum number of attempts	40	
RANSAC immediate acceptance threshold, inliers	35	
minimum number of RANSAC inliers	8	

You can reference to Appendix 2, and in there, Figure A2.1. Hey, let us throw here another completely irrelevant reference, see the book [2].

4 DISCUSSION

We have to discuss what we learned.

Notice the automatic page breaks.

4.1 Future Work

It is always nice to give some ideas for the future.

5 CONCLUSIONS

Finally the conclusions. This is more compact that the Discussion, a sort of summary about how things went on a general level.

Now you can delete all this crap content and write your own. Have fun!

REFERENCES

[1] Alberto Ortiz and Gabriel Oliver. Radiometric calibration of CCD sensors: Dark current and fixed pattern noise estimation. In *IEEE International Conference on Robotics and Automation*, volume 5, pages 4730–4735, 2004.

[2] R.A. Adams. *Calculus*. Addison Wesley Longman, Inc, 4th edition, 1999. ISBN 0-201-39607-6.

Appendix 1. Appendix Guidelines

The appendices part starts with the command `\appendix`. Then, each appendix must be started with `\section{Appendix Name}` and ended with `\sectionend` to have the continues/continued markings right. For example, see the multi-page appendices after this one.

Appendix 2. Frame Schematics

This is an appendix. If you need more appendices, just make a new section here (the `section` command).

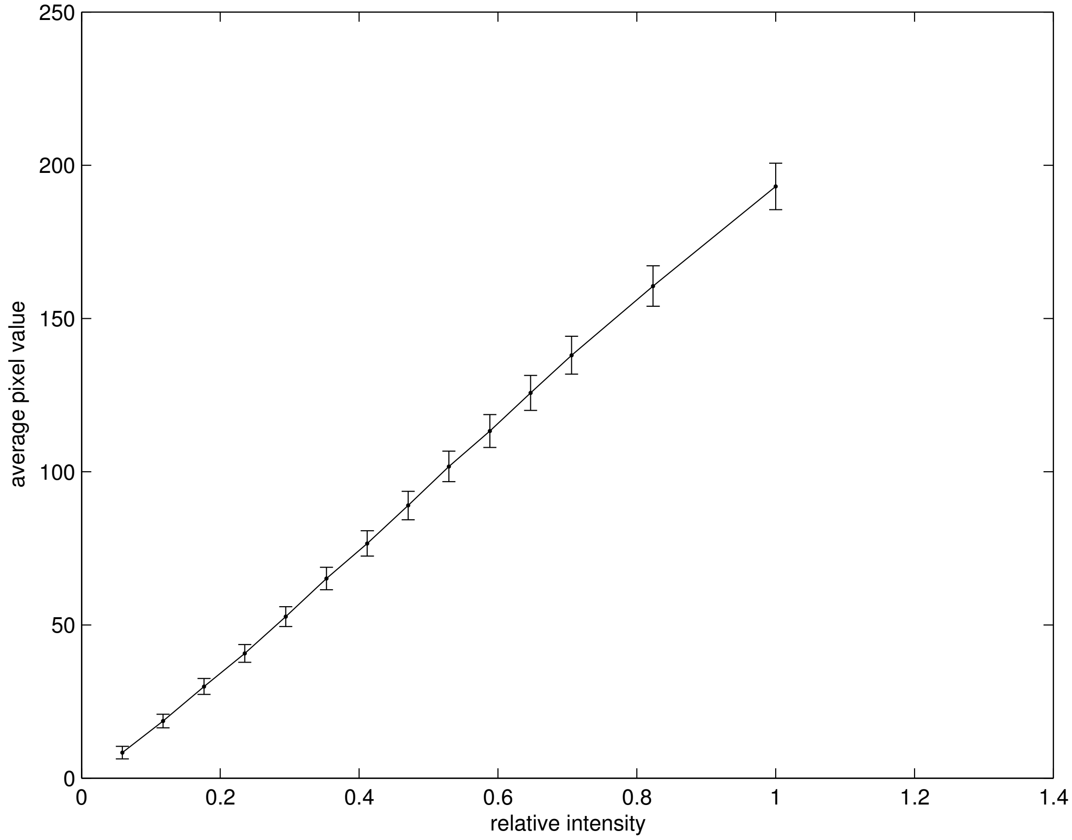

Figure A2.1. Overall design, only one half drawn.

huhu

Reference testing: Figures A2.1, A2.2, and A3.1. Table A3.1.

(continues)

Appendix 2. (continued)

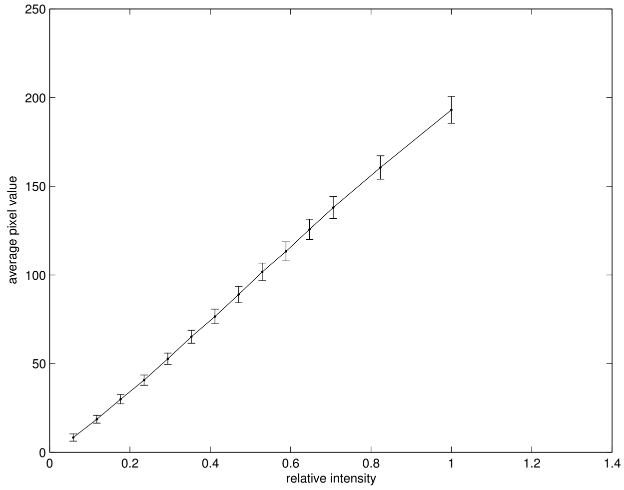

Figure A2.2. Another picture.

Appendix 3. The Second

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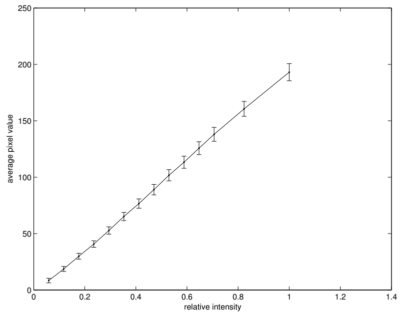

Figure A3.1. The same picture once more.

Table A3.1. Appendix test table.

minimum distance	10	px

(continues)

Appendix 3. (continued)

Aaand two more pages, to test the continues/continued marks.

(continues)

Appendix 3. (continued)

Aaand one more page, to test the continues/continued marks.