



UiO : **Department of informatics**
University of Oslo

Research methods

Intro to research methods
Methods for systems engineering

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Outline

- Introductory MSc Thesis case
- How to think about research methods
- Different approaches to research
- Measuring systems / machines / algorithms – through examples

Case: Master's Thesis project description - TIAGO



Below follows a number of different project description:

1. **Robot sensing:** Multi-modal Sensing for Emergency Monitoring of Older People for Privacy
2. **Robot ethics:** Machine Ethics for Robot Security
3. **Robot control:** Motion Preferences for Home Robot for Safety
4. **Robot control:** Reinforcement learning (RL) for safe human-robot interaction
5. **Robot safety:** Exploring the concept of safety in care robots
6. **Robot design:** An explorative study on Universal Design principles and care robots
7. **Human-robot interaction:** The theoretical and practical challenges with informed consent in AI-based care robots
8. **Human-robot interaction:** The role of sociomorphism (rather than anthropomorphism or zoomorphism) in HRI
9. **Human-robot interaction:** "It takes two to <<TIAGO>>: An investigation on intuitive non-verbal interaction with social robots.
10. **Human-Robot Interaction:** "Let the robot take care of grandma"

How to do a thesis?

- Project: Do *X* with the robot
 - How can we learn something new while doing that?
 - How to do it such that it matters for others?
-
- Research: “a detailed *study of a subject*, especially in order to discover (new) *information* or reach a (new) *understanding*”



Example: robot control

- Project: *Make the robot find the fastest way from X to Y without colliding with humans or obstacles on the way*
- How can we learn something new while doing that?
- How to do it such that it matters for others?

- Compare algorithm A with algorithm B
 - A may be known, state of the art
 - B may be self-developed algorithm
- Test it multiple times
 - The people may move, obstacles change
- Do statistics
 - To say with confidence that there really is a difference



Example: human-robot interaction

- Project: *Make the robot cooperate with a human on a task by handing over objects*
- Design two approaches
- Test with different people
- Multiple options:
 - Measure time to complete a task
 - Surveys – e.g. how did you experience (1..5) and free comments
 - Interview participants



Example: robot design

- Project: *Design a new robot head for use in care homes*
- Involve the potential users of the robot in the process
- Discussions, interviews, observation
- Prototyping, multiple iterations



Example: robot design – engineering approach

- Project: *Design and prototype a new hand mechanism for gripping of some type of objects*
- Simulations and prototyping of new mechanism
- Measure performance properties
 - Gripping accuracy
 - Gripping force
 - Speed
- Compare with existing approach if possible



Example: robot control – theoretical approach

- Project: *Extend the arm and investigate the kinematics and workspace of the robot*
- Use mathematics / mechanics theory to develop precise equations of the robot's movements given the extension
- Use established conventions when formulating the solutions



Did your research project fit into one of these?

Science and research

Science

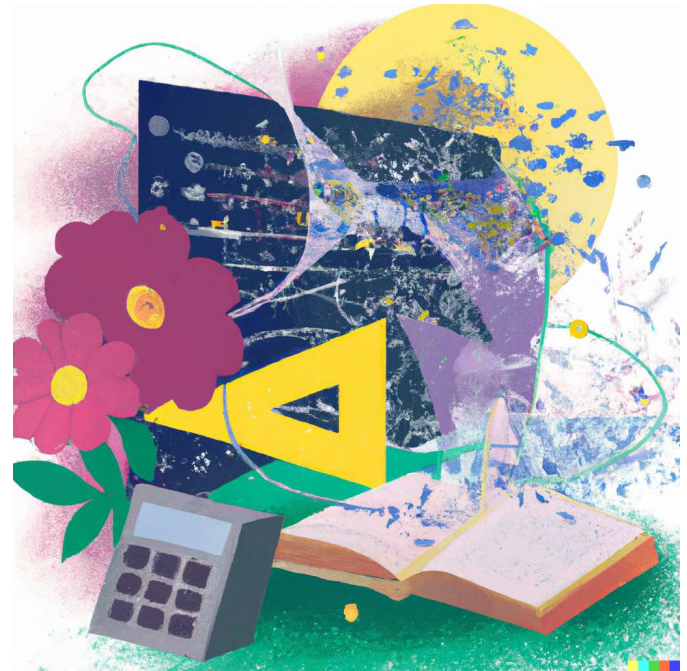
- (*knowledge* from) the careful study of the *structure and behaviour* of the physical world, especially by watching, measuring, and doing experiments, and the *development of theories to describe the results of these activities*
- Many types of science!

