State-Based Plot Coloring
Revised Concept & Project Management

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Team #36
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1. Abstract

Our project is a State-based Plot Coloring which is designed to help users monitor their condition of machines. It allows users to see their condition of machines into four different states which are a rolling state, a startup state, a running state, and a shutdown state with different colors. It makes this project to be unique because it can offer users convenience way of observation for the condition of their machines in four different states. Each state represents a specific machine state, so it can possibly help people to have less failure of their machine since the user might be able to take an action on the problems after observing the graph. In conclusion, the objective of the project is intended to be designed to let the users be able to observe what states their machines are in and check whether their machines have problems. The project is implemented in C# and Oxyplot for the ease of development and better performance for the User interface.

2. Project Description

2.1 Main goals of the project

The goal of the project is to create the logic for handling edge cases for General Electric's condition monitoring software. The edge cases are for when a machine is in multiple states at the same time and when multiple machines in the same plot have overlapping data. Our project is trying to achieve this for state based coloring of data using Trend Plots, Waterfall Plots, and Bode Plots. This is needed because it benefits General Electric's condition monitoring software and allows the users of the software to better understand what state their machines are in and if there are problems with the machines.

2.2 Intended users or user groups

Our projects audience is primarily aimed at the sponsor we are working with. They are sponsoring the project to see what logic we come up with to handle the edge cases where the machines are in multiple states at the same time and when multiple machines data overlaps. If the logic accomplishes their needs they intend to implement it into their own software. If our project satisfies the needs of our sponsor and gets implemented into their own software then their customers using the software will also be users of our project.

2.3 Main functionality and characteristics

The software we create will need to read in example machine data and plot the data based on different states the machine is running in using colors to distinguish the states. The different states are rolling state, startup state, running state, and shutdown state. The values for the states can be determined by default values for a given machine or by the user of the software. The states can have overlap such as the startup state can be defined as 500-3500 RPM and the running state can be defined as 3200-3800 RPM. Our software will need to be able to virtually display these cases of overlap in the three different plots. In addition to this the software will also need to be able to display a readable plot for multiple machines data overlapping in the same plot.

2.4 Technology description

The software will run on the Microsoft Windows Operating Systems for personal computers. It will be implemented using C# with Windows Presentation Foundation (WPF). We will use Extended WPF Toolkit to build the color picker that allows a user to pick a color from predefined color palettes. In addition, we will use Visual Studio, which is an integrated development environment from Microsoft, to develop our software. The software will be developed using our personal computers.

2.5 Dependability properties

2.5.a Reliability

The software produced will need to be reliable due to the software's intention to be used for monitoring machines. If the software fails and a machine has an issue then the issue won't be able to be seen which can result in a catastrophe for the machine. To achieve reliability the team will do extensive testing on the software.

2.5.b Security

The system will not be vulnerable to outside attacks and because it is only a monitoring system it would not be affected by attacks. Due to this the team will not focus on making the system secure from attacks.

2.5.c Safety

Since the system monitors big machines safety plays a big role in the software. To ensure safety the team will be making sure the plots are easily readable to allow users to see if a machine is functioning incorrectly.

3. Significance

3.1 What makes this project worthwhile and interesting to pursue?

We will design software to display data in different plots, such as the Trend Plot, the Cascade Plot, and the Bode Plot, to help users understand the data provided. The project proves both interesting and challenging. It will be quite interesting to see what the plots look like and extract insights from data. In addition, there will be a large amount of data that we need to display. We need to display the plots as cleanly as possible so that the user can easily tell if there are problems with the machines by seeing the plots.

3.2 How will the project help your professional growth?

General Electric (GE) provides us with the opportunity to work with it. We will learn new a programming language, which is C#. We will use one of the Agile methodologies to develop our software. Mr. Eric Gilchrist will give us suggestions on how to develop a good software using

Scrum. After finishing this project, we will have a better understanding of Scrum that is useful for rapidly creating good software that is maintainable, dependable, efficient, and usable. This project will help us learn the useful skill to become great engineers.

