On the non-phenomenological use of the word ‘behaviour’ in adaptive behaviour and robotics research

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1 The two meanings of ‘behaviour’

Since Simon[1] and Brooks[2], robotics researchers have understood that the behaviour of a robot system is a function of the structure and dynamics of its physical construction, the environment in which it finds itself, and its internal control system.

Simultaneous with the growth in popularity of this view there has been an increasing use of the word ‘behaviour’ to refer to non-phenomenological objects. It is now common to refer to a subroutine in a robot controller as a ‘behaviour’, the word designating a set of instructions rather than the outcome of those instructions as they are executed. We believe that behaviour-as-subroutine is an unhelpful word, because it implies that the subroutine is the entire cause of the robot’s visible, external actions. It confuses the subroutine with the observable behaviour of the system. This is in conflict with the most important ideas behind adaptive systems, behaviour-based robotics and ethology, in which behaviour is considered the result of coupled interaction between active controller components, physical construction and environment.

This paper presents some examples and a simple experiment to show that the two meanings of ‘behaviour’ are distinct and incompatible. We suggest that the non-phenomenological use of the word ‘behaviour’ is an unhelpful mistake and assert the usefulness of the classical meaning.

1.1 Behaviour-as-phenomenon

The English word ‘behaviour’ is thus defined in the Oxford English Dictionary (abbreviated for space):

1. Manner of conducting oneself in the external relations of life; demeanour, deportment, bearing, manners.
2. transf. The manner in which a thing acts under specified conditions or circumstances, or in relation to other things.
3. attrib. and Comb., esp. in Psychol., as behaviour-cycle, data, -study, -system, -trend; behaviour pattern, a set or series of acts regarded as a unified whole

No alternative technical definition is provided in standard texts on animal behaviour, e.g. [3]. “Adaptive Behaviour” is a specific class of behaviour, i.e. that which enhances reproductive success in animals.

1.2 Behaviour-as-subroutine

The earliest known use of behaviour-as-subroutine is by Payton in 1986, in discussing a robot controller architecture:

> Each expert sub-module of the reflexive planning module [...] is divided into two distinct elements: a perceptual component called a ‘virtual sensor’ and an action component called a ‘reflexive behavior’ or a ‘behavior’. [...] The abstracted data is then fed into the reflexive behavior which evokes vehicle control commands based on this data. Under normal circumstances, several virtual sensors and reflexive behaviors are operating asynchronously and in parallel.[3]

Payton uses ‘behaviour’ in a way which is incompatible with behaviour-as-phenomenon, which can not have data fed into it, nor can multiple instances operate simultaneously in one agent.

Nicolescu and Mataric provide a representative use of behaviour-as-subroutine:

> [B]ehaviors are built from two components: one related to perception (Abstract behavior), the other to actions (Primitive behavior). The abstract behavior is simply an explicit specification of the behavior’s activation conditions (i.e., preconditions), and its effects (i.e., postconditions).[4]

Here "abstract behaviors" are logical entities involved in action selection that do not themselves produce any observable effects on the world. 'Abstract behaviour-as-phenomenon' would be an oxymoron, while 'abstract behaviour-as-subroutine' is perfectly reasonable.

2 The problem

While Payton and Mataric explicitly invoke Brooks' ideas on the decomposition of controllers, Brooks himself appears to have never used the word behaviour-as-subroutine. This linguistic difference may hint at the later authors' misinterpretation of Brooks approach. Brooks' robots tend not to execute sequences of discrete, goal-seeking programs; rather their layered modules are often simultaneously active, with the activity of several modules contributing to the behaviour-as-phenomenon of the robot [2].

It is common for words to aquire new meanings, and multiple meanings of the same word may not cause confusion in small communities, where the intended meaning is clear from context. It could be argued that this is the case here. But behaviour-as-subroutine has a specific problem for the adaptive behaviour community, illustrated by the following examples.

Alice programs her robot with a behaviour-as-subroutine she labels *chase Venusian*. But as her robot's environment never contains a Venusian, Alice's robot never exhibits Venusian-chasing behaviour. Bob's robot controller contains a behaviour-as-subroutine labeled *follow wall*. Due to a programming error, when *follow wall* runs, the robot is observed to spin on the spot and emit smoke. Clive's version of *follow wall* is error-free, but as his robot has a broken wheel motor, it does not exhibit wall-following behaviour.

We devised an experiment to further examine the meanings of 'behaviour' in a robot system. Bastani and Vaughan programmed two Pioneer robots to perform a series of interactions intended to resemble an animal courtship ritual, in which a 'male' robot locates a green ball and leads the 'female' robot to it. The robots were programmed in the behaviour-based paradigm, with subroutines intended to produce specific behaviour at run time; *approach green objects, go home*, etc. The robots are shown in Figures 1 & 2; details are omitted here for lack of space, but will appear in a complete version of this paper.

Ethologists Hutchison and Hutchison, experts in animal courtship behaviour but completely naive roboticists, were asked to observe the robot system for as long as they wished and answer the question "What is the behaviour of the robots?". The resulting description, or 'ethogram', resembled the robot's control program in some respects, for example identifying a 'go home' behaviour, but differed in others. In particular, the biologists identified a 'kissing' behaviour, where the robots would repeatedly approach each other's noses. As far as the programmers were concerned, this behaviour was the undesirable result of imperfect visual sensing and hysteresis in the robots' motor controllers. There was no 'kissing behaviour-as-subroutine', or anything like one, in the robot's control program or in the heads of the programmers, but there unquestionably was a 'kissing behaviour-as-phenomenon'. The robots were also described as showing 'male' and 'female' behaviour, matching the intention of the programmers, despite the control programs containing no representation of the concepts of 'male' or 'female'.

