A Visualisation Course in a Game Development Curriculum

V. Sundstedt[†][1]

[1]Blekinge Institute of Technology, Sweden

Abstract

Visualisation courses can often be found as part of a computer science curriculum. These basic or advanced level courses are often taught in terms of information visualisation, scientific visualisation or a combination of both. Other visualisation courses focus more on visual aesthetics. This paper presents and discusses a visualisation course curriculum which is aimed at students specifically studying computer science programmes with a focus on digital game development. Since computer games of today keep generating an increasing amount of data it is more important than ever to educate our game development students with the theory behind visualisation and key data visualisation techniques. In the design and evaluation of the visualisation in games curriculum, it was found that concepts within the area of visualisation are relevant to many areas of digital games. This paper describes the curriculum for a university course which might not be commonly found in traditional game development programmes. It particularly presents the course structure and the lessons learned which together with existing literature demonstrate important concepts to consider in the area of visualisation in games.

Categories and Subject Descriptors (according to ACM CCS): K.3.2 [Computer Graphics]: Computer and Information Science Education—Computer science education, Curriculum

1. Introduction

Fundamental computer science programmes often teach courses in visualisation [The13], in particular, visual analytics, scientific visualisation or information visualisation. Visualisation is used to gain new insights and enhance understanding in data that would not otherwise have been possible. The topic of visualisation in games and game analytics is an increasingly important part of business intelligence [NDC13], digital game play and development, and can be used to educate and motivate players [Haz14]. Digital games of today generate more data than ever and it is important to be able to visualise and understand this data effectively. Both players and people watching need to understand the game [HHA04] and developers need to visualise aspects of the development process when making game design decisions [ALA*10]. With an increase in eSports, it is also important to effectively understand player behaviour for teams to improve their skills and strategies [KWP14]. Recently Mike Ambinder at Valve Corporation was a keynote speaker at CHI PLAY 2014 (ACM SIGCHI Annual Symposium on Computer-Human Interaction in Play) and he highlighted that more data than ever is stored from online games and that there is a need to be able to understand and visualise this information. Telemetry, or tracking and analysing behavioural data from games, has also increased in importance in the last few years [MeNS11, WKG*14, MBWMN14,FCD*15]. This paper presents how aspects of a traditional visualisation course curriculum has been targeted towards digital game development education. The developed course curriculum is presented as an example, which is part of a five-year Master of Science in Engineering: Game and Software Engineering degree at Blekinge Institute of Technology (BTH) since it was developed in 2010. Game engines can also be used for 3D model visualisation in for example architectural walkthroughs, archaeology, medicine, etc., but this course is focusing on data visualisation. The approach taken in the design of the course was to cover key aspects in traditional visualisation courses which would be of relevance for the digital game programme. The content was then complemented with the state of the art research influenced assignments in the computing laboratory at BTH. The overall research question asked in this paper and that warrants future discussion in the light of the above is:

- How should a visualisation course in a game development curriculum be structured?

The paper is organised as follows. Section 2 presents some background and related work in the area of curriculum design in traditional visualisation courses as well as giving examples of important aspects in visualisation techniques in games. Section 3 outlines the visualisation in games course curriculum currently taught at BTH. Section 4 presents some of the lessons learned and discusses how the current course could be modified for next year in the light of the evaluation performed in this paper. Finally, Section 5 presents some conclusions and needed future work in the area.

† vsu@bth.se

DOI: 10.2312/eged.20161020

2. Background and Related Work

There are many great resources for planning content in traditional visualisation courses, and there are several key textbooks in the area [Tuf90, Tuf01, HJ04, Spe07, War12, Mun14, RBB14, WGK15]. The sections below present two important parts about the design of the visualisation in games course curriculum in this paper. The first part presents two significant resources summarising key aspects in traditional visualisation course curriculum. This is followed by a literature review of some previous work focusing on visualisation techniques in games.

2.1. Example Visualisation Curriculum

Recently a Computer Science Curriculum 2013 report [The13] was published which includes recommended concepts to teach in courses on visualisation. Some of these insights relevant to the course presented in this paper are directly summarised below based on this report. In the Interactive Visualisation course curriculum [The13] it is recommended to cover topics such as: *(1) principles of data visualisation, (2) graphing and visualisation algorithms, (3) image processing techniques, and (4) scalability concerns. Learning outcomes mentioned include: (1) comparing common computer interface mechanisms with respect to ease-of-use, learnability, and cost, (2) using standard APIs and tools to create visual displays of data, including graphs, charts, tables, and histograms, (3) describing approaches to using a computer as a means for interacting with and processing data, (4) extracting useful information from a dataset, and (5) analyzing and selecting visualisation techniques for specific problems, and (6) describing issues related to scaling data analysis from small to large data sets.*