Research

- a detailed *study of a subject*, especially in order to discover (new) *information* or reach a (new) *understanding*
- Many ways to do research!

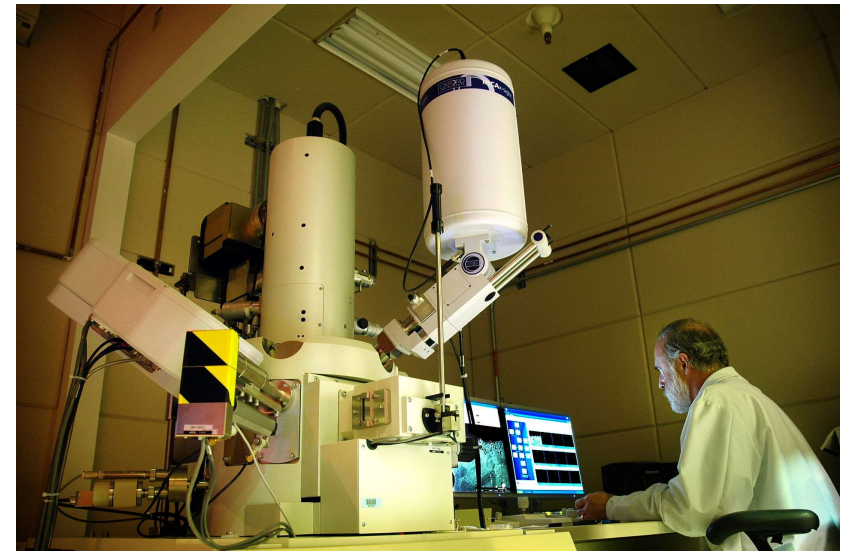
Branches of science

- Natural science
 - Life science, physical science
- Social science
 - Sociology, anthropology, economics, ...
- Formal science
 - Mathematics, theoretical computer science, ...
- Applied science
 - Engineering, medicine, computational science, ...
- Humanities
 - Languages, philosophy, arts, ...
- Interdisciplinary science
 - Cognitive sciences, music technology, ...
- **At IFI we cover several of these!**



Research methods

- Empirical research / non-empirical research
- Basic research / applied research
- Research in different sciences often use different research methods
 - Some methods are valued higher in some fields
- **There is no single “correct” research method in informatics / computer science!**



