Aalto University
ELEC-E8004 Project work course
Year 2020

Project plan

Project # 1-3
Distributed intelligent production involving remote actors

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Information page

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Approval

The Instructor has accepted the final version of this document

Date: 05.02.2020

1) Background

Autonomous ground vehicles (AGVs) are now widely used in industry, and their prevalence is one factor contributing to the need for changes on industrial automation and control systems. Automation and control equipment is becoming more heterogeneous and interconnected, calling for increased interoperability and flexibility. Further, integration of spatially separated system components through untrusted and unreliable communication channels is raising new challenges in industrial automation.

This project aims to develop a solution to enable secure and reliable control of an AGV located in RMIT VXLab, Australia, from Aalto Factory of Future (AFoF), Finland. Secure IP-based solutions for communication over a long distance will be developed. Another key problem will be how to satisfy real-time constraints over the variable-latency communication channel. In addition, some work will be done to integrate a local AGV with Energy-Autarkic Actuator and Sensor System (EnAS) demonstrator. EnAS itself is already functional; it is automated with IEC 61499 applications running on IceBlock controllers.

This kind of remote control functionality could be beneficial for many manufacturing applications. Consider the following scenario: multiple specialized manufacturing plants are geographically separated, and each plant is responsible for manufacturing or preparing some parts of an end-product. Reliable automated interaction of the plants is required for high production efficiency. Further, product driven manufacturing often requires high flexibility in processes that can only be provided by an AGV.

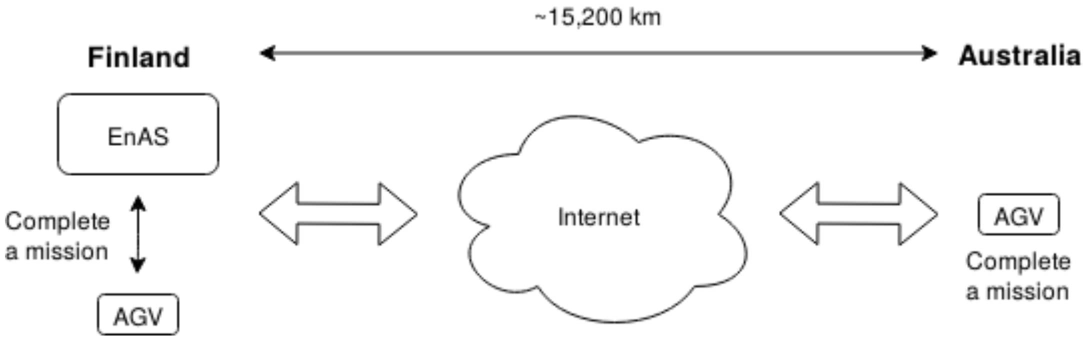


Figure 1. Illustration of the remote control problem.

2) Expected output

Two main objectives for the project are formulated:

1. Setup a secure IP-based communication channel between AFoF and RMIT VXLab.
2. Demonstrate remote control of MiR 100 AGV located in Australia from Finland.

These main objectives consist of multiple smaller objectives. Setup of the communication channel requires the team to first choose an appropriate physical setup. The MiR AGV must connect to a gateway device (or possibly more than one intermediary device), which then must establish a secure IPSec tunnel between the communication end points. An appropriate protocol to be used on top of the IPSec protocol shall also be chosen. The complete network configuration and implementation shall be done with reliability, security, flexibility and credibility in mind.

Second main objective consists of choosing an appropriate technology for controlling both the local and the remote MiR AGVs. The AGVs have a REST API developed by the manufacturer as well as a ROS library developed by third-parties. One or possibly both of these technologies shall be chosen for defining and executing missions that must be completed by the AGVs. The local AGV should also interact with the EnAS. Then, real-time constraints related to the remote control must be defined and appropriate solutions developed to overcome any issues.

Finally, the main objectives are combined and a demonstrative distributed intelligent production system is designed and implemented. The expectation is that the final demonstrative system has credible security and is robust against the issues of long distance variable-latency communication channels. Further, each system component shall be carefully documented. An instruction manual created and an illustrative video recorded.

Other expected outputs are the business pitching, business pitch slides submission, business aspects document submission and submission of the final report. These are discussed in detail in Section 5 (Work packages and Tasks of the project and Schedule).

All official documentation (project plan, business assignments, final report) will be submitted by MyCourses.