In the Visualisation course curriculum [The13] it is recommended to cover topics such as: *(1) visualisation of 2D/3D scalar fields: colour mapping and isosurfaces, (2) direct volume data rendering: ray-casting, transfer functions, segmentation, (3) visualisation of vector fields and flow data, time-varying data, high-dimensional data: dimension reduction, parallel coordinates, non-spatial data: multi-variate, tree/graph structured, text (4) perceptual and cognitive foundations that drive visual abstractions, (5) visualisation design, (6) evaluation of visualisation methods, and (7) applications of visualisation. Learning outcomes include: (1) describe the basic algorithms for scalar and vector visualisation, (2) describe the tradeoffs of visualisation techniques in terms of accuracy and performance, (3) propose a suitable visualisation design for a particular combination of data characteristics and application tasks, (4) analyze the effectiveness of a given visualisation for a particular task, (5) design a process to evaluate the utility of a visualisation algorithm or system, and (6) recognize a variety of applications of visualisation including representations of scientific, medical, and mathematical data; flow visualisation, and spatial analysis.*

Another key resource is the ACM SIGGRAPH Curriculum for Visualization [Dom15] which also gathers useful material in the area of "Education for Visualization". The editor is Gitta Domik, and it was prepared by the ACM SIGGRAPH Education Subcommittee on "Education for Visualization". They identify eight main themes which are directly summarised below with some selected subcategories potentially relevant even for this course: *(1) introduction to visualisation: history, definitions, sample applications, impact of future technology, (2) data: examples, relationships, models, (3) users and tasks: human performance issues, visualisation and task goals, evaluation, (4) mapping: models of mapping strategies, difficulties in the mapping strategies, visual context, (5) representations: general discussion, computer graphics, selection criteria, techniques, (6) interaction issues: interaction flow, interaction design, human performance, implementation, evaluation, (7) concepts of the visualisation process, and (8) systems and tools.*

2.2. Visualisation Techniques in Games

There are several different types of visualisations in games. In [Haz14] it is described that visualisations can be used for: (1) status information to provide players with data such as health, score and experience points or (2) training to improve gameplay. It is also reported in [Haz14] that observers make use of data visualisations by being informed about for example kill and death ratios. Pre-attentive processing is also reported as key in games to quickly understand information [Haz14]. Hayden Duvall [Duv01] also highlights the importance of considering visual psychology and perception in game design. Colourblindness is another aspect that is mentioned, and several games have settings that can adjust the game to be better suited for people with eye deficiencies [Haz13]. Another important aspect that Duvall introduces is principles of Gestalt psychology applied to game design. Greg Wilson [Wil06] discusses Head-up displays (HUDs) and how necessary game information is conveyed when one trend is to move away from relaying on these. In eSports, it is key to being able to visualise what your team have done to develop better strategies [KWP14]. Eye tracking, for example, can be used to generate heatmaps and gaze plots which are important tools in this process. Eye tracking technology can be a useful tool in analysing digital games, and hence aspects of the course have been designed around this technology [ENY06, SSWR08, SWB09]. Eye tracking has also been used as an interaction technique in computer games [Sun10] and eye tracking companies invest more research in this area. A great overview of suitable design patterns for how to successfully apply visualisation techniques in games can be found in [BEJk12]. Although there is a significant number of visualisation in games research articles, and one relevant textbook [NDC13] available, the resources have been found to be scattered in the design of this course curriculum.

3. The Visualisation in Games Course Curriculum

The aim of the visualisation in games course is to introduce data visualisation techniques. Large amounts of data can be difficult to understand and process. By using visualisation techniques, it can give us a simplification of data that otherwise is too complex. Game development is one important area for visualisation and other areas include engineering, technology, environment, and health as examples. The visualisation course has a basic classification level (corresponding to undergraduate level) and the main subject area is computer science. It is worth 7.5 credit points (cp) in the European Credit Transfer System (ECTS). The prerequisites for the course are 60 completed cp within computer science and of those at least

3.5 within databases. The course is taught in Swedish, English or a combination of both. The course is part of a technical Master of Science in Engineering curriculum which consists of mainly programming, project work, maths and physics, engineering skills, thesis work, and some optional courses. It aims to give specialist competence in game technology as well as a foundation in software engineering. The structure of the course include lectures, computing labs, supervision, individual and group project work, presentations of student work, and reading scientific literature and using it practically within the assignments. An overview of the course can be seen in Figure 1. As can be seen, the course is front-loaded in lectures so that focus can be on the group project and supervision of this towards the end.

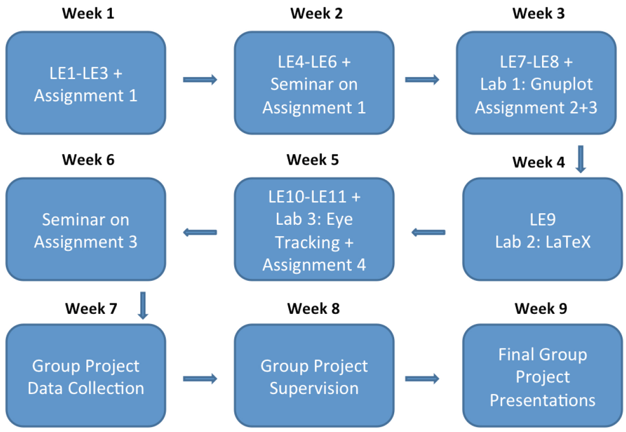

Figure 1: *An overview of the course structure spanning over nine weeks. As can be seen the course is front-loaded in lectures so focus can be on the group project towards the end.*

3.1. The Learning Objectives

The learning objectives of the course are described below. The motivation for the learning objectives is based on experiences from more traditional visualisation courses as well as how the course needed to fit within the curriculum and overalls goals of the programme. After the course the student should be able to:

Knowledge and Understanding: Describe how different techniques can contribute to creating an effective visualisation.