3.3 What are the new/innovative characteristic of your project?

Innovative characteristic of the project is that there are 4 specific states which machine operation is divided into. It will help users to identify and to understand their machine easily. Also, users are able to change or control the visualization of each state. By changing the colors of the line on graphs from the output, users are able to distinguish or discover the data easily.

3.4 Similar or related projects or applications

Emerson Electronics, CIS Vibration Monitoring and National instrument condition monitoring systems are the products that are similar to our software. For example, CIS AMREIN states that "CIS Vibration Monitoring is designed to cover complete and economic protection from basic protection systems to extended complex multi- machine applications with up to 108 channels per rack" [CIS, website]. NI states that "A condition monitoring system helps engineers to understand the health of machinery and avoid downtime" [NI, website]. Emerson states that they offered a number of hardware system in order to help their supermarket customers to maximize their energy reduction opportunities [Emerson, website].

3.5 Business, market potential, or open source value

In industrial society, unexpected machine failure is a huge and critical problem for companies. It can cause immeasurable damage to companies in terms of their productivity and amount of export. To minimize and to prevent the damage from the unexpected machine's failure, it is essential for people to be able to handle and monitor what happens to their machine in real time because the use of condition monitoring allows maintenance to be scheduled, or other actions to be taken to prevent failure and avoid its consequences. Since different machines can encounter different problems, and people need a solution for the problems, the Market Potential of the State-based Plot Coloring will be great because the it can help people to easily distinguish their machine condition in four different states in real time. Furthermore, it allows users to visualize their machine status in their own unique color on the graph.

3.6 Potential for further development beyond CS 426

For further development, we plan to provide more options that users can change a way of visualization of the output. There will be a potential for a function that the additional visualization could be on/off if users want.

4. Legal and Ethical Aspects

There will be a potential restriction on the use of our software since it is developed based on Window operating system only. Unless there are needs that developers plan to develop the

software for other OS, the application is only able to operate in the window system. Also, there are challenges to meet users in terms of the ease of use. Since the software is designed to offer people convenience, there will be a hard time to meet all the different kind of people who have a different kind of preference. As current technologies and the expectation of an application from people are rapidly changing and evolving, we plan to have communication with users based on the agile methodology. By communicating with them, we are able to face our weakness and get advice from the users. It allows us to know the user's requirements and opinion, so it can ensure that our modification will meet the users and react to the changing specification of the software. Also, we did not choose any expensive 3D library to develop high quality of the project. We consider the acceptable cost to users, so we make an effort to find alternative resources such as OxyPlot and WPF that can still provide great quality for users. It helped us to have a balance between the product quality and cost and help us to meet the highest professional standards.

5. Changes and Progress since the Initial Project Concept

5.1 Briefly summarize the progress made so far.

We have developed the user interface for our project. For 2D graphics, the WPF coordinate system locates the origin in the upper-left corner of the rendering area. We have changed it to the customer coordinate system whose origin is in the bottom-left corner of the canvas. We have added two classes, which are ChratStyle2D and ChartStyle3D. They define all chart layout-related information.

5.2 Concisely indicate major changes that have occurred since your early October 2017 project concept; also, additional planned major changes, if any. Explain the reasons for all these changes.

We will implement the Cascade plot rather than the Waterfall plot because our sponsor changed the project requirements. Also, because the documentation of the Oxyplot, which is a free 2D plotting library, is bad, and most good WPF plotting libraries cost about 1000 dollars, we decide to make our own 2D and 3D coordinate systems rather than use a plotting library by modifying some existing 2D and 3D coordinate systems that we found online. Furthermore, according to the requirements that our sponsor provided us, instead of dealing with real-time data, we will focus on displaying data nicely in the Trend Plot, the Cascade Plot, and the Bode Plot when there is an overlap between states and between machines.

