ENGEN582-24X
Honours Research and Development Project

Ahuora Adaptive Digital Twin Platform

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Proposal Summary

The nature of this R&D project is to develop a pinch analysis (PA) software and UI to be used with existing process integration software - namely the Ahuora Adaptive Digital Twin platform. Currently in the New Zealand process heat generation is the second largest contributor to energy-related greenhouse gas emissions (MBIE, n.d.) this is partially due to how process chemical plants are outdated and inefficient - especially in terms of process heat optimization. This is generally accepted to be because of the age of most plants in New Zealand - which were constructed at a time where energy usage and efficiency wasn't as important as it is today. The Ahuora Adaptive Digital Twin Platform aims to mitigate the environmental and economic consequences of this by providing a system where process engineers can model their plants and apply analysis tools - like pinch analysis - to these plants. The current technologic gap for this issue is that currently:

1) Existing tools aren't accessible enough - the hardware systems for plants are typically outdated and incompatible with modern software systems, this is being addressed holistically by the Adaptive Digital Twin platform.
2) The Adaptive Digital Twin platform does not currently have the analysis tools in place to reduce the energy use and emissions of these plants.

The aim of this project is then to develop one of the analysis tools that the Adaptive Digital Twin platform will use to indicate where energy optimisation can be done through heat transfer between material streams. This project includes both the system that calculates the PA as well as the interface in which the PA is accessed and the results are displayed.

The expected outcome of this project is a piece of software that can perform PA on a given flow sheet using the most widely recognised algorithms to do so. Some systems are already accessible so further research will need to be conducted to see if these systems can simply be integrated into the platform instead. Along with the software, a UI will be developed so users can interact with the system - this UI should align aesthetically with the current Adaptive Digital Twin platform, and have considerations made to usability and the user experience. The PA system and its accompanying UI will follow standard software engineering principles such as readability, maintainability, and reliability in its design and implementation.

1. Background

The Ahuora - Centre for Smart Energy Systems is an MBIE funded company dedicated to reducing carbon emission in the process integration sector. Currently, process heat is the second largest contributor to energy-related GHG emissions - in 2016 roughly 8.3 million tonnes of CO2 equivalent gasses were released by process heat alone (MBIE, n.d.). The way that Ahuora is hoping to lower these emissions is through the development of their Adaptive Digital Twin platform, a piece of software that allows the simulation of chemical industrial plants and provides analysis tools to show inefficient or outdated plant designs - one such analysis tool is pinch analysis.

PA is a technique that can optimize the energy consumption of a system through a heat exchanger network. PA can identify lost or excess heat in a system and recycle that heat for other streams that require heating by analyzing the heat distribution and changes throughout a given system - lowering operating costs and energy usage by decreasing the amount of external heat that needs to be supplied.

Analysis tools like PA will form the backbone and primary functionality that reduces GHG

emissions in the Ahuora Adaptive Digital Twin platform - as it stands currently the technological gasp for this project include:

1) The need for a process modeling software to improve control and decision making in the process chemical sector.
2) There is a distinct lack of analysis techniques and packages that can interface with the Ahuora Adaptive Digital Twin platform.

Some previous work that has been done to address this gap is the OpenPinch platform and its Python derivative. The OpenPinch platform is a PA tool that uses Microsoft Excel spreadsheets as input and outputs of the system. OpenPinch is open source and free, but is generally limited in the scope of interfacing with other systems as well as the fact that the UI isn't especially user friendly. To address this, a package has been written in Python that uses the algorithms from OpenPinch to perform PA, but has a much broader use case for other systems. This package is better suited to be used with the AADTP but still suffers in the way that it was built to be used with Excel sheets while the AADTP uses a more intuitive flow sheet structure, so this package will need to be updated and retrofitted to work with the Ahuora software platform.

2. Overall Aim of the Project

The overall aim of this R&D project is to develop a PA tool in Python and Typescript that can be used alongside - and interacted into - the Ahuora Adaptive Digital Twin platform. The two main components are the frontend side of the application, and the backend - the frontend will be developed as a part of the Ahuora platform while the backend will be a stand-alone analysis package that will interface with the Ahuora platforms backend.