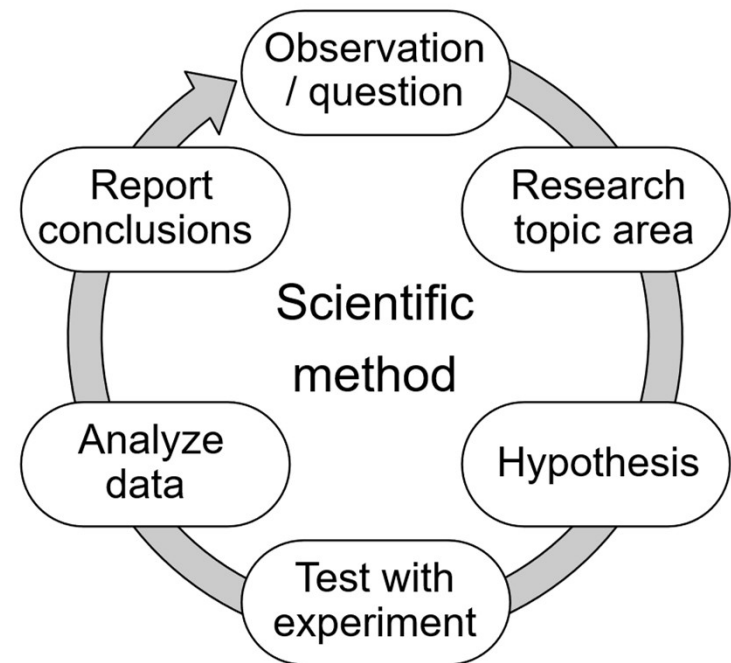
Research method examples

- Natural science
 - Scientific method
- Social science
 - Surveys, interviews, focus groups
- Formal science
 - Prove theorems, develop theories, ...
- Applied science
 - Apply other sciences to improve or find new solutions to problems
 - e.g. engineering and medical
 - Often using some variant of the scientific method
- Humanities
 - Interpretation, aesthetic interpretation, speculative reason
- Interdisciplinary science
 - Mix of the above!



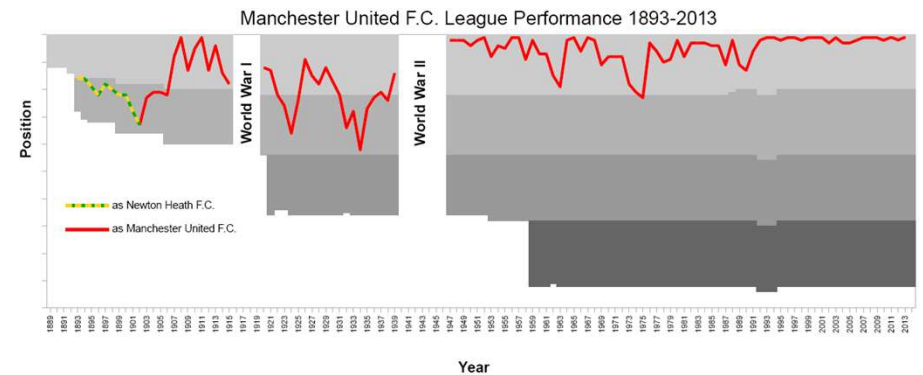
Scientific method

- Aim: Objectively explain events of nature in a reproducible way
- Standard in natural sciences
- Also works in many informatics topics



Quantitative and qualitative

- Quantitative and qualitative approach
 - Quantitative:** working with numerical data and statistical analysis
 - Qualitative:** working with more non-quantitative, oral descriptions and explanations, and interpretations
 - Surprisingly,** both can be applied to subjective as well as objective data
- Empirical and non-empirical
 - Empirical: collecting data
 - Non-empirical: using existing knowledge to gain new insights



Theorem: $2 = 1$.

Proof.

Let $a \neq 0$, and let

Multiply both sides by b :

Subtract a^2 from both sides:

Factor:

Divide by $b - a$:

Now, as $a = b$, we have

Simplify:

As $a \neq 0$, divide by a :

