**Department of Process Engineering**
**Final Year Project (C) 478 – Project Approval Form**

| Name of Supervisor | Student Name and Number |
|---|---|
| Prof TM Louw | EK Hickling (21553750) |

## Project Title

Data reconciliation for advanced process monitoring of a distillation column

## Project Description and Objectives

Data reconciliation is a method used to leverage redundant measurements along with conservation equations to filter measurements and reduce instrument noise, for enhanced process monitoring and control. Data reconciliation may also be extended to detect gross errors such as sensor failure. The goal of this project will be to assess the use of data reconciliation for enhanced process monitoring of a distillation column, specifically for fault detection related to sensor failure.

## Project Outcome and Deliverables

The following requirements must be met for the project to be considered successful:

- Implementation and validation of a dynamic model of a distillation column, under simplified conditions.
- Implementation and assessment of data reconciliation for improved measurement accuracy for the model plant.
- Implementation and assessment of gross error detection to identify simulated sensor failures for the model plant.
- Critical analysis of the benefits and challenges associated with data reconciliation.

## Project Characteristics and Requirements

**Applicability to Chemical Engineering:** The student must engage with selected knowledge in the research literature of the chemical engineering discipline. Briefly describe the relevance of this project to chemical engineering.

The project considers the use of advanced data analytics for process monitoring, which is relevant to the operation of all chemical- or minerals processing plants. The selected case study represents an important unit operation in many chemical processing plants.

**References:** Are sufficient literature sources available and accessible to support this topic? Provide at least two examples.


(1) Crowe, C. M. (1996). Data reconciliation—progress and challenges. Journal of process control, 6(2-3), 89-98.
(2) Tong, H., & Crowe, C. M. (1995). Detection of gross erros in data reconciliation by principal component analysis. AIChE Journal, 41(7), 1712-1722.
(3) Özyurt, D. B., & Pike, R. W. (2004). Theory and practice of simultaneous data reconciliation and gross error detection for chemical processes. Computers & chemical engineering, 28(3), 381-402.


**Infrastructure, Resources and Funding:** Are there special infrastructure, resource, or funding requirements for this project? If so, specify how these will be provided.

All simulations and analyses will be conducted using MATLAB. No additional funding is required.

## ECSA Graduate Attributes

**2. Application of scientific and engineering knowledge:** Apply knowledge of mathematics, natural sciences, engineering fundamentals and an engineering speciality to solve complex engineering problems.

Knowledge of the following areas of mathematics and/or natural science and/or engineering fundamentals shall be applied:

- Process Modelling and control
- Separations technology

Sufficient complexity shall be captured in:

- The implementation of a complex dynamic model of an important operation
- The implementation and evaluation of an advanced process monitoring strategy

**4. Investigations, experiments, and data analysis:** Demonstrate competence to design and conduct investigations and experiments.

Design a series of computationally intensive simulated experiments with stochastic inputs. Critically analyse the results of the simulated experiments using appropriate statistical tools.

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**6. Professional and technical communication:** Demonstrate competence to communicate effectively, both orally and in writing, with engineering audiences and the community at large.

A well-structured, well-written, professional technical report shall be submitted for assessment. In addition, oral and poster presentations shall be delivered to examiners as part of the formal assessment.

**8. Individual, team, and multidisciplinary work:** Demonstrate competence to work effectively as an individual, in teams and in multidisciplinary environments.

The student shall work under the guidance of a supervisor. The supervisor shall provide sound, professional advice, and administrative support, but shall not do the work on behalf of the student. The student shall, therefore, demonstrate competence to interact, devise and conduct the investigation effectively as an individual, as follows:

- Regularly meet with the supervisor (including taking minutes of meetings).
- Implement an advanced process simulation using scientific computing software.
- Analyse and interpret results using appropriate statistical techniques.
- Present findings in a report and during oral presentations, all though individual efforts.

**9. Independent learning ability:** Demonstrate competence to engage in independent learning through well-developed learning skills.