Skills and Abilities: Be able to visualise information with the help of visualisation tools. Be able to apply visualisation techniques in a larger visualisation project. Both verbally and with visual techniques be able to describe a visualisation process to others. Independently and critically be able to assess and value information as well as critically discuss relevant aspects, questions, and situations. Be able to use terms and concepts within visualisation (in particular within information visualisation and scientific visualisation).

Values and Attitudes: Have the ability from a computer science perspective to make evaluations of relevant scientific aspects. Independently be able to review and evaluate their work.

3.2. The Content

The foundations of the course are basic concepts in data visualisation but with an explicit focus on computer games. Key concepts within visualisation such as perception, cognition, techniques and algorithms for visualisation are being introduced. Different software for visualising data is being introduced as part of the course. Often at digital game development programmes, most courses are of a technical nature and students can lack academic writing and presentation skills as well as the experience of data generation, visualisation, and analysis. This is an important part of their final thesis projects and hence, the visualisation in games course was designed to include these aspects. These are not traditional topics covered but were missing in other parts of the programme.

The idea of this course is to formulate problems, generate relevant data and visualise data to get a deeper understanding. This is highly relevant to practice in preparation for the thesis work which often does not focus on how data is visualised. This is important regarding the quality of graphs but also the type of visualisations used to answer research problems. The course presents several books as reference literature [Tuf90,Tuf01,HJ04,Spe07,War12,NDC13] but the main reading material for the course is based on scientific articles. Some of these are presented in Section 2.2. The course has eleven two-hour lectures and three computing labs (Lab 1: Gnuplot, Lab 2: LaTeX, and Lab 3: Eye Tracking). The five assignments in the course are further presented in Section 3.3. Lab 1 and Lab 2 are important to Assignment 2 and Lab 3 to Assignment 4. The lectures on the course are: (L1) Visualisation Introduction, (L2) Perception and Cognition, (L3) Colour, (L4) Data Representations, (L5) Information Visualisation, (L6) Scientific Visualisation, (L7) Data Collection and Gnuplot (+Lab 1), (L8) Visualisation Techniques in Games, (L9) Academic Writing and LaTeX (+Lab 2), (L10) Eye Tracking in Games (+Lab 3), and (L11) Project Description.

L1 introduces the course and covers topics such as what visualisation is and the purpose and usefulness of visualisation. It shows different types of visualisations and application areas for visualisation techniques. It also covers some history of visualisation and discusses important work that changed how visualisation is seen. Related areas to visualisation are also presented to show a broader context. Why visualisation in games is important is also presented with state of the art research examples to highlight how visualisation techniques have helped answer research questions in digital game development. Finally some key conferences and journals are presented as relevant sources for reading important for the assignments. Assignment 1: Good and Bad Visualisations is given out in L1 as shown in Figure 1. L2 presents key concepts, such as Gestalt psychology, within perception and cognition which are of importance. L3 on colour gives an introduction to the importance of colour, what it is, and how we perceive colours. It also presents a brief introduction to the human visual system, pre-attentive processing, colour vision deficiency, characteristics of colour, colour models, colour design terminology, and colour standards. Finally, it presents how colour is used in games, and some subjective aspects of the meaning of colours. Figure 2 shows stimuli from a student group project exploring the concepts taught within perception and colour. In particular this project explored attention-driven visualisation guided by pre-attentive processing.

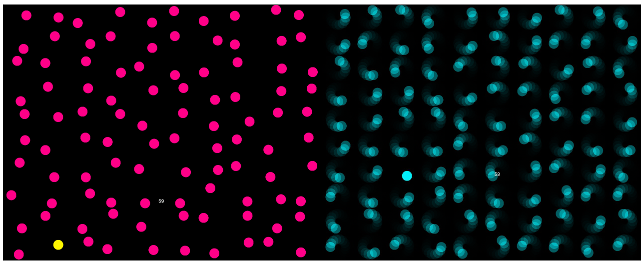

Figure 2: *Example stimuli from a student project exploring attention-driven visualisation guided by pre-attentive processing. Image courtesy of Anton Andersson, Johan Carlberg, Mattias Liljeson, and Robin Thunström.*