5.3 Outline major developments/accomplishments so far.

- User Interface (UI)
- 2D Coordinate Systems
- 3D Coordinate Systems

6. Project Responsibilities

6.1 Indicate and briefly describe the main subsystems or components of your product and

the related responsibilities of your team's members.

The scope of the project is to find the edge case of overlapping state change in the condition monitoring system. We will focus on the rolling state, startup state, running state, and shutdown state. The software that we will develop allows either the machine and the user to define these four states, and there may be an overlap between states and between machines. The software will be able to virtually display data with different colors in a Trend Plot, a Waterfall Plot, and a Bode Plot, and to handle the overlap between states so that the engineers who will use this software can easily identify the states of a machine and potential problems within a machine. The following lists the main subsystems or components of our product and the related responsibilities of our team's members:

- User Interface
  - Develop the UI for the Trend Plot – Zachary
  - Develop the UI for the Cascade Plot – Haoxuan
  - Develop the UI for the Bode Plot – Myeongwan
- Text File Reader - Haoxuan, Myeongwan, Zachary
- Trend Plot
  - Display data in the Trend Plot – Zachary
  - Handle the overlap between states in the Trend Plot – Zachary
  - Handle the overlap between machines in the Trend Plot – Zachary
- Cascade Plot
  - Display data in the Cascade Plot – Haoxuan
  - Handle the overlap between states in the Cascade Plot – Haoxuan
  - Handle the overlap between machines in the Cascade Plot – Haoxuan
- Bode Plot
  - Display data in the Bode Plot – Myeongwan
  - Handle the overlap between machines in the Bode Plot – Myeongwan
- Communication between different WPF windows
  - Tell other plots to update their plots if a change occurs. A change will occur when the user selects or deselects a polyline – Myeongwan
- Integration – Haoxuan, Myeongwan, Zachary

7. Project Monitoring and Risks

7.1 Outline

The team will monitor the project progress by having monthly meetings with the project sponsor. In these meetings the progress will be checked and evaluated to ensure ample progress has been made on the project. In addition to this, the progress made will be checked to ensure that the progress made is correct for the goals of the project. Other than meetings with the sponsor, the team will also check in on each others progress at least once every two weeks in the beginning and more often as the project gets closer to the deadline. Progress will be monitored based on completion of different components of the project such as individual functional requirements and systems. By monitoring the project in this manner the team will be able to complete the project on time.

7.2 Risk register

Risk Register						
		Current Risk		Mitigation Strategies	Residual Risk	
Risk Id	Risks	Likelihood	Effects		Likelihood	Effects
RP01	Team member leaves	Very Low	Catastrophic	- Ensure all team members are familiar with all parts of the software - Plan to have ample time to complete the project with less team members	Very Low	Serious
RP02	Team member gets sick	Moderate	Serious	- Ensure all team members are familiar with all parts of the software - Allow enough time to complete project checkpoints without a team member	Moderate	Tolerable
RP03	Team member not contributing	Low	Serious	- Inform instructors of student not contributing	Low	Tolerable
RP04	Technology change	Low	Serious	- Do research to ensure best technology for the project is in use - Allow enough time to change if necessary	Low	Tolerable
RP05	Requirements change	Low	Serious	- Meet with project stakeholders to confirm requirements - Allow enough time to handle changing requirements	Low	Tolerable
RP06	Underestimated time to develop software	Moderate	Serious	-Plan to complete the software early so if more time is needed it exists	Low	Tolerable
RP07	Receiving sample data delayed	Moderate	Tolerable	-Create temporary sample data -Continue asking for sample data	Moderate	Insignificant

RP08	Project does not meet requirements	Low	Serious	-Meet with project stakeholders often	Very Low	Serious
RP09	User Interface is not user friendly	Low	Tolerable	-Have users test the User Interface -Have project stakeholders evaluate User Interface	Very Low	Tolerable
RP10	Finished software contains bugs	Moderate	Serious	-Extensively test software	Low	Serious

8. Team overview

8.1 *Haoxuan Lin*

As a dedicated and hard-working Computer Science student who migrated to the United States, Haoxuan proved himself by gaining senior standing within the Computer Science department. Haoxuan's interest lies within algorithms and theory. He will develop the user interface, and display data in the Cascade Plot for this project. Upon graduation, Haoxuan plans on pursuing graduate studies.