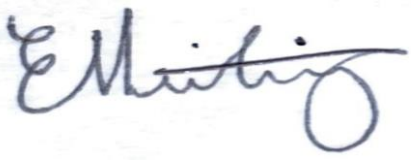
The student shall engage, independently and without formal lecturing, with new theoretical and/or practical concepts. Key concepts and skills to be mastered independently are:

- The implementation of a dynamic model with realistic stochastic disturbances using appropriate scientific computation software;
- Studying and applying concepts related to process monitoring which are not covered in the undergraduate curriculum, including data reconciliation and gross error detection

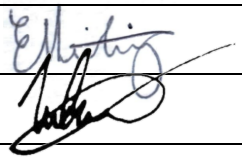
**Criteria for continuation of project (items to be delivered by June)**

- Implementation of a dynamic model of a distillation tower with stochastic disturbances.
- Rudimentary implementation of a data reconciliation strategy for improved measurement accuracy

**Sign-off:** This project has been registered and reviewed by the Department of Process Engineering and accepted as suitable for a Final Year Project.

| | Signature | Date |
|---|---|---|
| **Supervisor** |  | 25/3/2022 |
| **Student** |  | 25/03/2022 |
| **Coordinator** | | |

**Department of Process Engineering**
**Final Year Project (C) 478 – Short Minutes of Meeting**

| Name | Signature | Date |
|---|---|---|
| Ewan Hickling |  | 01-03-2022 |
| Tobi Louw | | 2022-3-1 |
| | | |

| Problems experienced and progress made since previous meeting |
|---|
| • Introduction to data reconciliation.<br>• Introduction to model development of binary distillation column. |

| Decisions and actions to be taken after meeting | Responsible | Deadline |
|---|---|---|
| Perform degrees of freedom analysis on the distillation column. | Ewan Hickling | 03-03-2022 |
| Start reading through the recommended data reconciliation book. | Ewan Hickling | |
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**All parties present must sign these short minutes at the end of the meeting**. Scan the signed document and send an electronic copy to your supervisor within 48 hours after the meeting. The original must be included in an appendix of your final report.

**Department of Process Engineering**
**Final Year Project (C) 478 – Short Minutes of Meeting**

| Name | Signature | Date |
|---|---|---|
| Ewan Hickling | Ewan Hickling Digitally signed by Ewan Hickling Date: 2022.05.18 13:26:30 +02'00' | 17/03/22 |
| Tobi Louw | Tobi Louw Digitally signed by Tobi Louw Date: 2022.05.18 15:32:03 +02'00' | 2022/5/18 |
| | | |

| Problems experienced and progress made since previous meeting |
|---|
| No problems with DOF. |

| Decisions and actions to be taken after meeting | Responsible | Deadline |
|---|---|---|
| Complete specification of variable types. | EH | 21/03/22 |
| Implement code into Matlab | EH | 31/03/22 |
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**Final Year Project (C) 478 – Short Minutes of Meeting**

| Name | Signature | Date |
|---|---|---|
| Ewan Hickling | Ewan Hickling Digitally signed by Ewan Hickling Date: 2022.05.01 09:02:47 +02'00' | 01/05/22 |
| Tobi Louw | Tobi Louw Digitally signed by Tobi Louw Date: 2022.04.28 20:48:04 +02'00' | 28/04/22 |
| | | |

| Problems experienced and progress made since previous meeting |
|---|
| Preliminary code has been written. Started reading on text book. |

| Decisions and actions to be taken after meeting | Responsible | Deadline |
|---|---|---|
| Complete code. | EH | 31/04/22 |
| Start with code for measurements. | EH | 31/05/22 |
| Continue reading through text book. | EH | 31/05/22 |
| Start writing on literature review and scope of project. | EH | 31/06/22 |
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| Name | Signature | Date |
|---|---|---|
| Ewan Hickling | Ewan Hickling Digitally signed by Ewan Hickling Date: 2022.05.01 09:17:24 +02'00' | 01/05/22 |
| Tobi Louw | Tobi Louw Digitally signed by Tobi Louw Date: 2022.06.07 07:00:33 +02'00' | 2022/06/07 |
| | | |

