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Interactive 3D Visualisation of Exoplanets

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Submitted in partial fulfilment of the requirements for
Bachelor of Software Engineering with Honors.

Abstract

We have lots of information about planets outside our solar system. This can be accessed from a database by anyone. However this information is complex and cannot be easily understood by laypeople. This is a problem as it means that the information gained about these planets is not being used effectively to convey knowledge to the masses. To resolve this a visualisation has been created that can convey this information in a way that interested lay people can understand. The result of this project is a visualisation system that can be used as an information source for laypeople wanting to increase their knowledge about planets outside of our solar system. This report outlines the project carried out, the visualisation created, as well as the evaluation to discover its effectiveness at fullfilling the goals driving its creation.

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Chapter 1

Introduction

This project seeks to design, implement, and evaluate an interactive 3D visualisation software system for displaying the content in the Kepler Exoplanets dataset. The deliverable is intended as a standalone 3D visualisation system with two modes of interaction of keyboard and mouse or Microsoft Xbox Kinect sensor. The resulting visualisation will convey the information in the dataset in a way that the target users, laypeople who have an interest in astronomy, can understand and interact with.

1.1 Problem Statement

many planets that have been located outside of our own solar system, these are called exoplanets

1.1.1 Understanding the content in the dataset

Understanding and analysing large datasets whose size defies simplistic analysis is a known issue that many areas of research are attempting to address from datamining to discover SOMTHING HERE in the data itself to visualisations to convey the information in a visual mannor. All of these research methods involve finding and displaying important aspects of the data so that users can more efficiently use it.

The content in the dataset used for this project is made up of records of each exoplanet discovered, each of which contains 46 fields.

1.1.2 Comprehension of planatery information

Much of the information regarding planets is criptic and uninituitive, this make its understandability difficult. Visualisations attempt to address this by displaying the information in a way that conveys the information in a simplisitic way that allows easier user comprehension.

something about faster cognition times

1.1.3 Exisiting solutions lack functionality

Existing data visualisation techniques using this exoplanet dataset lack the ability to display sufficient detail on each exoplanet and do not provide answers to questions that can be answered by the Exoplanet attributes in the dataset. Existing solutions display only the size, temperature, and orbital information about the exoplanets. While this is useful information that informs users of important facts about the planets, it does leave a lot of potential information unseen and overlooked, for example, information about the type of planet, planets with similar traits, solar system information, similarity to earth and habitability. This project will therefore be focused on researching, implementing, and evaluating a new interactive visualisation system that will display additional information to users not included in previous visualisation systems.

1.1.4 Effective user interaction with visualisation

A visualisation that soley displays information without effective methods of interaction will not have the immersive qualities that keeps users engaged as would be the case with an interactive visualisation

1.2 Key issues project addresses

To summarise the above sections, this project addresses the following key issues:

I1. Content in database form is difficult to view and understand.

I2. Planetary information if complex and difficult to comprehend without a visual reference.

I3. Exsiting visualisations for this dataset lack functionality.

I4. User interaction is needed in a visualisation to make the most of the data displayed.

1.3 Contributions of this project

This project will provide an extension of the Kepler Visualisation Tool [?] that conveys more information and is easier for users to interact with than the original. This extension will be evaluated by a user experiment to ensure that it is successful in conveying the information contained in the dataset.

The work and research completed for this project will allow for further improvement by other developers and researchers to extend and improve the visualisation created. This will provide further exposure of the Kepler dataset which will encourage learning about Exoplanets.

Chapter 2

Project Methodologies

2.1 Project management approach

Following a structured project managament approach is important as it avoids the problem caused by following a code-and-fix approach as described as 1) write some code. 2) Fix the problems in the code [?]. By following a process model it encourages thinking about requirements, design, and testing before coding is commenced.

The project methodology chosen for this project was a customised Spiral Model made up of requirements analysis, design, implementation, and evaluation phases as shown in the below figure. The reason for limiting the model to these 4 phases was because....