L4-L6 presents different types of data and graphs with examples from information visualisation and scientific visualisation. It covers guidelines for making visualisations more effective and presents important visualisation techniques. It also distinguishes different data types (quantitative/qualitative and continuous/discrete). Part of these lectures is also a discussion on good and bad data representations. L6 presents examples in scientific visualisation including work in medical visualisation and algorithms for visualising data (isosurfaces, vector fields, potential fields, colour mapping, contouring, volume rendering, and slicing). It gives examples from both 2D and 3D visualisations. L7 presents how data can be collected (simulation), processed (mean, standard deviation), presented (Gnuplot), interpreted, and published. LE8 presents visualisation techniques in games and Assignment 3: Game Visualisation Techniques is tightly coupled with LE8 in which the students analyse visualisation techniques from games. L9 provides an academic framework in which the result from L7 can be put into. A data simulation example is presented in L7 but the students are encouraged to work with their own simulations during the connecting computing labs (Lab 1 + Lab 2) in Assignment 2: Publishing Results. LE10 presents eye tracking technology and eye tracking visualisation techniques (heatmaps, gaze plots, areas of interest). Assignment 4: Eye Tracking Visualisation is built on the concepts taught in LE10. LE11 introduces the project and shows previous examples of student projects developed during the course of previous years for inspiration.

3.3. The Assignments

There are five assignments in the course. The first four assignments are individual and the fifth assignment is a project carried out in a group of 3-4 students. The assignments are listed below:

Assignment 1: Good and Bad Visualisations, 1cp, G-U
Assignment 2: Publishing Results, 2cp, A-F
Assignment 3: Game Visualisation Techniques, 1cp, A-F
Assignment 4: Eye Tracking Visualisation, 1cp, G-U
Assignment 5: Group Project, 2.5cp, A-F

The final course is graded using grades A Excellent, B Very Good, C Good, D Satisfactory, E Acceptable, FX Fail-complementation required, and F Fail. The final grade is an unweighed rounded average grade of the assessed moments of the course. If the grade lies exactly between two grade levels the rounding will be done to the lower grade. G-U has three levels and stands for G Pass, UX Fail-complementation required, and U Fail. Below is a description of Assignments 1-5. Assignment 1 is a gentle introduction to getting the students to reflect on what makes an effective visualisation. Assignment 2 is described in less detail since the LaTeX part has been decided to be removed from the course as discussed in Section 4. The motivation for Assignment 3-5, in particular, is the relevance to the ongoing state of the art research in the area of visualisation and games. The overall idea behind the relationship between the assignments is that they would have an increased level of complexity over the duration of the course. Having incremental activities in a curriculum is a useful pedagogical approach [PA14].

3.3.1. Assignment 1

Assignment 1 is based on one of the Berkeley CS294-10 Fall 07 Visualization [Agr07] course assignments. This assignment is given out during the first lecture and hence the students are not experienced with what makes good and bad visualisations at this point. Their task similar to the Berkeley course is to pick and discuss what they think are good and bad examples of visualisations. They should then redesign the bad visualisation and present their result in a seminar in the second week of the course, as shown in Figure 1. A passing grade G is awarded for successfully taking part in the seminar and handing in a report with motivations containing the good, bad, and redesigned visualisation. It has been very interesting to see the identified good and bad concepts also mentioned in the literature and which the students after the seminar will learn more about in the remainder of the course.

3.3.2. Assignment 2

Assignment 2 focuses on LaTeX and Gnuplot to provide a framework for publishing high quality and effective visualisations. In this assignment, the students create a simulated experiment where they collect data which is later processed and presented in a report created in LaTeX. Gnuplot is used to generate charts from the collected data. Tasks included in the assignment are calculating mean values, displaying charts with error bars, writing an analysis and discussion of the statistics, and ensuring that appropriate captions and references are used. For a passing grade E, the students need to run the experiment, generate a graph using Gnuplot, include it as a figure in LaTeX with an appropriate caption as well as discussing their result. For a grade D, they also need to calculate and plot a measurement of error and create two different graphs using Gnuplot. On the C level they need to show that they can include an equation, table, and citation in LaTeX, include a representative image from their experiment, as well as making sure captions and units are appropriate. A grade B requires the student to consider if a trend can be seen and discuss the concept of significant differences and large error bars in the result. For a grade A, they should also plot a trend line and discuss the experiment in more depth regarding this.

3.3.3. Assignment 3

Assignment 3 is about identifying how data is presented to the player in games since gameplay actively creates a large amount

