Practical and Theoretical Motivations for Replication of Experiments in Robotics: The complementary roles of benchmarks, challenges and competitions

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Euron GEM Sig IEEE RAS TC-PEBRAS

- 'Look Ma, No Hands' sindrome?
- Replication of experiments
- Performance measure benchmarks to allow results comparison
- Needed to foster research advancement and enable practical application of research achievements

Both replication and benchmarking are needed to foster a cumulative advancement of our knowledge of intelligent physical agents and even to correctly appreciate disruptive innovation in the science (?) and technology of robots.

Should we take inspiration from biology and medicine ?

If robotics aims to be serious science, serious attention must be paid to experimental method.

What is an 'experiment' in robotics?

The complementary roles of benchmarks, challenges and competitions

Replication&Falsification

There are different modulation of this concept, but whether we think we are in a cumulative phase in the development of a scientific field or in presence of a 'disruptive' creative paradigm shift, as somebody is claiming in nowadays robotics, a kind of widely accepted experimental methodlogy is needed in order to be able to ground the advancement of research on a shared quantitative language.

Replication&Falsification

It seems clear that in robotics the experimental methodology standards are currently in many cases weaker, and the sindrome 'it worked once, in my lab' could be more widespread than we may think.

Replication&Falsification

A limit to replication is given by the huge variability of robot machines.
Perhaps, following the biomedical analogy, we have to compare behaviors and performances of different 'animals'.

What about similar issues in Biology?

The definition of what should be considered a 'law of nature' in biology raises a number of issues. For reasons not very different from those raised from robotics research. The laws are usually not universal but apply to specific species: the Mendel laws apply to species with sexual reproduction, but not to all living species.
Almost every theoretical enunciate refer to a species or a set of species and has stochastic characteristics.

What about similar issues in Biology?

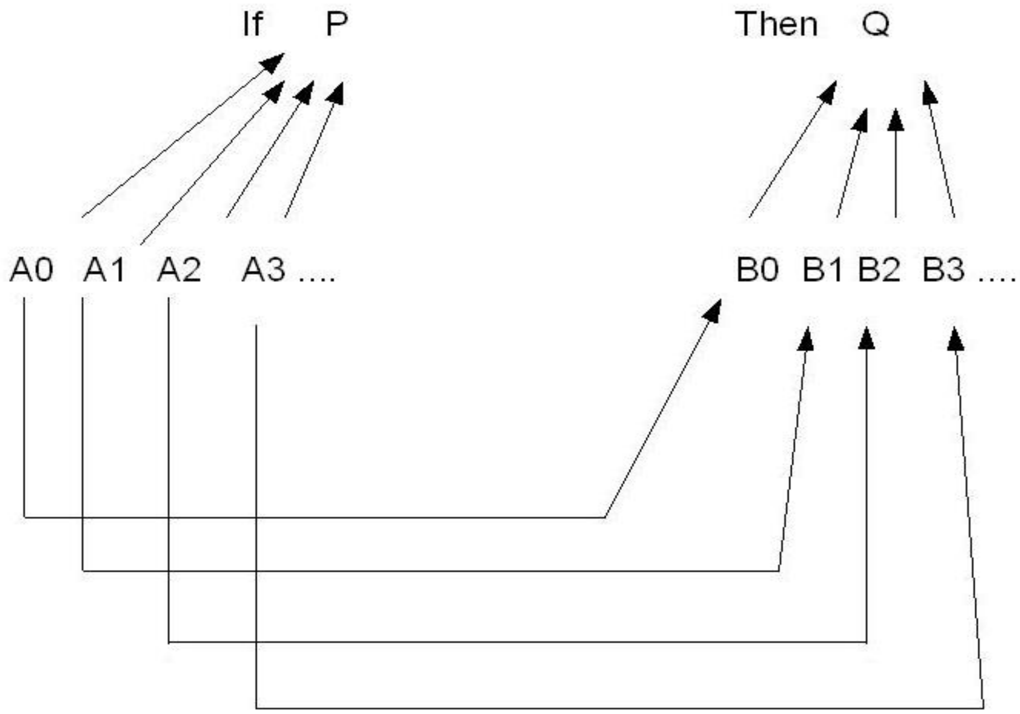
Systems are usually very complex, involve a huge numbers of variable and work in open ended stochastic environments. The same function, for example flight, can be performed in many different ways. The wing morphology and dynamics of a fly are quite different from those of a bird. On an other end, the wing of a penguin are used to stabilize swimming.

An interesting point is that the laws regarding a specific function in a species become true at a specific time, as a new function evolve, as depicted afterwards., and only if some initial conditions occur.

I	→	If P	then Q
t_0		t_1	t_2

Time dependence of biological 'laws'

The complementary roles of benchmarks, challenges and competitions



'Causality at different levels'.

The complementary roles of benchmarks, challenges and competitions

L1, L2, L3, ..., Ln — covering laws

C1, C2, ..., Cn — initial conditions

(explanans)

E — explanandum

Hempel-Oppenheim Schema

The complementary roles of benchmarks, challenges and competitions

Discussion
A new kind of papers?