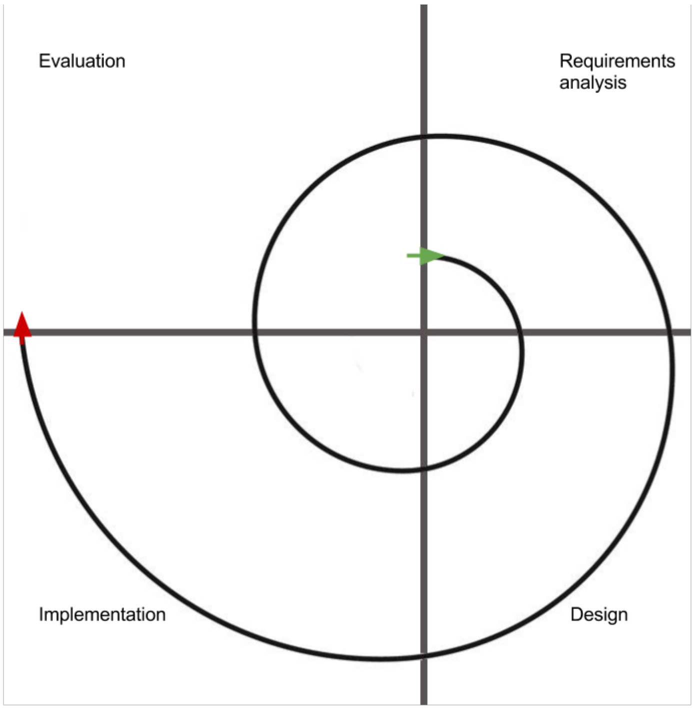

Figure 2.1: Spiral process model followed

For each feature produced in the visualisation a full iteration of the spiral was completed.

2.1.1 Requirements analysis

2.1.2 Design

2.1.3 Implementation

2.1.4 Evaluation

Following the completion of the implementation stage of this project a final user evaluation was carried out on the visualisation to discover if .....

The advantages of this methodolgy over others such as stricter models such as the waterfall model or a looser agile aproach......The reason that this was effective.......

This project management technique supported the creation of a visualisation as

The choice of this project management apprach meant ....

Weekly meetings with the supervisor of the project, Dr Stuart Marshall, were used to provide guidance and

Using using other supporting project management techniques such as Gantt charts [APPENDIX] and work breakdown structures(WBS) [APPENDIX] allowed efficient documentation of planning and work completed in the project as well as displaying the following stages requried to complete the project.

2.2 System design approach

To guide the creation of the visualisation a user oriented design approach was used, in particular making use of user models (personas) were created to create a sense of empathy and understanding for the forseen users of the visualisation in order to better understand the requrirements and design decistions to be made.

2.3 Key difficulties in project

As this project builds upon a previous system much of the exisiting code and execution flow needs to be modified. This requires understanding of how the system was originally built and designed. Because this system does not have any unit or integration tests, going ahead without a comprehenive knowledge of the core functionality would be foolish.

Encountered errors in Processing framework due to number of elements needing to be displayed on screen.

Having a time constraint of 300 hours for this project over the course of a year meant that ....

Chapter 3

Requirements Analysis

The use of User Centered design in this project afforded a method of

3.1 User models

3.2 Scenarios

3.3 Requirements summary

3.4 Existing systems

3.4.1 Worlds: The Kepler Planet Candidates - Non Interactive

This animation [?] shows planet candidates found by NASA's Kepler mission. These candidates are animated in orbit around a single star. They are drawn to scale with accurate radii, orbital periods, and orbital distances. They range in size from 1/3 to 84 times the radius of Earth. Colors represent an estimate of temperature with red indicating warmest, and blue indicating coldest candidates. This animation is layed out very similarly to the

