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To what extent are robotic experiments experiments? On the utility of looking at the philosophy of science

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To what extent are robotic experiments experiments?

- To answer this question we should have a definition of what an experiment is
- Here's the utility of looking at the philosophy of science (and of experiments in particular)
- What should we learn from it?
  - To acknowledge how problematic is answering this question
  - To draw inspiration from other scientific disciplines for mobile robot localization and mapping
  - To learn dealing with a fallibilist perspective (even in mobile robotics)

What are experiments?

- Not possible a single answer
- Experiment is controlled experience
  - Set of observations and actions, performed in a controlled context, to test a given hypothesis

Observing vs. experimenting

- Observing a drop of water through a microscope is not an experiment
- Observing the same drop through a microscope, after having colored it with a chemical reagent in order to evidence some microorganisms is an experimental procedure
  - Ability to control some of the features of a phenomenon under investigation
  - Purpose of testing the behavior of the drop under some controlled circumstances

Control of experimental factors

- Experiments consist in producing controlled circumstances
- The phenomenon under investigation must be treated as an isolated object
  - It is assumed that other factors not under investigation do not influence the studied relationship
- The choice of experimental factors to be controlled is crucial for any successful experiment

Properties rather than definitions

- Repeatability at different times and in different places to check the universality of experimental results
- Reproducibility by other scientists to confirm that their results are independent of the precise details of the experiments themselves
- Comparability of results of different instances of the same experiments
- Adoption of a precise language to give rigor and precision to experimental data
- Use of precise measurements to quantitatively describe the phenomena under investigation
- ...

Looking at science (and experiments) today

- From science as a unique corpus (basically physics in XVII and XVIII centuries) to specialization in specific scientific disciplines
- Consequent specialization also in the definition of experiments and their purposes
- Philosophers of science do not analyze experimental problems in physics, but in specific fields of physics (i.e. quantum mechanics) and, in some cases, in even more specific subfields (i.e. relational quantum mechanics)

Looking at engineering

- Can we draw useful inspirations for mobile robotics (mobile robot localization and mapping) from all these considerations?
- What if we move from the way experiments are intended in traditional scientific disciplines (physics, biology, …) to robotic disciplines?
- An engineering perspective is required
  - Also without discussing its disciplinary status, robotics has at least an engineering component concerning the design of artificial systems

Experiments from science to engineering

- Good experimental design practices (Montgomery 2005)
  - Experimentation is seen as a process composed of well-defined steps (definition of the goal, choice of the factors to explore, design and execution of the experiment, analysis of data, drawn of conclusions)
  - Experimental methodology appears to be a list of strategies and well-organized resources that can be exploited whenever necessary

Mobile robot localization and mapping

- The analysis of the state of the art of experimental methodology (Amigoni et al. 2009) evidences that a stable experimental methodology is still lacking
  - Even in the engineering sense of a set of strategies for good experimental design practices
  - Do-it-yourself approach

Drawing inspiration (from engineering and science)

- Both the engineering perspective and the scientific one must be taken into account in discussing the problem of experimental methodology in mobile robotic
  - It can be useful to draw inspiration from other fields of computer engineering (i.e. algorithmics) that have already developed a mature discussion on some methodological problems of experiments (Johnson 2002, Barr et al. 1995)
  - Moreover, it is worth stressing that an experimental methodology is more that a set of procedures that, once adopted, lead in a secure way to the expected result (Hacking 1981)

Experimental methodology: very general principles

- Comparison, reproducibility/repeatability, justification/explanation
- Principles deeply rooted in the history of science and in the birth of science as a collective and critical activity
- But also in accordance with other fields of computer engineering with a more mature discussion on experimental methodology going on

Comparison

- To know what has been already done in the past
- To compare new results with the old ones
- Comparison requires
  - Full documentation
  - Sincerity principle (reporting anomalies and negative results that can reveal something important)

Comparison in mobile robotics

- Increasing use of publicly available data sets (Victoria Park (Guivant et al. 2000), RADISH (Howard and Roy 2003), and Rawseeds (2006)) to set a common ground for comparing different systems
- Development of comparable implementations, starting from the description provided in papers and reports (Frese et al. 2005, Minguez et al. 2006) and also from the use of the same code that was used in previous experiments (Stachniss et al. 2007)

Reproducibility / repeatability

- Reproducibility is the possibility to independently verify the results of a given experiment
  - Different experimenters must be able to achieve the same result, by starting from the same initial conditions, by using the same type of instruments, by adopting the same experimental techniques
- Repeatability concerns the fact that a single result is not sufficient to ensure the success of an experiment
  - A successful experiment must be the outcome of a number of trials, performed at different times and places in order to guarantee that the result has not been achieved by chance, but is systematic

Reproducibility / repeatability in mobile robotics

- Implementation of similar experiments that should draw the same conclusions to understand which parameters influence the system (reproducibility) (Grisetti et al. 2007, Frese et al. 2005)
- Distribution of code and/or problem instances (repeatability) (Montemerlo et al. 2003)
- Experimentation increasingly based on results involving several data sets, referring to different kinds of environments (Liu and Thrun 2003, Paz et al. 2008)
- Adoption of standard data sets as benchmarks (Grisetti et al. 2007, Montemerlo et al. 2003)
- Report of anomalies in performance to highlight which issues deserve further study in the future (Grisetti et al. 2007)

Justification / explanation

- Justification deals with drawing justified conclusions on the basis of all the information collected during an experiment
  - It is necessary to collect, explain, and interpret data to derive the correct implications
  - Experiments are difficult to interpret and may not always give clear-cut results
- So why scientists have a reasonable belief in experiments?
  - Hacking (1983) proposes a number of strategies for believing in experiments

Pool of strategies

- They provide good reasons for believing in experimental results …
  - Observation of the predicted effect in a phenomenon
  - Collection of the same data by different instruments
  - Capability of the experimental apparatus to reproduce known phenomena
  - Reproduction of artifacts known in advance
  - Elimination of alternative explanations of the results
  - Use of an independent corroborated theory to explain the results
  - Use of an apparatus based on a well-corroborated theory
  - …
- … even if they do not guarantee that the results are always correct
- Experiments are fallible: this does mean it is impossible to reach well-justified conclusions, but that these conclusions are not guarantee once for all

Justification / explanation in mobile robotics

- Use of several data sets to derive well-justified conclusions (Frese et al. 2005, Liu and Thrun 2003, Paz et al. 2008)
- The correct behavior of a localization or mapping system is verified according to ground truth or visual inspection
- But how to rigorously demonstrate that a system works on instances for which ground truth is not available?
- This problem is related to the difficulty of generalizing the results obtained in an environment to other ones
- May be the strategies proposed by Hacking can help in further reasoning on this problem ...

To what extent are robotic experiments experiments?

- Robotics experiments share several properties with scientific experiments, even if their purposes are different
- To move toward a more stable experimental methodology in mobile robot localization and mapping, we consider relevant to discuss the following open issues
  - The union of experimental activities considered in mobile robot localization and mapping covers the three principles presented, but their intersection is almost a null set
  - A mobile robot is a complex system in which the relationships among their components and their impact on experiments require further consideration
  - The requirements for publishing in conferences and journals should be reconsidered to include also negative results