# ME44300

# 2024-2025

# Multi-Machine Coordination for Logistics

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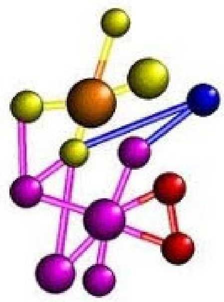

**Description of Project Assignment**

This project assignment aims to help you achieve the learning objectives of the course ME44300. After following this course, you should be able to:

LO1. describe large-scale machines and transport systems using system theory
LO2. explain the design of an automatically controlled system and of the automatic coordination of several controlled systems
LO3. explain the design of control architectures for large-scale interconnected machines and transport systems (centralized, distributed, single-agent, multi-agent, single-level, multi-level)
LO4. evaluate the pros and cons of different control architectures and their impact on multi-machine coordination
LO5. design an optimal control strategy for a single machine used in the transport network (truck, ship, crane, etc)
LO6. develop a multi-agent control framework for real-time logistics for large-scale transport systems.

The assignment consists of three main parts:

- Part 1 focuses on learning objective 1.
- Part 2 focuses on learning objectives 2, 4, and 5.
- Part 3 focuses on learning objectives 3, 4, and 6.

**Keywords** associated with this project assignment are: systems, control, transport, (artificial) intelligence, multi-agent systems, and model predictive control.

The remainder of this document describes the background of the assignment, the structure, the particular topics to address, and the planning.

If you have questions, contact Dr. Vasso Reppa (v.reppa@tudelft.nl).

## Introduction

Freight transport has been growing over the last decades and is expected to continue growing over the decades to come (see Fig. 1). Transport has so far been a major contributor to economic growth, but problems may arise towards accommodating the foreseen transport growth. To manage these problems, a more integrated way of looking at transport is being sought. Transport over road, rail, and water should not be considered individually, but collectively, being a much more large-scale system over which freight is transported in an intermodal way over a network of transport links and transport hubs. At the same time, besides efficiency, also sustainability aspects are becoming more and more important to be considered.

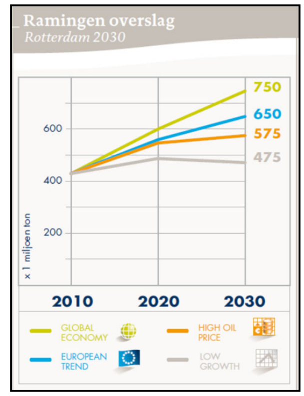


Fig. 1: Transport forecasts (Port Vision 2030, Port of Rotterdam)

Such a large-scale system can be considered as a *system of systems*, consisting of thousands of moving smaller components. Each of these components contributes to the transport process. Coordinating the movements of all these components in the most efficient and/or sustainable way is a huge challenge. The frequently occurring interactions among different components should be orchestrated carefully.

One way in which performance gains could be achieved is by better utilizing the possibilities that modern sensing, information and communication technologies offer. These technologies enable continuous monitoring of all kinds of processes, communication among components geographically widely spread, and fast, online data processing to support decision making. The general question that now arises is:

***How can these technologies be used to optimize the performance of the intermodal transport network?***

Benefit could be taken from these technologies by developing intelligent and innovative control algorithms for links, hubs, and individual components in transport networks. Such control algorithms should be aimed at optimizing interactions, e.g., by stimulating the automatic coordination of equipment (gantry cranes, trucks, quay cranes, AGVs, yard vehicles, and so on) in such a way that, e.g., transfer delays and lay times of ships are minimized, while throughput and profits are maximized. This small research project challenges you to investigate and conceptualize such intelligent algorithms.

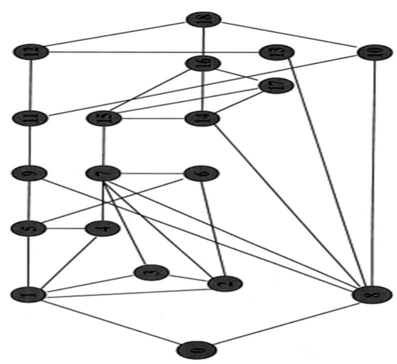

Fig. 2: Interacting(?) systems.

The overall goal of this project is *to* ***explore to what extent and in which way intelligent and automatic control and coordination principles could in the future be used to improve the performance of transport infrastructures.***

Designing controllers for all machines involved in transport over such a large network is a tremendous task. Therefore, in this assignment ***you will focus on one particular machine, and propose an intelligent controller for this machine on one hand and investigate the interactions of this machine with its direct surroundings (neighbors) on the other hand***. Hereby, you will use in your project as much as possible and explicitly the concepts introduced in the course.

**The assignment is divided into 3 parts:**

1) Definition of a particular system and definition of its optimal performance.
2) Proposing of an intelligent single agent control approach for the system defined.
3) Proposing of an intelligent multi-level, multi-agent control approach for the system you have defined and its interconnected systems.