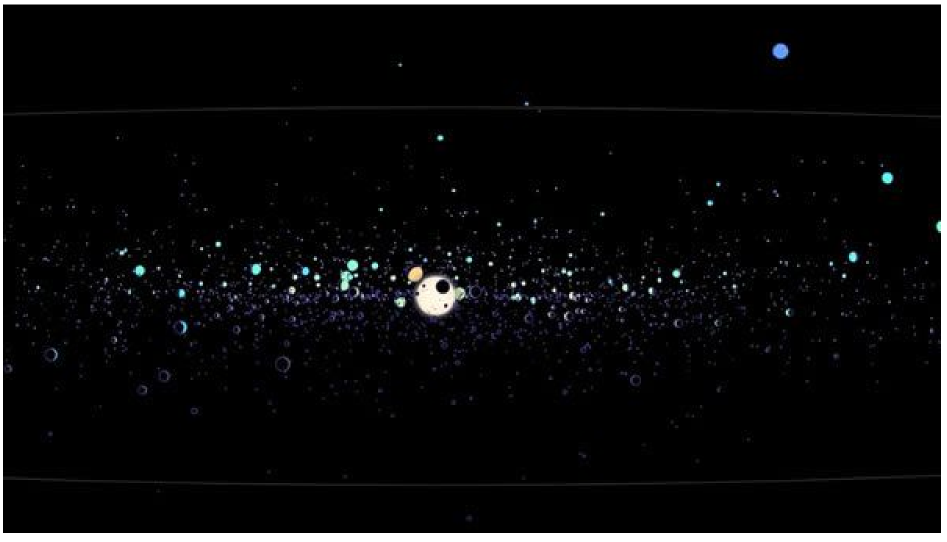

Figure 3.1: Image of Worlds Visualisation

Kepler Visualisation Tool that I am extending. This means that it provides insights into how my visualisation can be improved as Worlds is a much more visually appealing system. By researching how it displays its Exoplanets I can further improve my own visualisation.

3.4.2 The Kepler Orrery and The Kepler Orrery 2 - Non interactive

The Kepler Orrery [**?**] illustrates the exoplanet candidates in their own solar systems. The orbit radii are to scale with respect to each other and planet sizes are to scale with respect to each other, but orbits and planet sizes are different scales. The colors are in order of semi-major axis: two-planet systems (242 in all) have a yellow outer planet; 3-planet (85) green, 4-planet (25) light blue, 5-planet (8) dark blue, 6-planet (1, Kepler-11) purple. This system

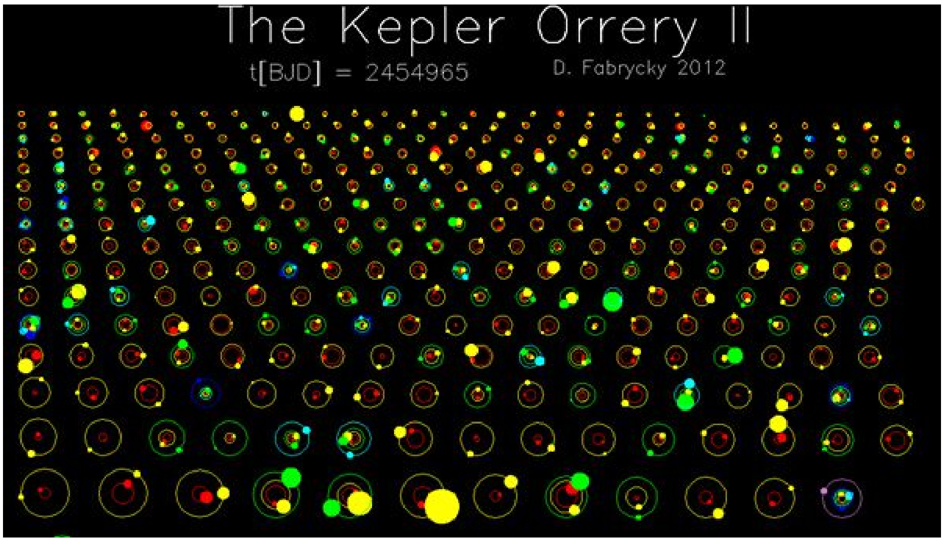

Figure 3.2: Image of The Kepler Orrery Visualisation

exhibits small multiples, a grid of small similar graphics or charts, allowing them to be easily compared. This provides insights into how I can use small multiples to display information about groups of planets. This will be important for displaying which planets share a solar system.