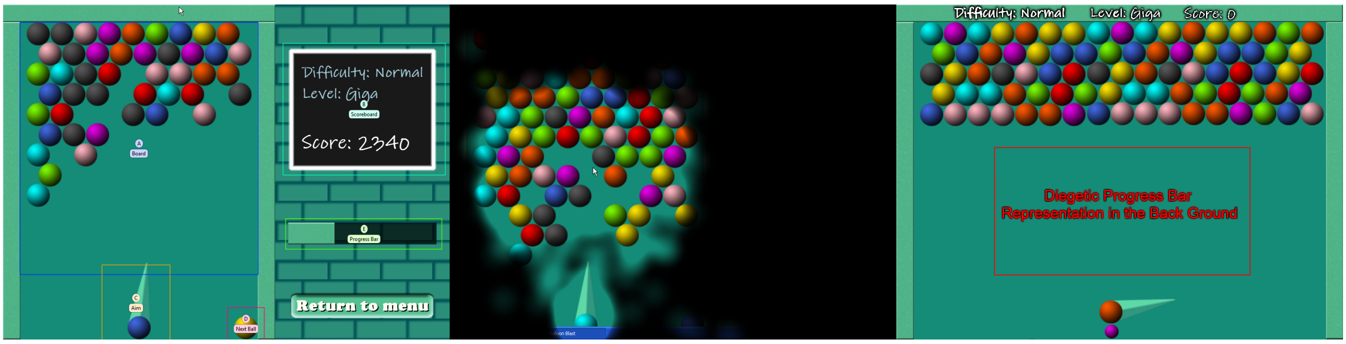

Figure 3: *Example project exploring what interface elements are used and important for the game experience: (left) original game with areas of interest used in the eye tracking analysis, (middle), transparent heatmap of attended areas by the player, and (right) redesigned game based on the eye tracking analysis. Image courtesy of Kim Restad, Max Danielsson, and Alexander Vestman.*

of information. The students evaluate how visualisation techniques and perception are employed in computer games. They pick one game to analyse for a lower grade (C-E) and two games for a higher grade (A-B). They are asked to discuss what data is visualised, what visualisation concepts are used, how the games are similar or differ (grade A or B), what good and bad design decisions have been taken and how appropriate the data is. They are also asked to relate their analysis to the existing literature on visualisation, the lecture material, and consider other ways visualisation techniques could be used in games. Their analysis should be submitted as a report of maximum five pages including images to support their conclusions. The references in the recommended reading [FS00, Duv01, Wil06, Zam08] act as a starting point and the students are also informed to reference any additional sources they use. The assignment is then discussed in a seminar.

A passing grade E is awarded for a carried out report that presents the relevant analysis and discussion from one game. The student should be able to give an example of how visualisation techniques and knowledge about perception are used in the game. The D grade allows minor problems with spelling but should otherwise be a well written and conducted report. A grade C also requires the student to reference concepts and techniques in the recommended reading list. For a grade B, two games need to be analysed and their report should integrate concepts to a meaningful structure based on several examples in the visualisation literature. The highest grade A is only obtained if the report has a deeper analysis where comparisons are being made as well as own reflections by the student. On this level, the report also needs to make appropriate references to other relevant articles in the visualisation literature.

3.3.4. Assignment 4

In Assignment 4 the students are introduced to eye tracking technology using a Tobii eye tracker. The students generate eye tracking data on a still image from a game in a computing lab which is later analysed using Tobii Studio to create heatmaps, scan paths, and area of interest visualisations. By getting an introduction to the eye tracker, the students can later choose to work with the technology in the group project. They need to have a question in mind that could be relevant to explore using eye tracking. Since the students have access to non-recording licences from Tobii they can analyse their data after the computing lab. They then submit a report containing the eye tracked image along with the different visualisation techniques and a discussion on which of the techniques was the most effective. A passing grade G is awarded for including the relevant visualisations in the report based around a relevant question and description of the eye tracking results. An example of a transparent heatmap generated based on eye tracking in a student project can be seen in Figure 3 (middle).

3.3.5. Assignment 5

The task in the group project assignment is to visualise data, to get insight, and to answer a question that is not possible by just looking at the data. The report of maximum ten pages should be centred around a hypothesis or research question which is framed by the material covered on the course. The discussion within the report should include what data is visualised, why the data is relevant to the question being answered, which visualisation technique was most powerful and why, and what the visualisation could tell about the hypothesis or research question. The report should also include images from their games and visualisations. To help structure the report and its content the students should follow academic writing guidelines as distributed as part of the course. The final report should be formatted with LaTeX using the appropriate features they need for their project (figures, tables, captions, labels, citations, etc.). If they aim at a higher grade on the course, it is very important that they use terms and concepts within the scientific literature to motivate their visualisations and to influence the discussion and analysis. The references in the recommended reading are a starting point and they are informed to reference any sources used. In the final group presentation, they should present their hypothesis, show their visualisation(s), and discuss how they have used visualisation techniques to create their result. Each group have 20 minutes to present their work followed by a 10-minute discussion.

A passing grade E is awarded for a carried out report that presents the hypothesis or question and data used for analysis and discussion. On this level, the report should handle some visualisation aspects (< 5) covered in the course. For a grade D the report should handle a larger number of visualisation aspects (> 5) covered in the course. A C grade report should also be well executed regarding spelling, structure, effective visualisations, high-quality graphics, and have relevant data for analysis and discussion. At the B level grade the students need to integrate concepts so they form a meaningful structure based on analysis from several examples in the visualisation literature. They should also make references to concepts and techniques in visualisation from the recommended reading list. For the highest grade A the students need to put the central facts into a deeper analysis where comparisons are being made and own reflections are introduced. In addition to referencing articles in the recommended reading list they also need to explore other scientific articles in the visualisation literature. Example stimuli of a group project using the eye tracker can be in Figure 3. In this project, the students had designed a game and explored using eye tracking what areas were the most attended. The game design was then modified based on the eye movement information from the observers. Figure 4 shows another student project in which the process of their game development project was studied in further detail.