| Problems experienced and progress made since previous meeting |
|---|
| Struggled to implement second set of ODEs. Thus, could not complete code nor implement measurements. Professor Louw made changes to my code and suggested a new approach. |

| Decisions and actions to be taken after meeting | Responsible | Deadline |
|---|---|---|
| Complete code with new approach. | EH | 10/05/22 |
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| Name | Signature | Date |
|---|---|---|
| Ewan Hickling | Ewan Hickling Digitally signed by Ewan Hickling Date: 2022.05.18 13:33:35 +02'00' | 11/05/22 |
| Tobi Louw | Tobi Louw Digitally signed by Tobi Louw Date: 2022.05.18 15:31:48 +02'00' | 2022/5/18 |
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| Problems experienced and progress made since previous meeting |
|---|
| Problems with code. Professor Louw suggested some changes to make. |

| Decisions and actions to be taken after meeting | Responsible | Deadline |
|---|---|---|
| Complete code with measurements. | EH | 24/05/22 |
| Read through linear steady-state data reconciliation. | EH | 24/05/22 |
| Implement linear steady-state data reconciliation into Matlab. | EH | 19/06/22 |
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| Name | Signature | Date |
|---|---|---|
| Ewan Hickling | Ewan Hickling Digitally signed by Ewan Hickling Date: 2022.05.27 08:22:40 +02'00' | 24/05/22 |
| Tobi Louw | Tobi Louw Digitally signed by Tobi Louw Date: 2022.06.07 06:59:48 +02'00' | 07/06/2022 |
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| Problems experienced and progress made since previous meeting |
|---|
| Code with measurements were implemented. However, last problem with code was due to liquid flow rates not being calculated correctly.<br>Examples of Data reconciliation were implemented in Matlab. |

| Decisions and actions to be taken after meeting | Responsible | Deadline |
|---|---|---|
| Finish code with measurements. | EH | 07/06/22 |
| Implement linear DR with all variables measured. | EH | 07/06/22 |
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|---|---|---|
| Ewan Hickling | Ewan Hickling Digitally signed by Ewan Hickling Date: 2022.06.06 15:48:14 +02'00' | 06/06/22 |
| Tobi Louw | Tobi Louw Digitally signed by Tobi Louw Date: 2022.06.07 07:00:15 +02'00' | 07/06/2022 |
| | | |

| Problems experienced and progress made since previous meeting |
|---|
| - Code is running as it should, however, results generated are not correct.<br>- Preliminary data reconciliation code has been implemented.<br>- Started with progress report write up. |

| Decisions and actions to be taken after meeting | Responsible | Deadline |
|---|---|---|
| Sort out results generated during the next two weeks. | EH | 21/06/22 |
| Finish progress report. | EH | 19/06/22 |
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| Name | Signature | Date |
|---|---|---|
| Ewan Hickling | Ewan Hickling Digitally signed by Ewan Hickling Date: 2022.07.10 14:20:41 +02'00' | 05/07/22 |
| Tobi Louw | Tobi Louw Digitally signed by Tobi Louw Date: 2022.07.11 08:29:04 +02'00' | 11/07/22 |
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| Problems experienced and progress made since previous meeting |
|---|
| Parameters included into model. Some issues still remain, however, model's data is sufficient to perform DR on it. |

| Decisions and actions to be taken after meeting | Responsible | Deadline |
|---|---|---|
| Finish implementing linear DR (fully & partially measured variables). | EH | 19/07/22 |
| Present linear DR results to Professor Louw via PowerPoint. | EH | 19/07/22 |
| Research non-linear DR. | EH | 19/07/22 |
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| Name | Signature | Date |
|---|---|---|
| Ewan Hickling | Ewan Hickling Digitally signed by Ewan Hickling Date: 2022.08.17 11:21:18 +02'00' | 02/08/22 |
| Tobi Louw | Tobi Louw Digitally signed by Tobi Louw Date: 2022.08.17 12:11:43 +02'00' | 17/8/2022 |
| | | |

| Problems experienced and progress made since previous meeting |
|---|
| - Linear DR completed, without observability analysis (measured & unmeasured)<br>- Struggled to implement non-linear DR |