3.4.3 Celestia - Interactive

Celestia [**?**] is a free real-time space simulation that lets you visually experience the universe in three dimensions. It is an open source system written in C++. This visualisation is much larger and more encompassing system than is needed for this project, as it is a full 3D space simulation. However is does offer insights into how to effectively portray planets and their orbits (See Figure 2.3). It also provides textures that can be used in my visualisation to depict what planets actually look like to increase user immersion.

3.4.4 Kepler Visualisation Tool

An existing system built with Processing is the Kepler Visualisation Tool[**?**, **?**]. It is a simple visualisation focusing on displaying the candidate Exoplanets temperatures and their locations in relation to their distance from their nearest star, so that a sense of scale can be perceived. Each candidates estimated size, orbital speed, and orbital separation is accurately depicted, and each planet is color-coded according to its estimated effective temperature. The existing work in this system would serve as foundation for this project. Because much

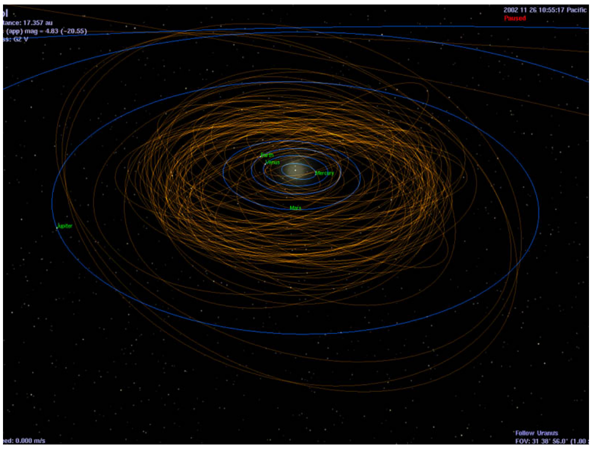

Figure 3.3: Image of Celestia Visualisation

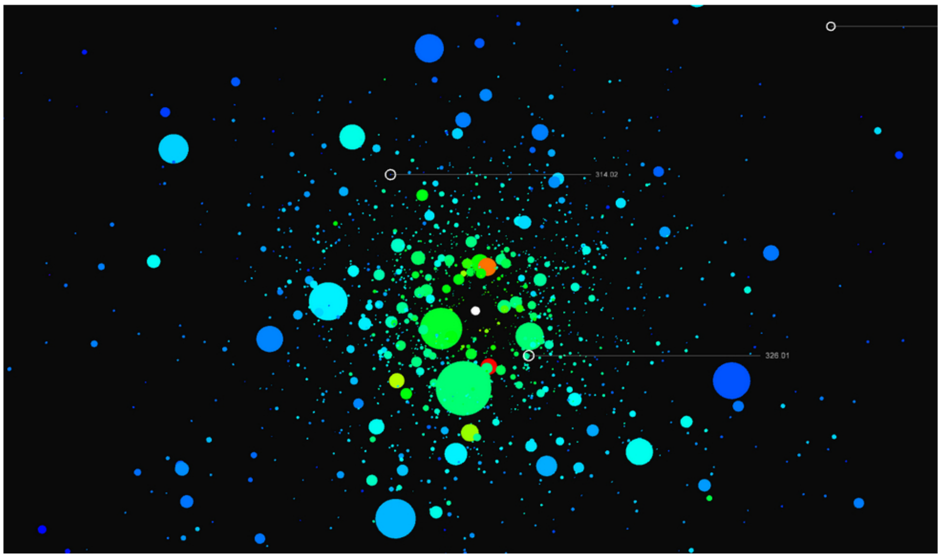

Figure 3.4: Kepler Visualisation Tool Orbital View

of the visual aspects, and initial data manipulation of the existing system are already complete. It means that implementing the features needed for this projects completion could be focused on more heavily and larger improvements to the existing system can be undertaken, such as better labeling and information displays and user interaction methods.