Some of the major backend and frontend specific requirements for this system can be found in *Table 1*. Aside from these requirements there are also more general software requirements that are applied to most software projects. Some of these include modularity, minimum performance requirements, readability , maintainability, reliability, and security. Readability and maintainability are particularly important for this R&D project as the project is based around chemical engineers who may not be familiar with software systems like this one - so technologies such as Python which is widely thought to be the easiest to read are utilized.

The largest requirements for this project are those involved in the development of the frontend UI and integration. The majority of the PA system has already been developed by a different engineer, but this version is older than the current version of OpenPinch - so further development may be required. It's because of this that a larger focus will be applied to how users interact with the PA system rather than the system itself - as most of the infrastructure is already in place for the system. This includes wireframing, prototyping, usability testing, and developing all the requirements for the displaying of information.

Specification	**Description**	**Section**	**Priority**
Unit Testing	Testing isolated portions of the backend following *TDD* practices.	Backend	Medium
Integration Testing	Testing how the frontend interacts with the backend	Frontend	High
Compatibility with	The system can interact with the Ahuora	Backend	High

AADTP	Adaptive Digital Twin platform and its data.	Frontend	
User Feedback Report	Logs noting the progression of the design and feedback from user testing.	Frontend	High
Wireframing	Rough drafts of frontend UI design.	Frontend	Low
Prototyping	Polished UI design with some basic functionality.	Frontend	Medium
Pinch Analysis	Retrofitting OpenPinch algorithms to be used with the AADT platform.	Backend	High
Total Site analysis	Separate systems (groupings/zones) can be evaluated as a whole.	Backend	Medium
Distributed Computing compatibility	The system leverages parallelism in its design to use the distributed network being developed.	Backend	Low
Graphical Charts Representation	Frontend structures that support the display of various charts and figures.	Frontend	High

Table 1 - R&D Project Requirements

3. Research and Development Plan

The general R&D plan for this project is roughly split into three distinct sections: research, system development, and UI development - seen in the Gantt chart in the appendix. Each of these sections can be further divided into the smaller sprints that they are composed of. For the research section, the first step is to perform a literature review on PA to familiarize myself with the technique and look into more general software practices for the other aspects of this system, literature review as an assignment will be done until the beginning of april - but there is an expectation that the practice of literature review will be conducted throughout the entirety of the project. The second step during research overlaps with the literature review and is the existing solutions research - namely OpenPinch and other PA software that already exists.

The second major portion of this R&D project is the development of the system functionality - also referred to as the backend in this case. The backend development will follow an iterative design and testing cycle - where feedback and testing is done alongside the development of the system. The ethics approval for all user feedback and testing is in the process of being applied for, so any and all user testing will take place only after this has been approved - process and chemical engineers will be used at this stage to improve and consult on the designs being worked on. In addition to this, test driven development will be utilized alongside the development and will follow the practices found in Kent Beck's *Test Driven Development By Example* (Beck, 2003). Some of these methodologies that will be used throughout development include:

- Maintainability: the software should follow practices that allows for easy maintenance and updates in the future.
- Readability: the source code of the project should be easy to read and understand for those not in the software engineering profession.
- Reliability - the software should take steps to ensure the software is resistant to errors and fails gracefully.
- Scalability - measures should be taken so that the software can scale along with the systems

it is integrated with.
- Validation - comparing output results of the system against known correct outputs to verify authenticity.

The third and final stage of this project will be the development of the frontend UI that users will interact with. Prototyping will be the first step, with technologies such as Figma being used to wireframe - the prototyping will have the largest amount of user testing for this R&D project. Similar to the backend development stage, the frontend development will also follow test driven development using the Jest testing library to facilitate unit and integration testing with the backend, and React with Typescript for the actual development process. Once the frontend has been completed to a satisfactory degree the whole system can be tested once again and any additional user feedback will be implemented at this stage. A holistic view of the plan for this R&D project can be seen in the appendix.

4. Resources

The majority of the resources that will be required and aren't currently available are contained in the first column of Table 2. The most important of these resources are the personnel required for usability testing and system design. Having access to those who will use the system when it has been released and being able to apply an iterative design technique for this is instrumental in the plans for the frontend design specifically.