8.2 *Myeongwan Beom*

Myeongwan is an international student, and he has always had a strong mechanical aptitude and a strong ability to think critically. He is proficient in operating systems and programming languages. He will display data in the Bode Plot for this project. Upon graduation, Myeongwan hopes to obtain a position with the software industry.

8.3 *Zachary Young*

Zachary grew up in Nevada, and he has a broad range of experience in the field of game development. He thrives on challenge, and it was one of the reasons why he chose to major in Computer Science and Engineering. He will virtually display data in the Trend Plot, for this project. Upon graduation, Zachary plans on obtaining a career within the computer game industry.

8.4 Advisory overview

8.4.1 *Eric Gilchrist*

Mr. Eric Gilchrist graduated in 2015 with a bachelor's degree in Computer Science. After he graduated, he worked full time at Sierra Integrated System as a Project Manager for two years. He currently works for General Electric as a Software Engineer, and he works on their main software product there called "System1", which is a machine condition monitoring system.

9. Contributions of Team Members

Haoxuan Lin spent 4 hours contributing to the following:

- Cover Page
- Project Description
- Changes and Progress since the Initial Project Concept
- Project Responsibilities
- Team Overview
- Contributions of Team Members
- References

Myeongwan Beom spent 4 hours contributing to the following:

- Abstract
- Significance
- Legal and Ethical Aspects

Zachary Young spent 4 hours contributing to the following:

- Project Description
- Project Monitoring and Risks

10. References

10.a Articles

Alexander Ypma. Learning methods for machine vibration analysis. 12 November 2001.
<http://rduin.nl/papers/thesis_01_ypma.pdf>

This research describes the methods that can be used for machine vibration analysis and machine health monitoring. It provides readers with a lot of examples to help them understand the learning approach to machinery health monitoring. It helps us to understand why our project is important for monitoring the machine health.

Chockalingam Aravine Vaithilingam, Gilbert Thio, Rajparthiban Rajkumar. Health monitoring of induction motor for vibration analysis.
<http://www.jee.ro/covers/art.php?issue=WU1264295972W4b5ba024a5c9d>

This article explains why condition monitoring system is important. It helps readers understand the meaning of the data. The condition monitoring system, which is described in this article, plots data in different ways to help users analyze these data. It is important for us to know what the users' need is so that we can plot the data in the way that users can easily analyze these data.

Chen Lu, Yang Wang, Minvydas Raguiskis, Yujie Cheng. Fault Diagnosis for Rotating Machinery: A Method based on Image Processing. 6 October 2016.
<http://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0164111&type=printable>

This article describes the method based on image processing. Readers can use it to realize automatic feature extraction and fault diagnosis in two-dimensional space. This article goes into details about how to use the diagnosis method based on image recognition to provide a method for condition monitoring and fault diagnosis of rotating machinery.

10.b Websites

http://www.wpftutorial.net/Home.html

This website describes the Windows Presentation Foundation (WPF). It teaches readers how to use data binding and how to draw a 2D and 3D graph by using C# and the WPF. It also provides readers with books and instruction videos about WPF

https://www.codeproject.com/Articles/42174/High-performance-WPF-D-Chart

This website describes the high-performance WPF 3D Chart. It teaches readers how to set the camera, light, and 3D model. It also teaches them how to use auto zoom and color the 3D model. This website is useful for us to create the Cascade plot, which is considered a 3D plot.

10.c Reference Lists

CIS (website). Retrieved from http://cisamrein.ch/522/540.html

NI (website). Retrieved from http://www.ni.com/en-us/innovations/transportation-and-heavy-equipment/condition-monitoring.html

Emerson (website). Retrieved from http://www.emersonclimate.com/en-us/brands/Emerson/Pages/Electronics.aspx