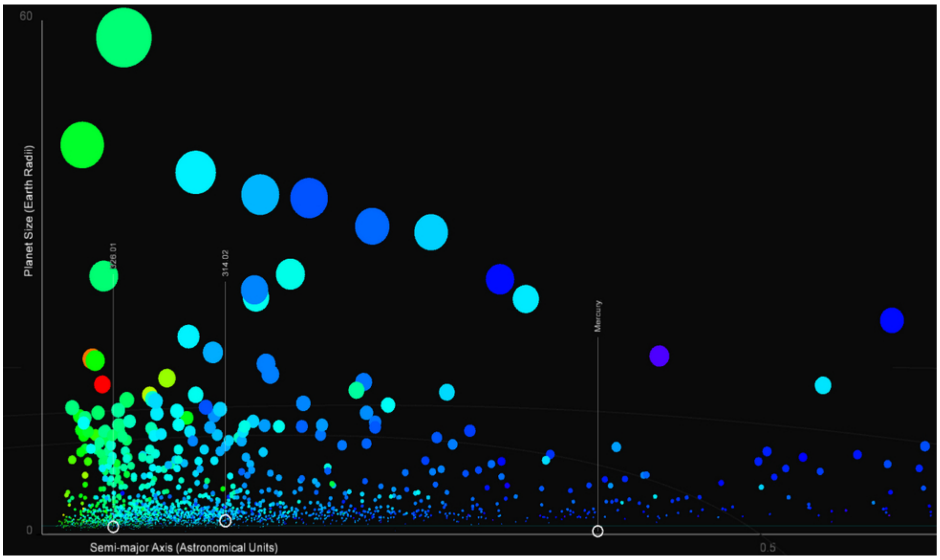

Figure 3.5: Kepler Visualisation Tool Graph View

Chapter 4

Solution Design: Improved Kepler Visualisation Tool

4.1 Design features

The visualisation for this project will be created using Processing, a Java framework for visualisations. As the time is short for this project, extending a previous visualisation that uses the same dataset, the Kepler Visualisation Tool [**?**, **?**], will increase the amount of progress that can be made in the time afforded.

The visualisation was designed to emphasis small multiples and filtering of the Exoplanets to display the information more clearly to users.

Instead of the visualisation only answering the 5 key questions as proposed in the proposal, the aim will now be displaying as much of the information in the dataset as possible without detracting from the effectiveness of the visualisation whilst still answering the questions.

This is because the 5 questions did not fully utilize the information in the dataset.

However I will need to ensure the effectiveness of the visualisation does not become diminished by trying to convey to much information which would lead to cluttering and overlapping in the visualisation, as well as information overload for users. There will also be larger emphasis placed on making the existing system more usable by improving the interaction methods for users. The following list outlines the new requirements for the visualisation being developed. This will be done by providing GUI elements for each form of interaction with the system, as well as ensuring all interaction methods are intuitive for users.

4.1.1 Visualisation Layout

Component Layout

As the majority of the interaction and movement of visualisation elements occurs in the center of the window it caused a aspect ratio that SOMETHING SOMETHING. It was BETTER to use 2 vertical columns to view and control the visualisation as it had a higher aspect ratio which allowed more of the content to be seen on the screen at once thanks to the fact that the majority of computer screens have a wide ratio.