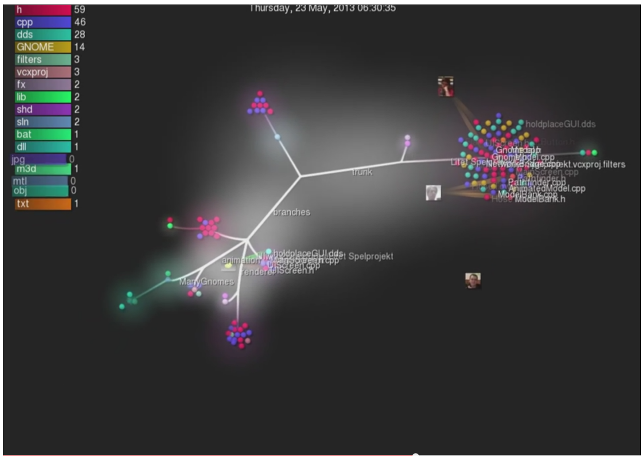

Figure 4: *Image generated using the Gource software version control visualisation as part of a project studying game project development. Image courtesy of Daniel Bengtsson, David Pejtersen, and Jens Stjernkvist. Gource software courtesy of Andrew Caudwell.*

4. Results and Discussion

Taking into account all years the course has been run the perception is that the students appreciate the course overall although some found it challenging regarding how much time it consumed. Based on the course evaluations lessons have been learned which has led to the course being redesigned in the upcoming year. Since the course started the material has been improved regarding clarifying the main focus of the course. There are still perceived overlaps in different parts of visualisation: information visualisation and visual aesthetics for example which at times have been confusing to distinguish on a game development programme. Some students appreciate more the design elements of the course, although it has a significant focus on data visualisation, whereas others would like to see it even more data focused.

The next iteration of the course will, therefore, clarify these aspects further and focus more on data visualisation. Based on the literature review it is crucial to cover aspects such as perception, cognition and colour, etc. but perhaps with more examples from games and less on traditional visualisation course examples. Based on the course evaluation the lectures could be made more specific and more closely tied to the assignments. Another suggestion has been to incorporate more psychology in relation to visualisation with a focus on games. This could be relevant with the ongoing trend in telemetry and game analytics. The group project allows the students to focus on a specific area that they find interesting in more depth.

The course does include a significant amount of report writing which is useful practice on the programme but Assignment 3 and Assignment 5 were perhaps perceived a little bit too similar. The intention was that Assignment 3 would focus on analysing existing game techniques based around the material covered on the course whereas Assignment 5 would allow more flexibility in what research questions could be posed opening up for creative group projects in the area. Assignment 4 was done separately to educate the students in how to use the eye tracker in case it would be chosen as the technology for the final group project. Since the feedback suggests that there are perceived overlaps within Assignment 3-5, perhaps thoughts could be put into how to join some of these together focusing more clearly on fewer assignments. Some students reported that it was interesting to carry out the assignment in the research laboratory.

There were different opinions regarding setting a maximum page length for the written assignments. Some felt they could write more and were restricted by the format and maximum page length. In general, the idea was that this would be a useful exercise to prepare for their thesis work and to be able to be more specific in what they wrote. Academic writing and LaTeX, which has been a part of the course for a few years, will be removed since it is now covered in earlier courses on the programme. This was not the case when the course started and it was, therefore, relevant to cover in relation to plotting and presenting data. Having these topics in separate courses makes more sense and gives space for further details on visualisation techniques in games.

Gnuplot was chosen as one tool but there are also many other visualisation tools available as suggested by the feedback. The course page also lists other visualisation tools suitable for information and scientific visualisation that could be explored in the final project. Some thought it took too long time to generate their own simulations for Assignment 2. They would rather have seen that they were provided with existing data sets to work with. This could perhaps be an option to free up further time to explore additional visualisation techniques for existing data sets. Someone commented on that the grading scale for Assignment 2 could be more suitable as G-U rather than A-F since it was more about showing knowledge in LaTeX and Gnuplot. Although more features were required for a higher grade, the depth in the assignment could perhaps have an even further increase in complexity. Another comment was that further knowledge in statistics would have helped. Some reported that the grading criteria were clear and that they appreciated knowing what was expected at each level.

One valuable feedback was the need for identifying a specific relevant course textbook and pages to read and this is true and could be improved. There is a gap for a suitable visualisation in games textbook which covers relevant aspects of visualisation applied to computer games in an easy to follow manner. There has been a recent relevant book [NDC13] but it is not written as a textbook for students specifically and has a broader coverage. Based on running the course for five years a lot of potential relevant visualisation in games resources have emerged and could be focused on further in the lecture series, computing labs, and assignments. Hence, the course will be redesigned for 2016 to meet better these demands and to have a more narrow focus in the light of these developments. For the next iteration of the course we will also try to incorporate relevant guest lectures from industry to highlight why data visualisation in games is important. Perhaps the course name should also formally be changed to Visualisation in Games to distinguish it further from more traditional visualisation courses. If this is done perhaps the learning objectives should also be revised to fit better with the new context.

