CRANFIELD UNIVERSITY

Mateusz Golab

Forward integration of simultaneous ordinary differential equations with graphical output

School of Engineering

Software Engineering for Technical Computing

MSc THESIS

Academic Year: 2011 - 2012

Supervisor: Dr Peter Sherar, Prof Joanna Polanska

August 2012

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Supervisor: Dr Peter Sherar, Prof Joanna Polanska

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This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Science

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ABSTRACT

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Keywords:

ODE, Runge-Kutta, Modified Midpoint, Predictor - Corrector, Web development, GWT, AppEngine, Datastore, Unit testing.

ACKNOWLEDGEMENTS

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LIST OF ABBREVIATIONS

|  |  |
| --- | --- |
| CU | Cranfield University |
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# Introduction

## Motivation

### Use Style Heading 3 for Subsection Headings

Heading styles 1-6 should be applied to the headings throughout the main body of your thesis as they are the basis for the Table of Contents and caption numbering. Headings 7-9 have been modified specifically for use in the Appendices. The appearance of the headings can be changed by modifying the relevant Heading styles.

There is no need to leave blank lines between paragraphs as the Normal style (in addition to 1.5 line spacing) automatically incorporates spacing between paragraphs. The style Table Text can be applied to tables to reduce the line spacing.

#### Referring to Headings

**To create a cross-reference to a heading:**

1. Click on the **References** tab on the Ribbon
2. Select the **Cross-reference** command to open the Cross-reference window
3. Under **Reference Type** choose **Heading**
4. Under **For which heading** choose your heading
5. Under **Insert Reference To** choose **Heading Number** and click **Insert**. Repeat to insert the **Heading Text**
6. Click **Close**

## Section Breaks

This document relies on section breaks to control page layout, page numbering and so on. Specifically, **Odd Page Section Breaks** have been used to ensure that the following chapter will always start on an odd ‘facing’ page.

It is recommended that you work with the non-printing characters visible at all times to minimise the risk of accidentally deleting the section breaks. The **Show/Hide** button is located in **Paragraph** group on the **Home** tab of the Ribbon.

## Inserting captions in the main document

Captions should be used whenever you insert a graphic, table or equation – to add a caption choose **Insert Caption** from the **References** tab on the Ribbon. Specify whether the label should be Figure, Table or Equation or create a new caption of your own.



Figure ‑ A figure caption

Table ‑ A table caption

|  |  |  |
| --- | --- | --- |
|  | Heading | Heading |
| Label | Detail | Detail |
| Label | Detail | Detail |

Equations and their captions can be placed ‘side-by-side’ by moving the equation and the caption into the cells of a borderless, 2 column x 1 row table as shown below. Simply copy and paste this table as many times as you need to for all subsequent equations, but remember to periodically highlight and update the equation captions by pressing the **F9** key (or right-click and select **Update Field** from the shortcut menu).

|  |  |
| --- | --- |
|  | (‑) |

For information on inserting captions in appendices see Appendix A.

### Referring to captions for figures, tables etc

Use a cross-reference when you want to insert text similar to ‘… as shown in Figure 5.1, below’

1. Click on the **References** tab on the Ribbon
2. Select the **Cross-reference** command to open the Cross-reference window
3. In the **Reference Type** drop-down list choose the appropriate label
4. Under **For which heading** choose your figure
5. Under **Insert Reference To** choose **Only label and number** and click **Insert**. Repeat to insert either **above/below** or **page number** if required
6. Click **Close**

## Updating Tables of Contents, Lists of Figures and Captions

Your table of contents, lists of figures and caption numbers will update automatically whenever you re-open the document, however you can ‘force’ an update at any time by highlighting the table or text and pressing the **F9** key (or right-click and select **Update Field** from the shortcut menu). To update all fields in a document press **Ctrl+A** then **F9**.

## Inserting Landscape Pages

It is often preferable to use a landscape page to display tables of data, charts or diagrams. Before changing an existing page from portrait to landscape it is necessary to enclose the page within a pair of next page section breaks. It may also be necessary to modify the page number format to ensure that page numbering continues from the previous section.