Selection of planets Kinect for improved user interaction and immersion

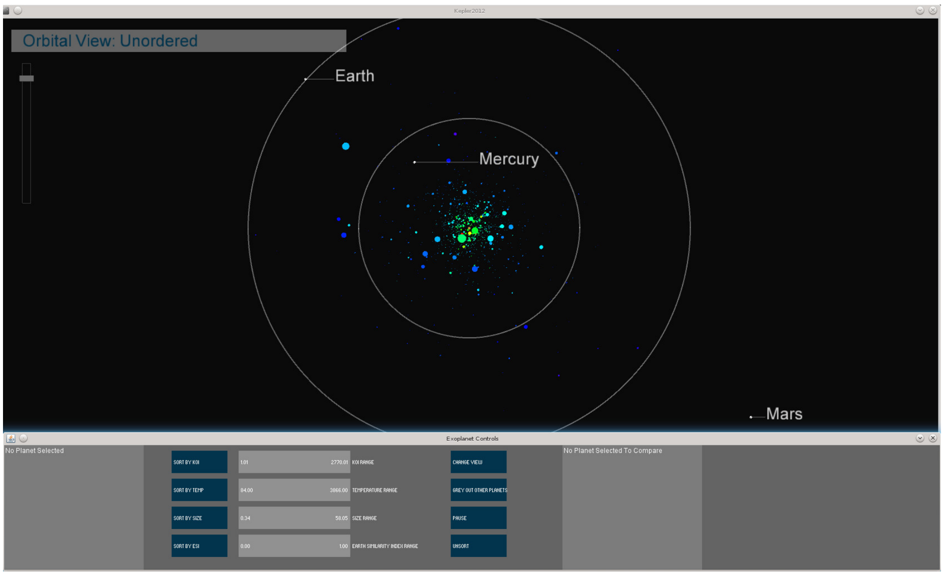

Figure 4.1: Original Horizontal Layout

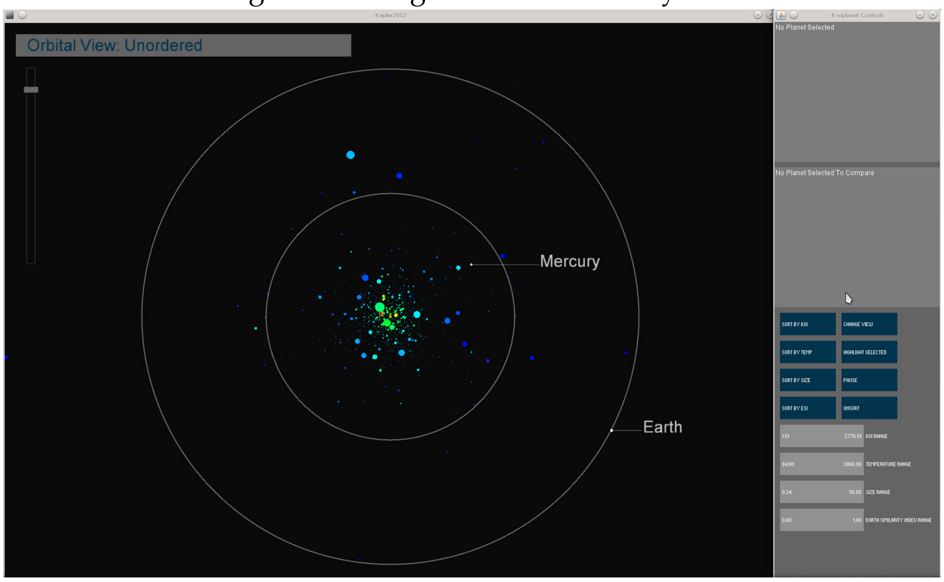

Figure 4.2: Improved Vertical Layout

Chapter 5

Visualisation implementation

5.1 Technology choice

5.1.1 System design and structure

5.1.2 Tools and artifacts used

Chapter 6

Visualisation implementation

6.1 Technology choice

6.1.1 System design and structure

6.1.2 Tools and artifacts used

Chapter 7

Conclusions

7.1 Future Work

The work from this project can be taken further in many different ways depending on how it is intended to be used. There is the option of using the system as a terminal that users would use at an observatory or attraction where prior knowledge of the system is limmited and amount of time users would spend on the system would be small. In this case further expanding the user experience and improved Kinect interaction would be benificial as immersion would be the decider on its success. Another option for the system would be for a standalone desktop system that users would use multiple times and so prior knowledge of how to use the system could be expected. This would mean that more complex functionality could be introduced witht he expectation that it could be used by users. The systems current state could me modified to fit into either of these two options.

Bibliography