5. Conclusions and Future Work

This paper has presented and evaluated an existing curriculum for a visualisation course developed with a focus on a digital game development programme. The research question posed at the beginning of the paper asked how a visualisation course in a game development curriculum should be structured. Based on the literature found over the last five years it is crucial to incorporate traditional concepts of data visualisation in a visualisation in games curriculum. Many aspects within perception, cognition, colour, visualisation algorithms, etc. are useful for game programming students. However it was found that a more specific approach and more game focused course material needs to be developed to improve further the course. As mentioned in the introduction data visualisation is also becoming increasingly important in many aspects of gaming. Hence perhaps a more relevant focus of the course should be based around these new areas targeted with real examples from industry and with a clear mapping to the most relevant concepts of information visualisation in particular. It is also key to have a discussion regarding how the learning outcomes of this course compares to a traditional visualisation course. Future work and an extension to this paper would include creating a synthesis of the results of the student assignments in relation to the existing literature.

6. Acknowledgments

The author would like to thank Charlotte Sennersten, Martin Lanner, Anton Gerdelan, Stefan Petersson, Prashant Goswami, Diego Navarro, Johan Hagelbäck, Henrik Cederholm, and Olle Hilborn, for their contributions to the development of the visualisation course. The author would also like to thank Kim Restad, Max Danielsson, Alexander Vestman, Mattias Liljesson, Robin Thunström, Anton Andersson, Johan Carlberg, Daniel Bengtsson, David Pejtersen, and Jens Stjernkvist for the student project example images. Finally, thanks to Andrew Caudwell for the Gource software and Tobii Pro for supplying us with extra non-recording licences to use in the course assignments.

References

[Agr07] AGRAWALA M.: Cs 294-10 fall '07 visualization. http://vis.berkeley.edu/courses/cs294-10-fa07/wiki/index.php/Main_Page, 2007. 4

[ALA*10] ANDERSEN E., LIU Y.-E., APTER E., BOUCHER-GENESSE F., POPOVIĆ Z.: Gameplay analysis through state projection. In *Proceedings of the Fifth International Conference on the Foundations of Digital Games* (New York, NY, USA, 2010), FDG '10, ACM, pp. 1–8. URL: http://doi.acm.org/10.1145/1822348.1822349, doi:10.1145/1822348.1822349. 1

[BEJk12] BOWMAN B., ELMQVIST N., JANKUN-KELLY T. J.: Toward visualization for games: Theory, design space, and patterns, 2012. 2

[Dom15] DOMIK G.: Acm siggraph curriculum for visualization (editor: G. domik, prepared by the acm siggraph education subcommittee on education for visualization). http://www.uni-paderborn.de/cs/vis, 2015. 2

[Duv01] DUVALL H.: It's all in your mind: Visual psychology and perception in game design. http://www.gamasutra.com/view/feature/131506/its_all_in_your_mind_visual_.php, 2001. 2, 5

[ENY06] EL-NASR M. S., YAN S.: Visual attention in 3d video games. In *Proceedings of the 2006 ACM SIGCHI International Conference on Advances in Computer Entertainment Technology* (New York, NY, USA, 2006), ACE '06, ACM. URL: http://doi.acm.org/10.1145/1178823.1178849, doi:10.1145/1178823.1178849. 2

[FCD*15] FELTWELL T., CIELNIAK G., DICKINSON P., KIRMAN B. J., LAWSON S.: Dendrogram visualization as a game design tool. In *Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play* (New York, NY, USA, 2015), CHI PLAY '15, ACM, pp. 505–510. URL: http://doi.acm.org/10.1145/2793107.2810284, doi:10.1145/2793107.2810284. 1

[FS00] FIORITO J., STITT C.: Lessons in color theory for spyro the dragon. http://www.gamasutra.com/view/feature/131581/lessons_in_color_theory_for_spyro_.php, 2000. 5

[Haz13] HAZELL J.: The data visualization-ification of video games. http://www.dundas.com/blog-post/the-data-visualization-ification-of-video-games/, 2013. 2

[Haz14] HAZZARD E.: Data visualization in games. http://vasir.net/blog/game-development/data-visualization-in-games, 2014. 1, 2

[HHA04] HOOBLER N., HUMPHREYS G., AGRAWALA M.: Visualizing competitive behaviors in multi-user virtual environments. In *Proceedings of the Conference on Visualization '04* (Washington, DC, USA, 2004), VIS '04, IEEE Computer Society, pp. 163–170. URL: http://dx.doi.org/10.1109/VISUAL.2004.120, doi:10.1109/VISUAL.2004.120. 1