$$b = a$$

$$b^2 = ab$$

$$b^2 - a^2 = ab - a^2$$

$$(b + a)(b - a) = a(b - a)$$

$$b + a = a$$

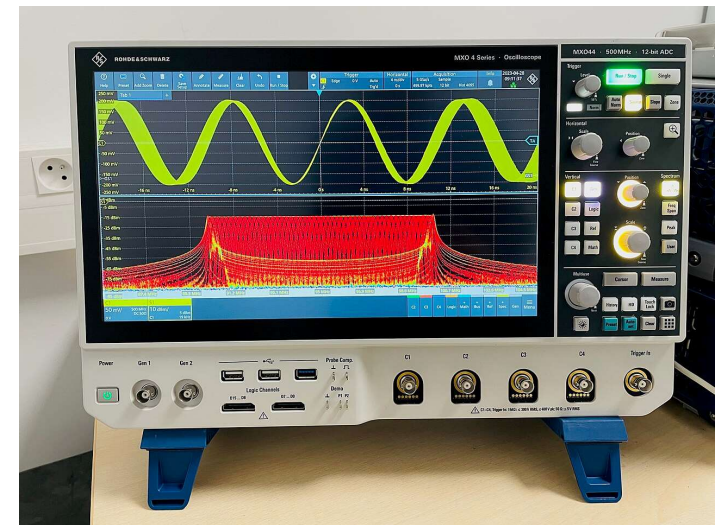
$$a + a = a$$

$$2a = a$$

$$2 = 1$$

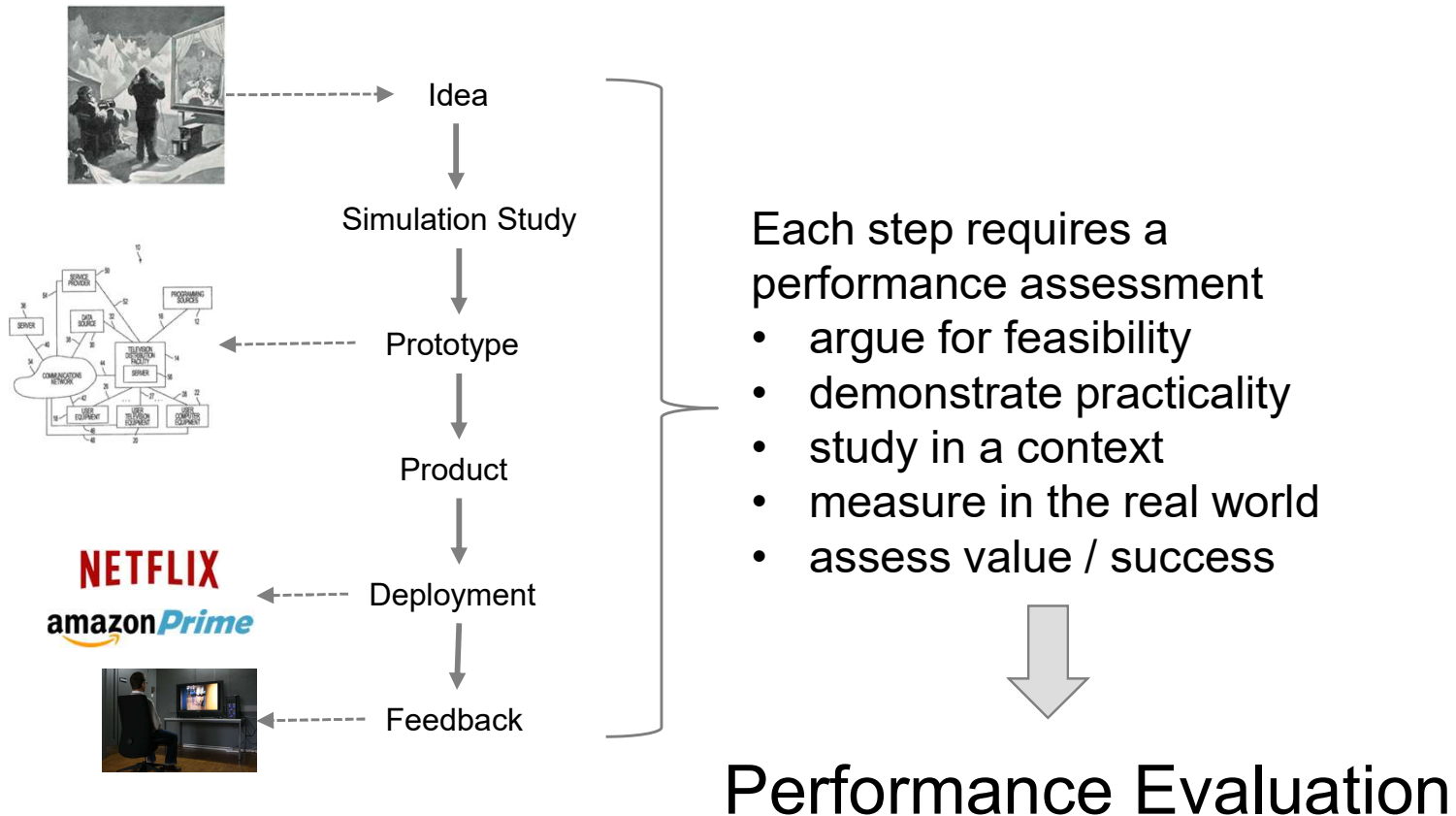
Engineering / systems projects: quantitative focus