Some of the existing accessible resources are solutions for PA, online literature regarding software and analysis tools, and the platform that the analysis system will be integrated into. The existing tools and Ahuora Adaptive Digital Twin platform will help the most from these, as the entire system will be based on these two resources.

Required Resources		**Currently Available Resources**	
Name	Description	Name	Description
Stakeholders	Users for the system.	OpenPinch	The VBA macros that pinch analysis will be based on.
Chemical Engineers	Engineers for consulting on system functionality.	Relevant Literature	Documents pertaining to pinch analysis / System design.
Flowsheet Data	Data to apply pinch analysis to.	AADTP	The platform that the system is being integrated into.
Workspace	A computer / environment to work from		

Table 2 - Resources

Some of the risks involving the required and available resources include ethics approval and data integrity.

Ethics approval: When discussing the design and conducting usability testing with the stakeholders and chemical engineers I require, it is very important that I receive ethics approval from the

university beforehand. This is to mitigate the risk to both the stakeholders and myself in regards to the ethics of the testing and the validity of the results.

Data handling / integrity: Some of the data I will be handing may come from protected or sensitive sources. This may be a model of an actual plant that has been procured or from an otherwise sensitive source. It is important that this data is sourced ethically - ie from the company - and that I'm not exposing this data anywhere where I don't have explicit permission to do so. This is to protect company secrets and Ahuora from any legal repercussions.

5. Sustainability and/or Vision Mātauranga

The core motivation behind this R&D project is reducing energy consumption in the process heat sector. For most businesses this is to reduce heating costs, but for Ahuora this project aims to reduce the GHG emissions associated with the generation of process heat. “In 2016… process heat made up 28% of all energy-related GHG emissions and is the second largest source of energy-related emissions behind transport” (MBIE, n.d.). This statistic of 28% of energy-related GHG emissions demonstrates how important it is to New Zealand to reduce the GHG emissions of process heat to achieve their goal of net zero GHG emissions by 2050 (MBIE, 2022).

Through the application of PA in the Adaptive Digital Twin platform, the process heat required to run these process plants can be reduced by a wide margin each year - thus in turn reducing the GHG emissions by extension. For a very inefficient plant, target energy reductions of up to 40% is achievable (*Pinch Analysis*, n.d.), but generally the industry standard is to aim for energy reductions of 10% per year - although for many plants this isn't typically achievable.

Given the incentive of long term savings on heat generation, this project hopes that its stakeholders will apply this PA system on their process plants and in turn reduce the GHG emissions. PA and other similar analysis tools are the primary way that Ahuora hopes to promote a cleaner process chemical sector that aligns with New Zealand’s goals of net neutral GHG emissions.

The scope of this project does not include any considerations to vision mātauranga in its design or implementation. As a company these considerations have been made by Ahuora and this R&D falls within this scope.

References

Beck, K. (2003). *Test Driven Development*. Addison-Wesley.

MBIE. (n.d.). *Process Heat – Current state fact sheet*. Ministry of Business, Innovation & Employment. Retrieved March 6, 2024, from https://www.mbie.govt.nz/dmsdocument/152-process-heat-current-state-fact-sheet-pdf

MBIE. (2022, May 16). *Emissions Reduction Plan*. Ministry of Business, Innovation & Employment. Retrieved March 6, 2024, from https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/low-emissions-economy/emissions-reduction-plan/

Pinch Analysis. (n.d.). Pinch Analysis. Retrieved March 6, 2024, from https://pinch-analyse.ch/en/pinch-analysis

6. Appendix


ID
Name
2024
Feb 2024
Mar 2024
Apr 2024
May 2024
Jun 2024
Jul 2024
Aug 2024
Sep 2024
Oct 2024
Nov 2024
1 Research (Literature)
4 Research (Existing Solutions)
3 Unit Testing
2 System Development
5 System Testing
6 Prototyping
7 User Testing (Design)
8 UI Development
9 Front-end Development
10 Software Testing (Whole)
11 Usability Testing
12 Memos
13 Dissertation
14 Poster