3) Phases of project

Phases of the project and related milestones include:

- Planning phase: Project management formulation.
    - Milestone M1: Create a project plan

- Business aspect phase: Business formulation and documentation
    - Milestone M2: Produce business assignments such as business pitch slides, business aspects document

- Development phase: Software development of the MIR robot's control, networking and integration
    - Milestone M3: Achieve to move the robot at AFoF for the first time with networking

- Testing phase: Assessment of control, networking and integration
    - Milestone M4: Achieve to move the Australian robot remotely

- Final phase: Conclusion and final document creation
    - Milestone M5: final presentation at final gala on May 19th, also returning the final report and preparing and returning technical data, video and instruction manual

4) Work breakdown structure (WBS)

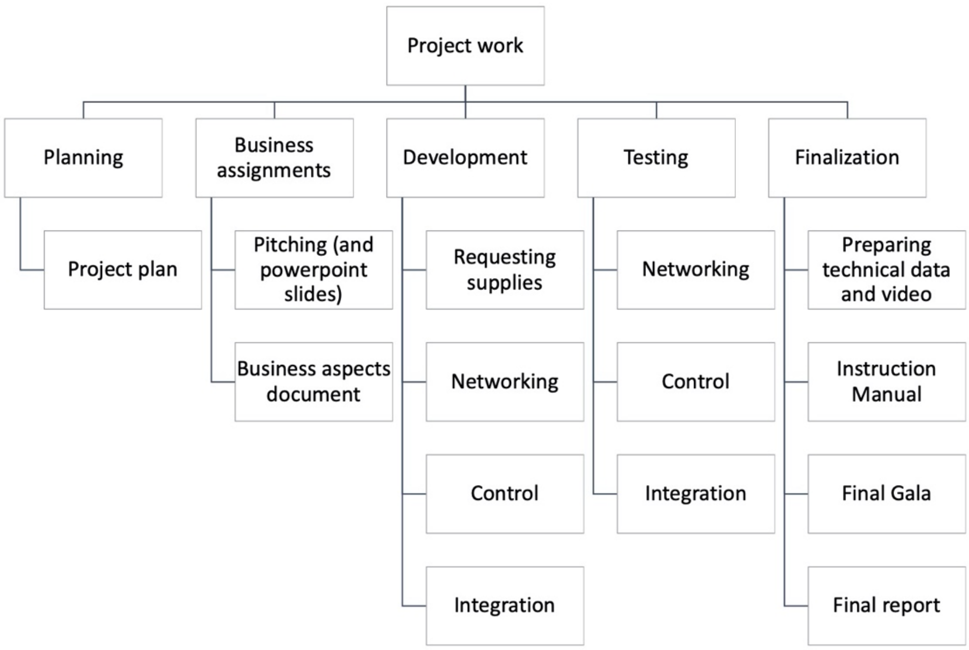


Figure 2. The work breakdown structure of the project work is shown in the figure above.

5) Work packages and Tasks of the project and Schedule

5.1) Work packages (WP)

- Project planning Work Package, WP1
  - Tasks: project plan writing, getting acceptance of it from the instructor, returning it by February 6th
  - Deliverable: D1 project plan (M1)
  - WP1 responsible: Juhani Lähde
- Business Work Package, WP2
  - Tasks:
    - Prepare pitching assignment (WP2.1),
    - Prepare business aspects document (WP2.2)
      - Business Pitch slides submission by,
      - Business Aspects Document submission (milestone M2)
  - Deliverables: D2.1 Pitch slides March 6th, D2.2 Business aspects document March 13th.
  - WP2 responsible: Minh Duc Pham
- Development Work Package, WP3
  - Tasks: requesting supplies and services (WP3.1), developing code to move the robot and interact with a distributed automation system:
      - networking (WP3.2)
      - control (REST/ROS) (WP3.3)
      - integration with a 61499 NxtStudio distributed automation system (WP3.4)

    - Deliverables: Not expected, but completion of M3 is expected (moving the robot at AFoF for the first time with networking)
    - WP3 responsible: Panu Salo

- Testing Work Package, WP4
    - Tasks: testing locally at Otaniemi and remotely, move the MIR robot and interact with a distributed automation system Testing happens partially simultaneously with WP3 (development)
        - Testing the networking (WP4.1)
        - Testing the control (REST/ROS) (WP4.2)
        - Testing the integration (WP4.3)
    - Deliverable: Test report (video or document). Completion of M4 is expected: moving the Australian robot remotely
    - WP4 responsible: Niko Karhula

- Final documentation Work Package, WP5
    - Tasks:
        - Finalizing the robot (WP5.1)
        - Writing the final report (WP5.2)
        - Also preparing technical data, video and instruction manual (WP5.3)
    - Deliverable: Final report (and attachments). Completion of M5 is expected (final presentation at final gala on May 19th).
    - WP5 responsible: Paavo Kajola

Everyone in the group can also support any work package.