- Some kind of system (software, robot, hardware) is designed and implemented
- It would be good to measure the performance of the system
 - To show that the system does what it's supposed to do
 - To compare it to other systems
- Focus is on quantitative methods



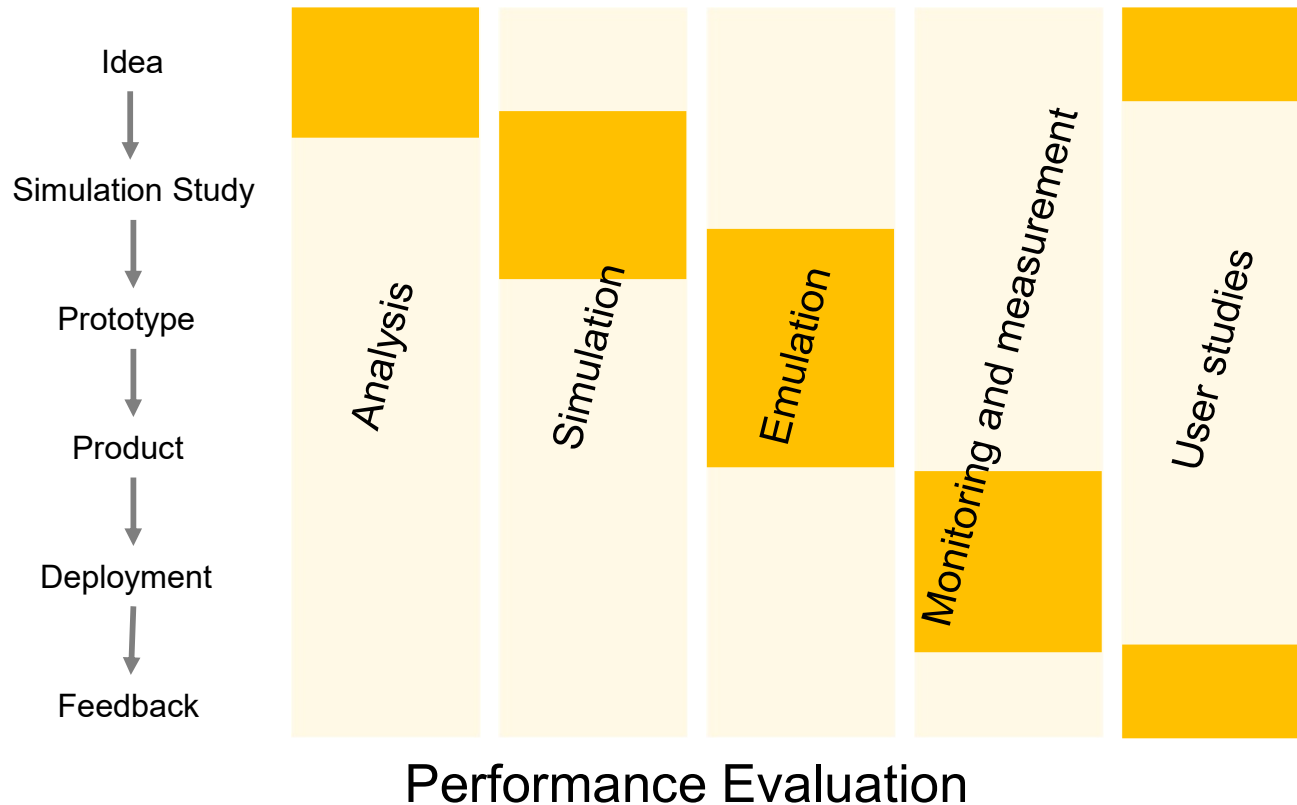
Engineering / systems

Engineers and researchers solve quantifiable challenges

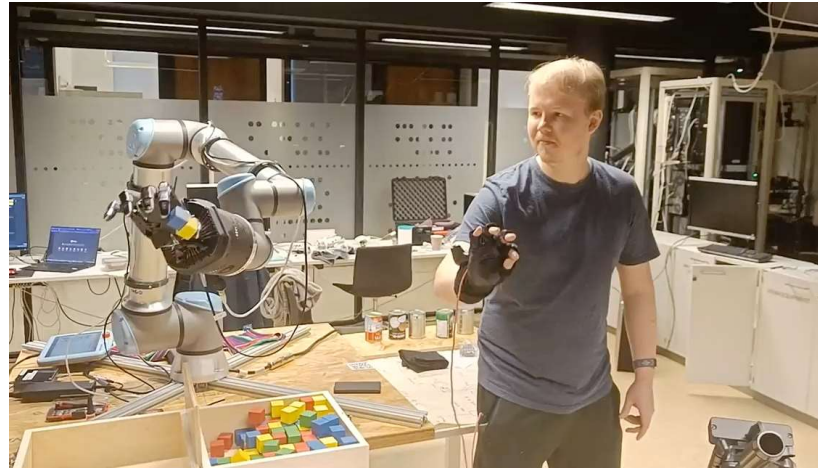


Quantitative Performance Analysis

Engineers and researchers solve quantifiable challenges



Example: engineering and evaluating systems



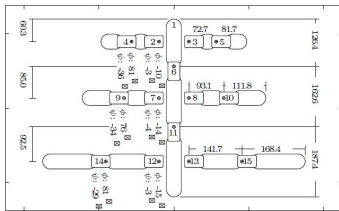
- Topic: *remote presence through the robot arm and hand*
- Project: protocol and services to convert hand pose tracking to joint rotations of the Shadow Hand
 - Use **Internet** transport protocols to design and implement a low-latency **protocol**
 - Use **kinematics** to control arm and hand motion
 - Use **mathematics** to transform coordinate systems