[HJ04] HANSEN C., JOHNSON C.: *The Visualisation Handbook*. Academic Press, 2004. 2, 3

[KWP14] KRIGLSTEIN S., WALLNER G., POHL M.: A user study of different gameplay visualizations. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (New York, NY, USA, 2014), CHI '14, ACM, pp. 361–370. URL: http://doi.acm.org/10.1145/2556288.2557317, doi:10.1145/2556288.2557317. 1, 2

[MBWMN14] MIRZA-BABAEI P., WALLNER G., MCALLISTER G., NACKE L. E.: Unified visualization of quantitative and qualitative playtesting data. In *CHI '14 Extended Abstracts on Human Factors in Computing Systems* (New York, NY, USA, 2014), CHI EA '14, ACM, pp. 1363–1368. URL: http://doi.acm.org/10.1145/2559206.2581224, doi:10.1145/2559206.2581224. 1

[MeNS11] MOURA D., EL NASR M. S., SHAW C. D.: Visualizing and understanding players' behavior in video games: Discovering patterns and supporting aggregation and comparison. In *Proceedings of the 2011 ACM SIGGRAPH Symposium on Video Games* (New York, NY, USA, 2011), Sandbox '11, ACM, pp. 11–15. URL: http://doi.acm.

org/10.1145/2018556.2018559, doi:10.1145/2018556.2018559. 1

[Mun14] Munzner T.: *Visualization Analysis and Design*. A K Peters/CRC Press, 2014. 2

[NDC13] Nasr M., Drachen A., Canossa A.: *Game Analytics: Maximizing the Value of Player Data*. Springer Science & Business Media, 2013. 1, 2, 3, 7

[PA14] Peters C. E., Anderson E. F.: The Four I's Recipe for Cooking Up Computer Graphics Exercises and Assessments. In *Eurographics 2014 - Education Papers* (2014), Bourdin J.-J., Jorge J., Anderson E., (Eds.), The Eurographics Association. doi:10.2312/eged.20141029. 4

[RBB14] Raschke M., Blascheck T., Burch M.: Visual analysis of eye tracking data. In *Handbook of Human Centric Visualization*, Huang W., (Ed.). Springer New York, 2014, pp. 391–409. doi:10.1007/978-1-4614-7485-2_15. 2

[Spe07] Spence R.: *Information Visualization: Design for Interaction*. Pearson, 2007. 2, 3

[SSWR08] Sundstedt V., Stavrakis E., Wimmer M., Reinhard E.: A psychophysical study of fixation behavior in a computer game. In *Proceedings of the 5th Symposium on Applied Perception in Graphics and Visualization* (New York, NY, USA, 2008), APGV '08, ACM, pp. 43–50. URL: http://doi.acm.org/10.1145/1394281.1394288, doi:10.1145/1394281.1394288. 2

[Sun10] Sundstedt V.: Gazing at games: Using eye tracking to control virtual characters. In *ACM SIGGRAPH 2010 Courses* (New York, NY, USA, 2010), SIGGRAPH '10, ACM, pp. 5:1–5:160. URL: http://doi.acm.org/10.1145/1837101.1837106, doi:10.1145/1837101.1837106. 2

[SWB09] Sundstedt V., Whitton M., Bloj M.: The whys, how tos, and pitfalls of user studies. In *ACM SIGGRAPH 2009 Courses* (New York, NY, USA, 2009), SIGGRAPH '09, ACM, pp. 25:1–25:205. URL: http://doi.acm.org/10.1145/1667239.1667264, doi:10.1145/1667239.1667264. 2

[The13] Computer science curricula 2013 - curriculum guidelines for undergraduate degree programs in computer science. https://www.acm.org/education/CS2013-final-report.pdf, 2013. 1, 2

[Tuf90] Tufte E.: *Envisioning Information*. Graphics Press, 1990. 2, 3

[Tuf01] Tufte E.: *The Visual Display of Quantitative Information*. Graphics Press, 2001. 2, 3

[War12] Ware C.: *Information Visualization: Perception for Design*. Morgan Kaufmann, 2012. 2, 3

[WGK15] Ward M., Grinstein G., Keim D.: *Interactive Data Visualization: Foundations, Techniques, and Applications*. A K Peters/CRC Press; 2 edition, 2015. 2

[Wil06] Wilson G.: Off with their huds!: Rethinking the heads-up display in console game design. http://www.gamasutra.com/view/feature/130948/off_with_their_huds_rethinking_.php, 2006. 2, 5

[WKG*14] Wallner G., Kriglstein S., Gnadlinger F., Heiml M., Kranzer J.: Game user telemetry in practice: A case study. In *Proceedings of the 11th Conference on Advances in Computer Entertainment Technology* (New York, NY, USA, 2014), ACE '14, ACM, pp. 45:1–45:4. URL: http://doi.acm.org/10.1145/2663806.2663859, doi:10.1145/2663806.2663859. 1

[Zam08] Zammitto E.: Visualization techniques in video games. Electronic Visualisation and the Arts (EVA 2008), 2008. 5