5.2) Tasks

Estimated working hours in tasks are estimated in the table 1 below.

Table 1. Estimated working hours in tasks

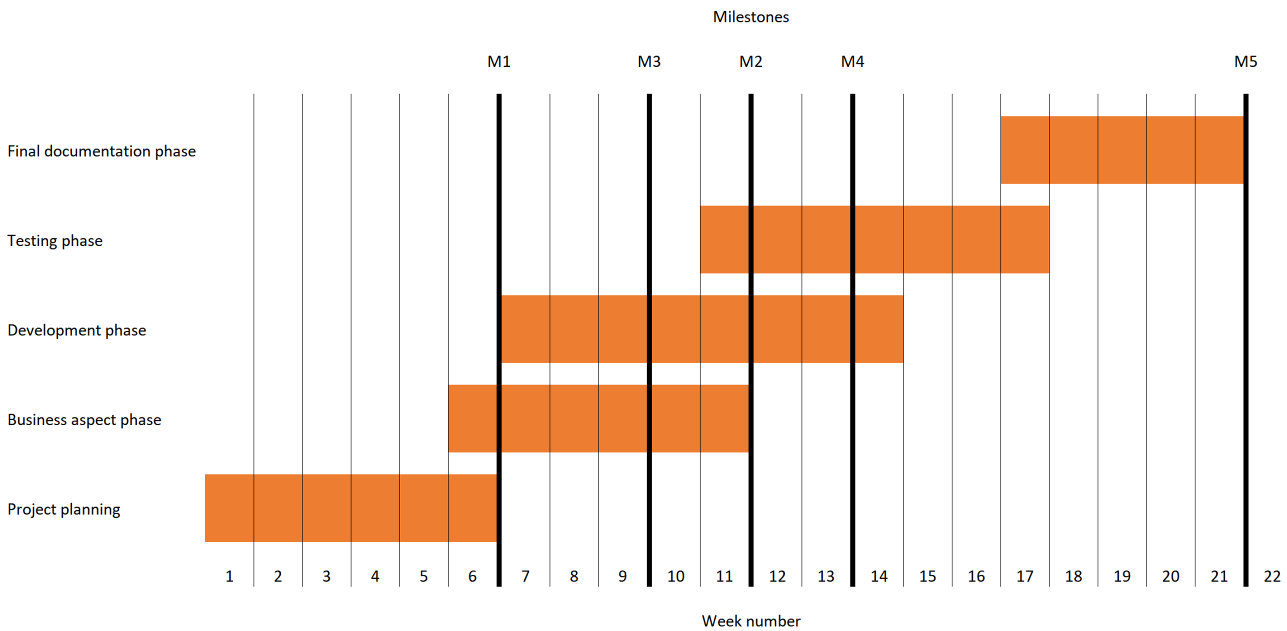
Task	Working hours (h)
Project planning	45
Business assignments	50
Requesting supplies and services	50
Development (networking, control and integration)	180
Testing	180
Meetings	40

5.3) Detailed schedule

- Weeks 1-6: project planning phase
  - Meetings, project plan writing, getting acceptance to it from the instructor, returning it by February 6th
    - Milestone M1, (Week 6)
- Weeks 6-11: business aspect phase
  - Business assignments: Business Pitch slides submission by March 6th
  - Business Aspects Document (accepted by instructor) submission by March 13th
    - Milestone M2 (Week 11)
- Weeks 7-14: development phase
  - Requesting supplies and services, developing code (control, networking, integration)
    - Milestone M3, moving the robot at AFoF for the first time with networking
- Weeks 11-17: testing phase
  - Testing code locally at Otaniemi and remotely
    - Milestone M4, moving the Australian robot remotely
- Weeks 17-21: final documentation phase
  - Final testing of the robot
  - Milestone M5
    - Preparing technical data, video and instruction manual of the system prototype (for Aalto Wiki)
    - Final gala, presentation at Otaniemi TUAS building on May 19th
    - Final report, by May 29th

Different phases in the schedule will partially happen simultaneously too (like business aspect phase and development phase, or testing phase and finalization phase).

A Gantt chart of the project's phases estimated durations is below.



6) Work resources

These hours are estimations, first estimated in a group meeting on January 23rd. Real working hours can vary a lot from these estimations, depending on people's other courses etc. On week 8, there is an exam week, why working hours can be less than usually.

Personal availability during the project

Table 1. Number of hours available for the project (excluding lectures and seminars) per week.