 - Deal with **real-world limitations** of the trackers and robots such as drift and resolution

Example: engineering and evaluating systems



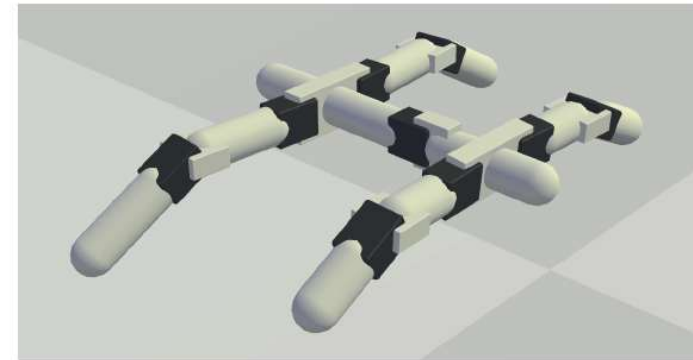
- Topic: *remote presence through the robot arm and hand*
- Project: *motion prediction with EEG support*
 - **Collect data** from direct arm/hand control
 - **Predict** human hand and finger **motion** from tracking information using **machine learning models**
 - **Analyse EEG** data to find a relation between it and human motion
 - Predict motion from combined motion tracking and EEG data

Example theses



Thesis: Lifetime learning in evolutionary robotics

- Algorithm investigation combining global + local search in simulated and real robots
- Develop variants of algorithms, compare performance
- Run algorithm experiments in simulation and test on real-world robot
- Performance: forward movement speed
 - Measured in simulator
 - Measured using motion capture system



