Active balance may emerge from homeostatic adaptation to natal change of medium

N.M Wilkinson
University of Sussex
Department of Informatics
Brighton BN1 9QJ UK
nmw20@sussex.ac.uk

Abstract

Active balance is a major domain of investigation in robotics, with relevance to both the engineering of robust tools and the scientific understanding of animal behaviour. This theoretical paper concentrates on 'motivational' or heuristic aspects of how to generate and guide activity towards the particular physical behaviours we recognise as getting up and balancing. I suggest that reliable development of both 'getting up' and balancing behaviour may be structured by the adaptation of prenatal behavioural preferences to the natal change of containing medium. Further to this, I suggest that manipulation of medium may find application as a developmental tool in epigenetic robotics. The implication of these proposals is that robot balancers may gain significant advantage from 'prenatal' motor development in fluid suspension.

1. The importance of medium

The specific hypothesis outlined in this paper arises from a general interest in the developmental relevance of containing medium, and the effects of manipulation of medium. In land animals, prenatal development occurs in fluid, and postnatal in air. Considering the agent-environment as coupled dynamical systems, qualities of the containing medium may be identified as relevant control parameters for agent activity. Wave transmission qualities, density, chemical composition etc will all affect the nature of existence for the contained agent. Thus a change of medium implies change of significant control parameters; and hence change in an agent's conditions of being. Therefore it seems pertinent to ask the question; what will be the behavioural expression of a self-regulating system attempting to maintain or recover internal stability in the face of a change of medium? Here I concentrate on the effects of relative density, and in particular on buoyancy.

Relative density of agent and medium will control the agents buoyancy. A developing agent immersed in a fluid medium of similar density to itself will experience and get to know its own body in (approximately) neutral buoyancy. A medium which supports the agents body should greatly simplify and facilitate this process. The sensorimotor skills the agent learns during this period, for example co-ordinated rhythmic stepping ((Robinson and Kleven, 2005) investigate prenatal stepping in rats), will stabilise over time with respect to current and ongoing control parameters. Stability will depend to a greater or lesser extent on the relevant parameter settings. For example, in fluid suspension an agent is able to step freely without supporting its own body weight. In air, it is not. The only way (other than disappearing) for the sensorimotor activity underlying free stepping to stabilise is through structural coupling with a substrate.

The development of patterns of activity stable in neutral buoyancy may provide sensorimotor invariants to structure plastic change such that, when placed in air, the system only regains stability by resisting the effects of negative buoyancy. The behavioural expression of this adaptation may turn out to be getting up off the floor and balancing. Or equally of lying on the back and kicking, depending on contextual circumstances. Resisting negative buoyancy whilst doing co-ordinated rhythmic stepping seems a reasonable, if abstract, description of balanced walking. Thus manipulation of medium, coupled with conservative homeostasis and appropriate mechanisms of plasticity, may generate heuristic constraints which direct the developing system towards learning balancing behaviour.

One of the reasons manipulation of medium is interesting as a motor development tool is that, because it literally contains the body, it offers a way to generate and perturb whole-body, Gestalt sensorimotor invariants. This presents opportunities for bodily integration and self-identification through ongoing adaptation, structured by a whole-body 'goal';

internal stability in the face of change of medium.

In some sense, medium may be regarded as a form of 'innate' developmental scaffolding. Just as the support of a conspecific can bootstrap the ontogeny of skilled motor activities, so the support afforded by containing medium may do the same. The development and entrenchment of co-ordinated rhythmic stepping, for example, will be facilitated by nearly neutral buoyancy. The implication is that fluid suspension/neutral buoyancy during initial motor development may be a contingency well worth affording robots. It is worth noting that manipulation of medium is widely used to scaffold the re-learning of walking in accident victims. The hypothesis outlined here can be distilled into the observation that nature uses the same trick for learning walking in the first place.

2. Active balance may emerge from homeostatic adaptation to change of medium

How might a self-organising developmental system, as opposed to a designer specified system, enact the classification of falling as bad and balancing as good? How can value be grounded in sensorimotor experience?

As (Di Paolo, 2003) carefully argues, closure of the sensorimotor loop is necessary but not sufficient to develop goal oriented agents. Success or failure to exhibit 'adaptive behaviour' does not affect the natural viability or state of the agent in any concrete sense. The phototaxic behaviour of a Braitenberg vehicle may be understood simply as movement, rather than as action; the light is not a goal in any autonomous sense. If we swap the light sensors of a Braitenberg vehicle that 'loves' light, it will act just like a vehicle that 'fears' light. The goal of phototaxis is ephemeral, a consequence not a cause of the agents ongoing internal organisation.

Whilst identifying survival, or continuation of an autopoietic core, as the 'mother of all values', Di Paolo also suggests a compromise which does not require robots to metabolise and self-create. Rather than giving robots a life, it may be enough to give them a 'way of life'. This is identified with the development (and perturbation) of habitual behavioural preferences.

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‘Habits, as self-sustaining dynamic
structures, underly the generation
of behaviour and so it is them that
are challenged when behaviour is
perturbed.  An interesting hypothesis
is that often when adaptation occurs
in the animal world this is not
because organismic survival is
challenged directly but because the
circular process generating a habit
is.’
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(Di Paolo, 2003)

Di Paolo's robotic models (Di Paolo, 2000) have demonstrated homeostatic adaptation to radical sensorimotor disruption such as reversal of eye position, in experiments reminiscent of Kohlers experiments with goggles ((Kohler, 1962)). In the test phase, the robots light sensors were reversed. Some lineages could adapt their internal organisation to this disturbance and regain phototaxis. This makes phototaxis seem more like a goal (if an arbitrary one) in the strong sense, because it is robust to sensory disturbance, unlike the Braitenberg vehicle where phototaxis can be reversed by swopping sensors. Here phototaxis is both cause and consequence of the agents ongoing internal organisation. A goal such as the recovery of free stepping in negative buoyancy could occupy a similar role.

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