	Panu Salo	Niko Karhula	Juhani Lähde	Minh Duc Pham	Paavo Kajola	Explanation
Week 1	0-1 h	0-1 h	0-1 h	0-1 h	0-1 h	
Week 2	10-15 h	10-15 h	10-15 h	10-15 h	10-15 h	
Week 3	10-15 h	10-15 h	10-15 h	10-15 h	10-15 h	
Week 4	10-15 h	10-15 h	10-15 h	10-15 h	10-15 h	
Week 5	10-15 h	10-15 h	10-15 h	10-15 h	10-15 h	
Week 6	10-15 h	10-15 h	10-15 h	10-15 h	10-15 h	Project Plan
Week 7	5-10 h	10-15 h	10-15 h	10-15 h	10-15 h	
Week 8	5-10 h	10-15 h	1 h	1 h	10-15 h	Exam week
Week 9	10-15 h	10-15 h	10-15 h	10-15 h	10-15 h	
Week 10	10-15 h	10-15 h	10-15 h	10-15 h	10-15 h	Seminar presentation
Week 11	10-15 h	10-15 h	10-15 h	10-15 h	10-15 h	Business aspects
Week 12	15-20 h	15-20 h	15-20 h	15-20 h	15-20 h	

Week 13	5-10 h	10-15 h	10-15 h	10-15 h	10-15 h	
Week 14	5-10 h	10-15 h	10-15 h	10-15 h	10-15 h	
Week 15	5-10 h	10-15 h	10-15 h	10-15 h	10-15 h	Exam week
Week 16	10-15 h	10-15 h	10-15 h	10-15 h	10-15 h	
Week 17	15-20 h	10-15 h	10-15 h	10-15 h	10-15 h	
Week 18	15-20 h	10-15 h	10-15 h	10-15 h	10-15 h	
Week 19	15-20 h	10-15 h	10-15 h	10-15 h	10-15 h	
Week 20	20-25 h	10-15 h	10-15 h	10-15 h	10-15 h	
Week 21	10-15 h	10-15 h	20-25 h	20-25 h	10-15 h	Final reports
Total	**205-306 h**	**205-306 h**	**206-302 h**	**206-302 h**	**205-302 h**	

7) Cost plan and materials

The project manager is responsible for the budget. Changes for the budget need to be discussed with other team members in the meetings or through Telegram group before decisions. Using the budget needs to be negotiated with the instructor as well (university policy).

The initial budget of this project is 10000 euros.

Table 2. Cost estimation of the project.

Item	Quantity	Price per unit
Raspberry Pi	3	300 eur
Sending a member of the group to Melbourne	1	3500 eur
Miscellaneous	2000 eur	
Total	5800 eur	

8) Other resources

The main working place is at Aalto Factory of the Future (CS Building, Konemiehentie 2). Key cards have been granted to group members. Project team have access to 3D-printers at ADDlab facility.

Existing equipment for the project:

- The MIR 100 robot (will be at AFoF approximately in mid-February).
- Aalto internet (WLAN and 24-port switch at AFoF).
- EnAS demonstrator (to interact with MIR 100, demonstrator used also by another team).
- Group members are using their personal computers for the project.

Manuals/internet resources given by the instructor for the project are:

- MIR 100: https://www.mobile-industrial-robots.com/en/products/mir100/
- EnAS demonstrator: https://wiki.aalto.fi/pages/viewpage.action?pageId=151495823 https://wiki.aalto.fi/display/AEEproject/Wireless+and+Distributed+Automation+System+with+Smart+Update
- Automation controllers for production system: Iceblock, supported by NxtStudio, IEC 61499 enabled: https://www.nxtcontrol.com/en/download-area/
- ROS driver for MIR 100: https://github.com/dfki-ric/mir_robot

9) Project management

- The responsibilities of the project manager (Juhani Lähde) are:
    - responsible of the deliverables and scheduling
- The responsibilities of the instructor:
    - guiding/teaching and accepting the reports
- The responsibilities of the working package leaders:
    - their working packages (other people can also help and do the tasks if so agreed)

The work package leaders are (see 4.1 Work Packages for more details):

- project planning Work Package, WP1
    - WP responsible: Juhani Lähde
- business Work Package, WP2
    - WP responsible: Minh Duc Pham

- development Work Package, WP3
    - WP responsible: Panu Salo
- testing Work Package, WP4
    - WP responsible: Niko Karhula
- finalization Work Package, WP5
    - WP responsible: Paavo Kajola

10) Project Meetings

Project meetings are tried to be arranged regularly. In the first meeting, it was initially decided that meeting should be tried every week/once a week during the project course. Agenda for each meeting will be prepared for discussion before each meeting.