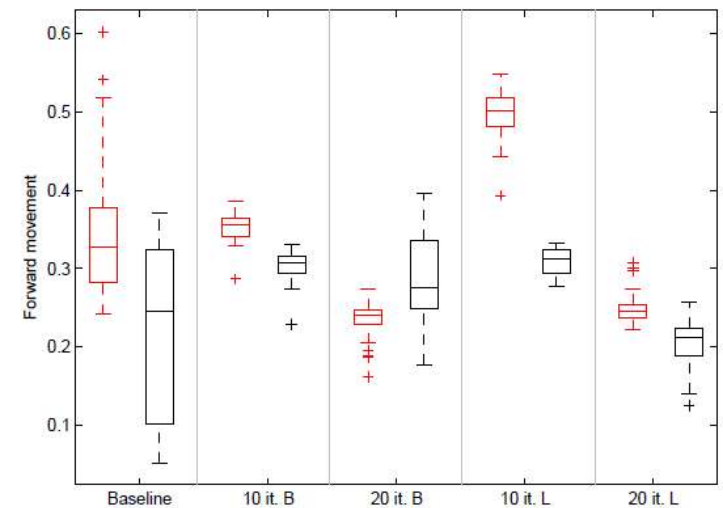
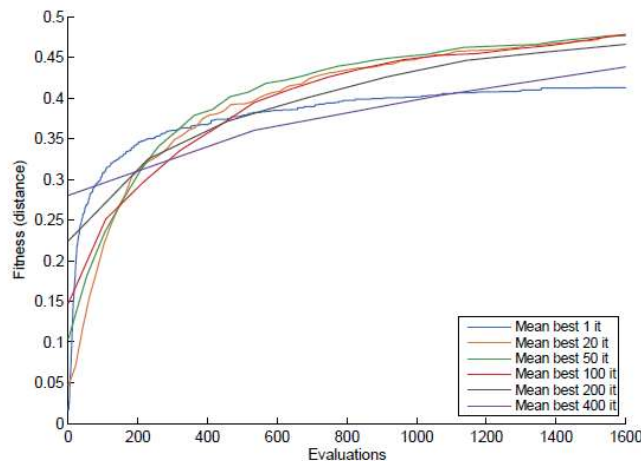
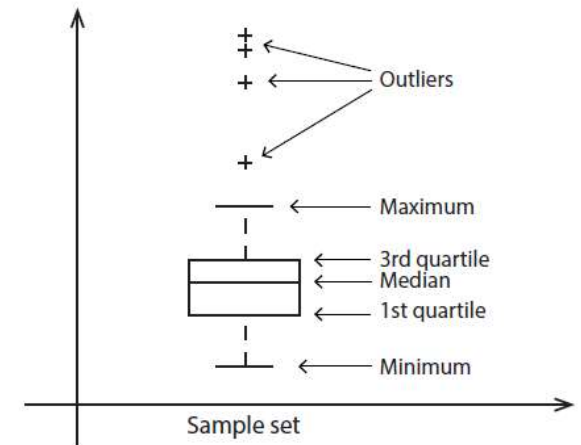
(a) In simulation



(b) The physical robot

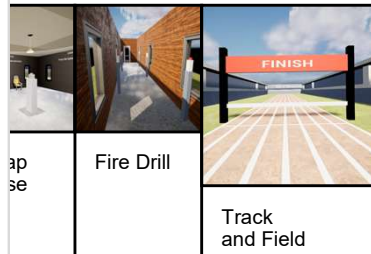
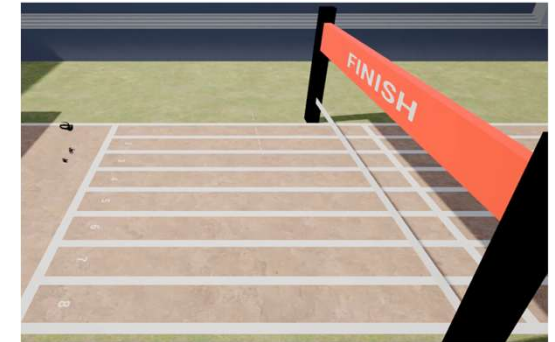
Analysis of results

- Baseline algorithm compared to variants
- Simulation vs. reality
- Multiple “samples” of both simulated and real robot experiments → statistics
 - 30 runs of the algorithms, 30 evaluations of the final results
 - Statistically significant differences?