**The details of these parts should be worked out by applying the concepts as introduced in the course's lectures (and supporting reading materials).**

## Part 1) Defining and describing your system and its optimal performance

1. Describe the assigned physical system under study in *your* project and the typical operational tasks it carries out in the transport process.
2. Provide the motivation and reasons for exploring ways in which the operation of this system can be made more intelligent.
3. Define the control objectives for the assigned physical system and describe the system variables to be controlled.
4. Formulate a state-space model for representing the dynamics of your system, including a description of relevant variables (states, inputs, outputs, disturbances) and their relations that characterize your system.
5. Propose formal definitions for performance of your system as a function of the state-space variables.

## Part 2) Proposing an intelligent single-agent model-based control approach for your system

1. Discuss key concepts of single-agent intelligent control mechanisms in a generic way.
2. Formulate a future intelligent model-based controller for your specific system with expected improved performance.
3. Design the body-brain diagram for your specific system
4. Make explicit the (computational) steps that the controller takes to determine its actions and the information that the controller receives.

## Part 3) Proposing an intelligent multi-level, multi-agent architecture for your system and its interconnected systems

1. Discuss key concepts of multi-agent and multi-level control architectures in a generic way.
2. Propose a future improved distributed control architecture for your system and its interconnected systems, including a diagram showing: (i) the interconnected systems, (ii) the flow of information between every controller and its controlled system, and (iii) the information flow between controllers and their relations with local computations.
3. Propose an approach for the controllers to resolve conflicts, and illustrate with examples how this approach would obtain agreement on shared variables.
4. Discuss the potential challenges to overcome towards the realization of the proposed architecture, including the changes in skills needed by future human operators.

## Organization & Timing

You will do this assignment in a group of 4 students.

You are expected to address the various topics together; each of you should support and be able to explain each part of the project. (Discussion and different points of view will emerge; make sure to document these properly and motivate why a particular decision was made.)

Shortly after the first lecture, **your group will receive the specific component around which your project** shall evolve.

The final report describing the outcomes of the project should be submitted electronically in PDF via BrightSpace by **June 16, 2025, 08.30 the latest**. This is a hard deadline.

BrightSpace Assignment functionality will be used to automatically verify the proprietary, original nature of the content of the final report (i.e., no plagiarism is present and appropriate references are made).

## Information and feedback sessions

For helping you to develop understanding of the concepts used, lectures will be organized and relevant reading and multi-media materials will be provided via the BrightSpace website.

For guiding you during the project, two feedback sessions will be organized throughout the course. In these sessions a group can discuss the progress and ideas of their project with one of the teachers.

Each feedback session (20 minutes) will focus on specific parts of the assignment:

- Feedback session "System Definition & Control" (**week 4.4**) – Focus on Part 1 & Part. 2.
- Feedback session "Control & Coordination" (**week 4.6**) **–** Focus on Part 2 & Part 3.

In the case that there are **issues within the group and/or imbalance in contribution** to the completion of the project, the group members may send an email to the teachers to inform them and may express the willingness to discuss the issues during the feedback sessions.

**Essential for an effective meeting:**
Prepare for each feedback session a prioritized list of questions and the relevant parts of your concept report that should be submitted via BrightSpace before the meeting.
Note: If nothing is submitted, then the meeting will be cancelled.

## Report

The final report should be structured following the partition of the description. i.e. :

- 3 Chapters that correspond to the 3 parts,
- one section for addressing one subquestion, e.g. Chapter 1, Section 1.1 Description of Physical System and operational tasks.

The report should be written in English.

The report is formatted as follows: Page size A4; font size max. 11pt; single line spacing, normal margins (2.54 cm from each side).

**Mention the group number, names and student registration numbers of the group members on the first page of each report, as well as the Master Programme that you follow.**

**Motivate all your statements and choices made.**

Include schematics/drawings/figures to support explanations.

Include references when you use information (including figures) from other sources.

Note: **Any suspicion of plagiarism/fraud will be forwarded to the Board of Examiners for further assessment.**

**Assessment procedure of this course**

During the assessment the level of understanding regarding the topics of the project and the lectures will be determined.

The final grade will be determined based on the assessment of the project report (50%) and the individual, closed-book written exam (50%) that will take place on **June 23**.

The final grade will be announced the latest on **July 4.**

The following resit options apply:

1) One time, the project report can be improved based on additional feedback received. A separate document addressing how the feedback has been addressed needs to be provided. The maximum grade for the new report is the grade 6. Final grade for the course is recalculated with the 50%/50% rule.
2) As an alternative to (1), one time, a new project with a new component can be carried out with the group, after which a new report is prepared. The maximum grade for the report is the grade 10. Final grade for the course is recalculated with the 50%/50% rule.
3) The **written exam can be retaken on July 14**. After the resit exam, the final grade is re-determined with the 50%/50% rule.

Note: The project grade (also the written exam grade) **is valid for 1 academic year and cannot be saved for the next year.**