**To insert a Next Page Section Break:**

1. Click to place the insertion point where you would like to switch from portrait to landscape page orientation.
2. Go to the **Page Layout** tab on the Ribbon
3. Select the **Breaks** command and choose **Next Page** from the drop down list
4. Repeat steps 1-3 to insert a second **Next Page Section Break** at the point where you wish to switch back to portrait orientation
5. Click somewhere between the 2 new section breaks and use the **Orientation** command on the **Page Layout** tab to change page orientation from portrait to landscape.

# Literature review

## ODE numerical routines

### 4th Order Runge-Kutta

### Modified Midpoint

### Burlish – Stoer

### Rosenbrock

### Predictor- Corrector

#### Adams-Bashforth-Moulton

## Technologies

### AJAX web development approach

### Google Web Toolkit

### AppEngine

### Datastore

# Methodologies taken

## Section Heading (use Heading 2)

### Subsection Heading (use Heading 3)

# Design

## Architecture

### Technologies applied

# Testing

## Test driven development approach

### Subsection Heading (use Heading 3)

## Testing methods

### Unit testing

### Cross – browser testing

# Implementation

## Parser

## Solver

## Graph Viewer

## Datastore connector

# 

# Results

## Testing process results

## Application’s outputs

# Discussion

## Results correctness

## Quality of implemented solvers

### Subsection Heading (use Heading 3)

## Bulletproofness of the parser

## Graph quality

# Conclusion

## Section Heading (use Heading 2)

### Subsection Heading (use Heading 3)

REFERENCES

Insert list of references here

APPENDICES

Whilst Heading 1 to Heading 6 can be used to number headings in the main body of the thesis, Heading styles 7–9 have been modified specifically for lettered appendix headings with Heading 7 having the ‘Appendix’ prefix as shown below.

Appendix Title (Use Heading 7)

Appendix Section (Use Heading 8)

Appendix Subsection (Use Heading 9)

Creating captions in Appendices

If you have chosen to include chapter numbers in your captions then follow the instructions given here to apply the same format to the captions in your appendices. This section explains how to caption the figures and tables in your Appendices, assuming that Heading 7 is numbered “Appendix A” and that the Figures and Tables are going to be labelled ‘Figure A-1’, ‘Figure A-2’, ‘Table B-1’ etc.

You will have to create new, separate labels that look like the ‘Figure’ and ‘Table’ labels you used in the main body of your thesis.

1. Select the **References** tab on the Ribbon then click on **Insert Caption**
2. Click **New Label**. Type **Figure\_Apx** then click **OK**
3. You now have two labels for figures, called **Figure** and **Figure\_Apx**  
   Repeat for table captions.
4. In the **Caption** box, type your caption text
5. Click **Numbering**. Tick **Include chapter numbering** and choose **Heading 7** from the drop-down list of styles and click **OK** twice
6. Your caption should look something like this:

**Figure\_Apx A‑1 This is the caption text for a Figure in the Appendix**

1. Delete the extraneous ‘\_Apx’ from the caption label so it reads:  
   **Figure A‑1 This is the caption text for a Figure in the Appendix**  
   **TIP:** Instead of deleting each ‘\_Apx’ individually use **Find & Replace** to modify all the labels at once.

Creating Lists of Figures and Tables for Appendices

This template already includes a List of Figures and a List of Tables, however you will have to create two new lists for the ‘Figure\_Apx’ and the ‘Table\_Apx’ labels.

1. Place the insertion point on a blank row after the existing List of Figures
2. Select the **Insert Table of Figures** command on the **References** tab of the Ribbon
3. Set the **Caption Label** box to ‘**Figure\_Apx**’ and click **OK**  
   **Note:** Word will put a single blank line between the original and new lists preventing it from appearing as one seamless list. However if you select the blank paragraph between the tables you can hide it by opening the Font dialog box from the Home tab and selecting **Hidden**.
4. Click after the List of Tables and repeat for the Caption Label ‘Table\_Apx’