Replication of robotics experiments

- Research Reporting in Biology and Medicine
- Evidence Based Medicine
- Early activities in robotics research replication

Discussion

The bare replication of experiments and the quantitative comparison of research results in robotics raise many challenging issues.
This is due to the variety of applications, tasks, mechanical structures, sensor sets, actuators, control system, software architectures, required levels of flexibility and autonomy, and so on.

Discussion

It is thought that in both these situations the epistemological model based on 'context' discussed above for biology and extended to robotics may provide a working framework.

Discussion
A new kind of papers?

We may think of theoretical/concept papers, proof of concept papers, and experimental papers , as we have started to define here, as steps in a research idea 'life-cycle'. We believe that more paper of the 'experimental' kind would greatly help the research activities in robotics and the industrial exploitation of the results.

Discussion
A new kind of papers?

- 'description' : a journal paper text+figures+ multimedia ….according to GEM Guidelines (or similar)

- Data sets (similar to IJRR 'Data paper'

- Complete 'code' identifiers and or downloadable code (executables may be enough)

- 'HW' description or HW identifier (if it is identifiable)

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It is not ‘theory’ it is ‘practice’

The complementary roles of benchmarks, challenges and competitions

The humble practitioner's standpoint

After years of activities ‘something’ is now possible!

The complementary roles of benchmarks, challenges and competitions

But this is not enough!

We need challenges

The complementary roles of benchmarks, challenges and competitions

We need competitions

The complementary roles of benchmarks, challenges and competitions

Also a new kind of competitions

If ‘cognition’ is important

More than everything …

we need a virtuous loop with an organized intertwined process:

-Benchmarks

-Challenges

-Competitions (including 'new kind' ones!)

The complementary roles of benchmarks, challenges and competitions

Sharing the information for making 'experiments' 'repeatable'

It is an urgent un-escapable practical need for research and exploitation

It is mandatory for the new science of sentient machines, simplexionics , morphological computation

Further information:

http://www.heronrobots.com/EuronGEMSig/

http://www.robot.uji.es/EURON/en/index.htm

http://www.nist.gov/el/isd/permis2012.cfm

http://www.eucognition.org/index.php?page=challenges

http://www.robocup.org

http://www.robotcompanions.eu/

Thank you!

Visual servoing example

Visual servoing control the movement of robot (video assisted mobile robots or manipulators) on the basis of feedback coming from a video device, like a video camera.

This example is relevant because formal proof are very difficult if not impossible in many if not most cases, as a consequence experimental work is necessary to assess the potential of different approaches to control.

Visual servoing example
Assumptions

For a visual servoing systems there typical which must be detailed. A non exhaustive list is given here:

- the visual features
- scene 3D model
- the kinematics model of the robot.
- dynamics model of the robot.

Visual servoing example
Assumptions

Plus the list related to image processing:

- background characteristics (homogeneous or if not color and luminance distributions)
- lighting conditions
- robustness to outliers in feature detection
- others inherent to real life experimentation.

Visual servoing example
Performance criteria

Generally speaking these criteria measure the convergence of the system to a predefined goal.

Non exhaustive list:

- the time of convergence
- the trajectories of the visual features in the image plane
- the 3D trajectory of the robot computation time
- positioning error after convergence.

A special attention must be paid to stability and robustness against image noise, the errors in the models (object, camera, robot), and the control parameters.

Visual servoing example
Measured characteristics

An unequivocal procedure to derive the quantitative aspects of the system must be given. For example visual features can be directly obtained from the video camera.

For manipulators what is directly measurable are the generalized joint angles while the end effector 3D trajectory must be estimated by the (direct) kinematic model.

Calibration procedures for the robot relevant characteristics and camera must be described.

In experiments the visual features (at least) must be variated and the variation policy documented.

Visual servoing example Implementation Information

The information given above don't allow by themselves the replication of results.

There more data needs than in other kind of papers:

- Visual servoing system configuration environment (either real or simulation) should be described in detail: in-hand vs. external camera, etc.
- model and control parameters
- ground truth for robot positioning and the environment

Visual servoing example Implementation Information

- Technical specification of the hardware platform
- Technical specifications of the camera (model, frame rate, resolution, etc.).
- Computer specifications (at least, processor and amount of memory, o.s., relevant configuration details)
- sw libraries (they should be available at least as linkable components) list and configuration

Probably the adoption of widely known sw libraries like ViSP, VXL, OpenCV may ease replication.

Visual servoing example
Parameter and variable distribution

Statistical distributions of all relevant parameter must be given (as in an open ended stochastic environment results will have a probabilistic formulation). This is by the way quite common in clinical research (as noticed before)

Visual servoing example
Parameter and variable distribution

The list of findings in the discussion/conclusion section should be against a detailed list of criteria within a detailed list of conditions as recalled above.

For example better convergence speed, robustness /weakness against certain parameters, behavior with respect to current technology visual servoing systems:

- visual features moving of the field of view
- workspace and singularity issues

The findings listed in a paper might be negative: the given algorithm in our test conditions fail under the listed set of conditions with respect to the listed series of criteria.

Discussion

Why we need both replication AND benchmarking?

FACT: Benchmarking is more studied than Replication (with caution ☺)

- SLAM
- Mobile Robots' Motion Control
- Robot Obstacle Avoidance
- Grasping
- Visual Servoing
- Autonomy/Cognitive tasks

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