As these examples show, any implemented subroutine is at most only partly responsible for a robot's behaviour, and may well produce no behaviour at all. Use of behaviour-as-subroutine encourages us to mentally decouple the controller code from the conventional behaviour, ascribe primacy and causality to the subroutine, and to forget some of the most important philosophical and practical contributions of adaptive behaviour research, particularly as it contrasts with conventional AI research. It is a strange irony that adaptive behaviour researchers should thus abuse part of their own name.

References

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[3] David McFarland, Dictionary of Animal Behaviour, Oxford University Press, 2006.
[4] David Payton, An Architecture For Reflexive Autonomous Vehicle Control, Proc. IEEE Int. Conf. Robotics and Automation, San Francisco, CA, USA, 1986.
[5] Monica Nicolescu and Maja Mataric, Linking Perception and Action in a Control Architecture for Human-Robot Domains, Proc., Thirty-Sixth Hawaii Int. Conf. System Sciences, Hawaii, USA, 2003.

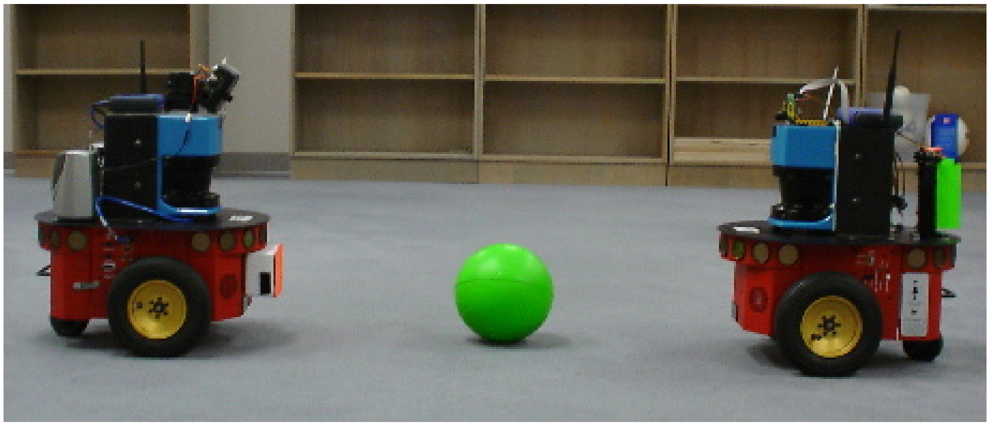

Figure 1: Pioneer 3-DX robots Priss & Roy with green football in their laboratory environment

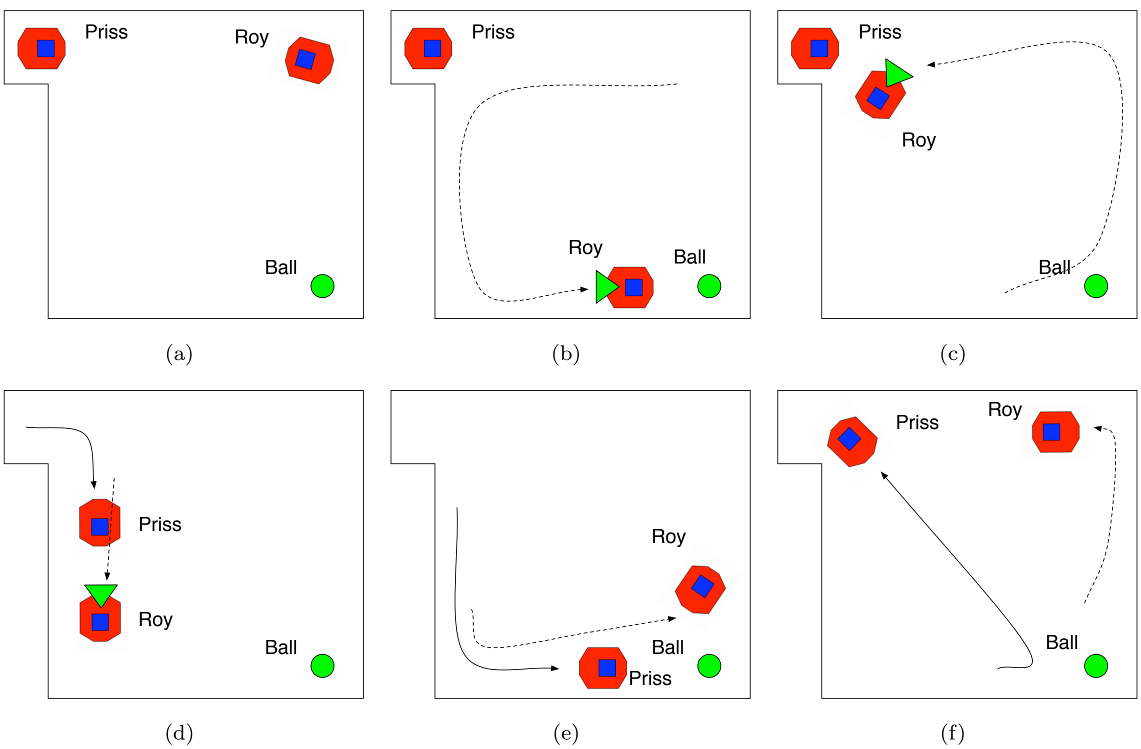

Figure 2: Schematic of the trajectories executed by Priss & Roy in a typical run (not to scale).