One student will work as a secretary who writes down what was discussed during the meeting (memo). At every meeting, main points for next meeting will be introduced and they will serve as a backbone for an agenda. Before the next meeting, the agenda will be further discussed and being added with emerging obstacles as the project is progressing.

According to the instructor, the role of the writer/secretary will rotate every meeting.

Most likely, meetings at AFoF (CS building) will take place more than once a week once the actual development phase with the robot begins.

11) Communication plan

The communication within the group internally will happen by email, Telegram, or by phone. At first, the group will start communicating with the instructor by email. For discussions in Australia (RMIT), Skype will be used.

12) Risk management

For each risk, management will also be done by talking about the current situation of the project and problems of it in meetings, in other words sharing information within the group to prevent risks.

Table 3. Risks estimated

Risks	Probability Scale: 1-5 5 = High risk	Severity Scale: 1-5 5 = High risk	Indicators	Response Plan	Pro-active Action
MiR100 arrival time unknown	4	5	Unavailability of the robot	Shipment tracking	Prepare and get ready on other parts first
Two available technologies for controlling	5	3	REST or ROS	Team decision	Independent study among team members
ISP dependent	4	5	High pings, no connections or lags	Careful setups with reserved router and switch	Try out sessions with RMIT lab
Policies and legislations (IT, procurement)	5	5	Bureaucratic documents, restrictions	Asking and obtaining detailed instructions	Discuss with supervisor
Time zone difference	5	5	Only 1 or 2 common working hours everyday	Pre-scheduled meetings	Regular communication with RMIT about the matter
Insufficient knowledge	4	5	Obstacles start to appear, malfunction parts	Group discussions and seeking for assistance from supervisors and fellow students	Independent studying

13) Quality

The quality of the project will be assured by appropriate testing of both the software and hardware of each phase and part. All group members are responsible for taking quality into account in the project. Observed problems in the quality will be discussed in the group meetings. Because the project manager observes how the project has proceeded, he will discuss with others if there are any quality issues.

The quality of the project can be measured by the following criteria:

13.1) Product qualities

Functionality

Does the system perform the functions presented in the project plan?

The user must be able to perform three primary functions remotely: Connect to the robot, move the robot around using some specified input device, and configure certain aspects of the robot.

Additional functionality requirements may arise as the project progresses.

Performance

The performance of the product will be measured by several quantitative metrics.

During manual operation of the robot, delay from input to response is measured in milliseconds. This total latency comprises the latency caused by the program, and the network round-trip time. The tentative requirement for total latency is under 500ms. This value may be updated during the project, according to the trend of real system performance. If large amounts of data is sent through the network (such as large images, video or other data), network speed (Mbps) is also measured. Both download and upload speeds are measured, as the two-way nature of the system may require us to both send and receive large amounts of data.

Reliability

System reliability is measured by testing and measuring system uptime during operation. The system will be required to run a set amount of time without crashing or loss of connection.

The score for this test will be given by the uptime percentage of the total test time.

Unit testing will be employed for implemented software modules. The performed tests depend on the module, but generally include checks for robustness against unexpected scenarios, such as malformed input.

13.2) Project qualities

Timeliness

Delay is measured in days/hours caused by missed deadlines. Delay accumulates if project module A is being worked on past its deadline, and module B, which is dependent on A, cannot be started on schedule.

Timeliness is tracked separately for each package.

Documentation

How well is the project documented? If the project documentation could be shared to another team, could they easily start extending it? In the absence of an existing documentation policy, this part will be measured qualitatively.

Completeness

How large a percentage of total planned modules were successfully implemented. Modules may be weighted based on their perceived importance.

14) Changes to the project plan

Possible changes to the project plan can be proposed by anyone within the team. Changes will be discussed within the group directly in meetings or indirectly through other means of communication such as email, Telegram, email or phone. The changes will only be made upon common agreement of the whole team and supervisor. The decision will be made through voting or polling. The option with the majority will be final. When there is an even result, the project manager and the supervisor votes are the determining vote.

15) Measures for successful project

The project shall be considered a success if the following aspects are fulfilled:

- All deliverables are released on time.
- The project packages are adequately documented.
- The product performs its main functions: Remote connection, manual operation, remote configuration.
- Product performance metrics for latency and robustness are met.

The following indicators will support the success of the project:

- Two demonstrative use scenarios of the MIR Robot are successfully formulated.
- A distributed intelligent production system is designed and implemented with regards to the two formulated scenarios.
- Interconnection between Aalto Factory of the Future and RMIT VXLab.
- The existence of feasible future works (research and business)