Thesis: Master of Puppets

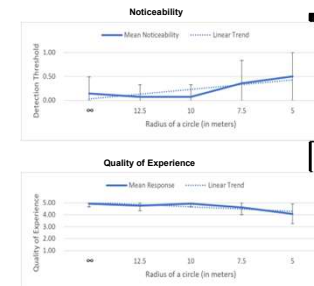
- Redirected walking:
Navigating large virtual worlds by walking in the smaller real-world spaces
 - Curvature gain: rotate coordinate systems while moving
 - Rotation gain: rotate coordinate systems while turning the head
- Evaluate the usability of redirected walking systems
 - How strongly do users perceive redirection?
 - What is their overall quality of experience?



Curvature Gain

- Best for the use of walking a long straight

Our results suggest we can walk the circumference of a circle with radius 7.5 meters



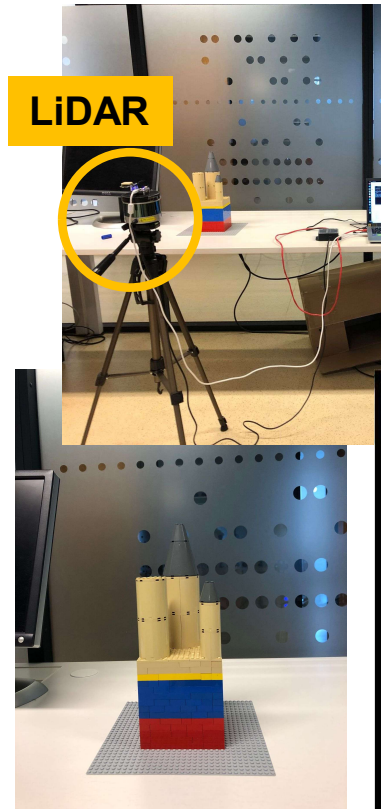
Witches' Cauldron

Dungeon

Thesis: From Laser Scan to RANSAC Primitive Fitting

— RANdom SAmple Consensus

- Laser scanners (LiDAR - Light Detection and Ranging) measure distances with high accuracy
- E.g. in self-driving cars to detect obstacles
- Many people attempt to recognize semantics from points directly
- We want to find primitive geometric forms, and understand what they are later



Plane: approximate normal vectors

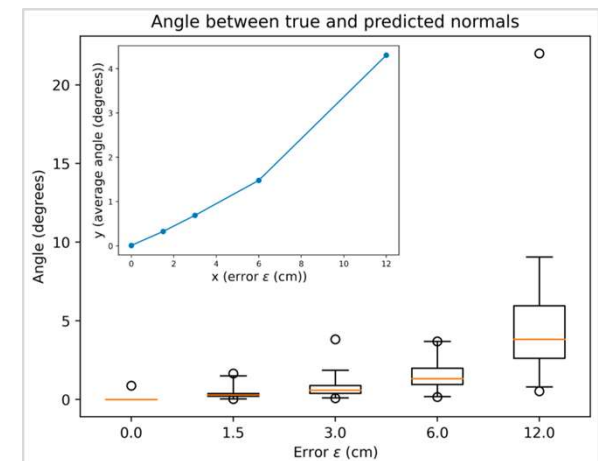
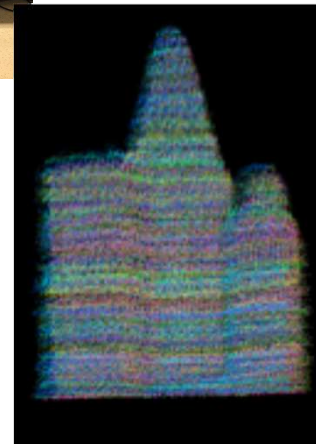
$$\vec{n} = (abc)^T$$

Sphere: approximate center and radius

$$C = \frac{1}{4} \sum_{i=1}^4 p_i \quad r = \frac{1}{4} \sum_{i=1}^4 \|C - p_i\|$$

Cylinders

...



Summary

**There are many
different types of
science and
research methods**

**Quantitative
methods are the
primary
choice when
engineering
systems**

**performance
measures,
simulations,
measurements,
statistics,
comparisons**



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discussion