| Decisions and actions to be taken after meeting | Responsible | Deadline |
|---|---|---|
| Finish linear DR completely (observability analysis included) & present results. | EH | 16/08/22 |
| Implement non-linear DR with preliminary results. | EH | 16/08/22 |
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| Ewan Hickling | Ewan Hickling Digitally signed by Ewan Hickling Date: 2022.08.17 11:25:26 +02'00' | 16/08/22 |
| Tobi Louw | Tobi Louw Digitally signed by Tobi Louw Date: 2022.08.17 12:11:30 +02'00' | 17/8/2022 |
| | | |

| Problems experienced and progress made since previous meeting |
|---|
| - Finished observability analysis for linear DR<br>- Implemented non-linear DR without observability analysis |

| Decisions and actions to be taken after meeting | Responsible | Deadline |
|---|---|---|
| Display results better for linear & non-linear DR | EH | 30/08/22 |
| Complete observability analysis for non-linear DR | EH | 30/08/22 |
| Create power-point explaining in detail progress made thus far and how results were generated | EH | 30/08/22 |
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| Ewan Hickling | Ewan Hickling Digitally signed by Ewan Hickling Date: 2022.09.12 16:24:21 +02'00' | 01/09/22 |
| Tobi Louw | Tobi Louw Digitally signed by Tobi Louw Date: 2022.09.19 10:18:01 +02'00' | 19/09/2022 |
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| Problems experienced and progress made since previous meeting |
|---|
| - Results generated for redundancy analysis satisfactory for linear & non-linear DR.<br>- Results generated for variance analysis satisfactory. |

| Decisions and actions to be taken after meeting | Responsible | Deadline |
|---|---|---|
| Implement step changes to view effects on important variables. | EH | 13/09/22 |
| Implement non-linear DR variance analysis. | EH | 13/09/22 |
| Start implementing GED. | EH | 28/09/22 |
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| Ewan Hickling | Ewan Hickling Digitally signed by Ewan Hickling Date: 2022.09.18 11:40:23 +02'00' | 13/09/22 |
| Tobi Louw | Tobi Louw Digitally signed by Tobi Louw Date: 2022.09.19 10:18:42 +02'00' | 19/09/2022 |
| | | |

| Problems experienced and progress made since previous meeting |
|---|
| >> Model results are satisfactory and display thereof as well.<br>>> Results are good and make sense, but current measurement structure incorrect. |

| Decisions and actions to be taken after meeting | Responsible | Deadline |
|---|---|---|
| Add more step changes for model results. Add random changes. | EH | 19/09/22 |
| Change measurement structure. Implement new approach for linear & non-linear DR. | EH | 19/09/22 |
| Implement GED. | EH | 27/09/22 |
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| Name | Signature | Date |
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| Ewan Hickling | Ewan Hickling Digitally signed by Ewan Hickling Date: 2022.10.14 20:26:44 +02'00' | 30/09/22 |
| Tobi Louw | Tobi Louw Digitally signed by Tobi Louw Date: 2022.10.18 08:55:27 +02'00' | 18/10/22 |
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| Problems experienced and progress made since previous meeting |
|---|
| - Implemented new measurement structure.<br>- Generated results for linear & non-linear good.<br>- Implemented linear GED strategy, preliminary results okay. |

| Decisions and actions to be taken after meeting | Responsible | Deadline |
|---|---|---|
| Update linear GED strategy as discussed with Dr Louw | EH | 14/10/22 |
| Implemented non-linear GED strategy. | EH | 14/10/22 |
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| Tobi Louw | Tobi Louw Digitally signed by Tobi Louw Date: 2022.10.18 08:55:16 +02'00' | 18/10/22 |
| | | |

| Problems experienced and progress made since previous meeting |
|---|
| - Mini meeting during the week helped a lot to complete the following:<br>> Implement successful linear GED strategy<br>> Implement successful non-linear GED strategy |

| Decisions and actions to be taken after meeting | Responsible | Deadline |
|---|---|---|
| Show results for GED strategy in another way | EH | 20/10/22 |
| Finish Report | EH | 20/10/22 |
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