Active Perception and Braitenberg Vehicles

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Abstract

Braitenberg Vehicles were originally a thought experiment, conceived by Valentino Braitenberg, with the aim of studying the most simple of artificial creatures and their reactive behaviours. Watching these machines select behaviours based on interactions with their environments and their reasons behind such selection forms the basis of active perception, an idea this paper aims to explore further in the context of Braitenberg Vehicles and more.

Keywords— Braitenberg Vehicles, Active Perception

1 Introduction

This paper looks at four of the Braitenberg Vehicles in particular, along with a comparison of behavioral strategies between one and two-eyed photo-taxis creatures and the complex behaviours these seemingly simple machines exhibit. These robotic vehicles can create a ”real life” test model for animal behaviour (Holland & McFarland, 2001); By drawing similarities between these synthetic creatures and those of the animal world one can interpret an animal's behaviours in terms of computing machinery and apply psychological language to describe such events (Braitenberg, 1986). When we consider the taxes of an organism, synthetic or otherwise, we can view those stimuli in the environment as an enhancement of that space for the organism's growth. Even if not immediately apparent how, an autonomous selection of certain aspects of available information may later prove relevant for rich behaviour (Floreano & Mondada, 1994). Active perception can explain this as an organism selecting its behaviours through its sampling of the environment and that through the organism's senses, a perception of that environment is made with those actions or behaviours as the building blocks (Gibson, 1983).

2 The Braitenberg Vehicles

Each of our four vehicles are equipped with a pair of sensors, to detect changes in the physical environment, and a pair of motors, to facilitate movement as a response to the environmental changes. These vehicles demonstrate photo-taxis, which is positive or negative displacement along a light gradient (Jackely, 2009). It follows that our stimulus is then a light source although it could have just as easily been heat, and the vehicles equipped with heat sensors, but this is inline with the original paper and a common form of taxes. Their motion itself is to model animal behaviour, the wheels abstracting locomotion and holding directional control. In this way they mimic forward moving animals, restricted by their non-holonomic constraints of motion (Arechavaleta, Laumond, Hicheur, & Berthoz, 2008).

2.1 The Coward - Vehicle 2a

The coward vehicle, shown in Figure 1, is made up of ipsilateral connections and has the behaviour of positive photo-taxis. There is no bias present on either side of its connections also.

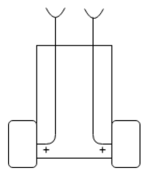
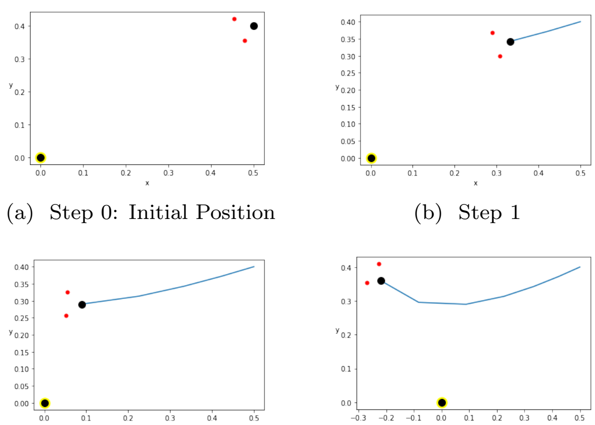


Figure 1: The Coward Vehicle

This vehicle is named the coward as it tries to spend most its time in places where its stimulus is not. In absolute darkness this vehicle will come to a halt and in presence of light it will speed up in an attempt to get away.



(a) Step 0: Initial Position (b) Step 1

(c) Step 2 (d) Step 3: Final Position

Figure 2: The movement of Vehicle 2a over a Set Time Step.

Figure 2 shows the motion of this cowardly vehicle - as it gets closer to the source the intensity of the stimulus increases and so does the velocity of the vehicle. The resulting behaviour is the so called fear as Braitenberg puts it. If the vehicle is placed on a direct collision course with its stimulus, and ignoring resistive forces such as friction, the coward will move straight towards the source, acting on its inputs it may see that route as its best means of escape back to its not so stimulating environment (Figure 3).

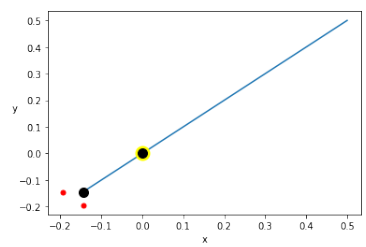


Figure 3: The Coward Vehicle Moving Through the Source

2.2 The Aggressor - Vehicle 2b

The aggressor vehicle follows the same link increasing the connection between perception and action (Rano, 2012) as its fearful counterpart, as denoted by the positive sign on its motors as seen in Figures 3,4. Its connections however, are contralateral meaning the left sensor links to the right motor and vice versa.

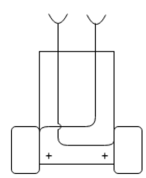


Figure 4: The Aggressor Vehicle

The wheel corresponding to the opposite of the highest stimulating side will turn faster meaning that in the presence of light, Vehicle 2b will turn towards the source and eventually try and hit it. Much like the the fearful behaviour shown by Vehicle 2a if pointed at the source it charge head on towards it (Figure 5).

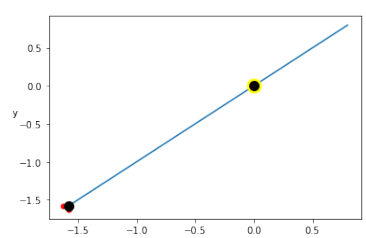
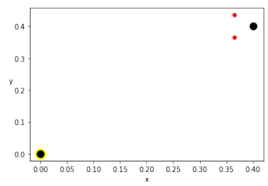
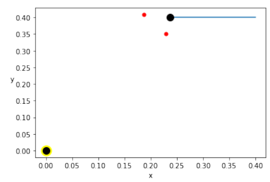


Figure 5: The Aggressor Vehicle

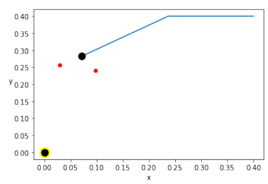
Figure 6 shows this more aggressive behaviour and as Braitenberg puts it, its inescapable fate of colliding once in close proximity of the stimulus. The behaviours of these type 2 vehicles are similar in the sense that they both dislike their respective stimuli. However, the coward will try its best to avoid the source unless the only means of escape is passing directly through whereas the aggressor will charge at high speeds the closer it gets as if to destroy the source. Unsurprisingly this behaviour was seen as aggressive and gave 2b the aggressor name.



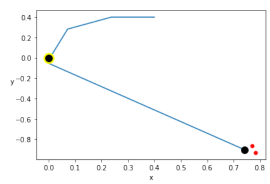
(a) Step 0: Initial Position



(b) Step 1



(c) Step 2



(d) Step 3: Charged Through Source

Figure 6: The movement of Vehicle 2b over a Set Time Step.

2.3 The Lover - Vehicle 3a

Whilst animalistic traits can be applied to the previous two vehicles, Braitenberg saw there behaviour as crude and that these synthetic vehicles should also know soothing and be able to relax in the presence of a stimulus rather than only ever be agitated by it. If we keep the same positions of the motors on the vehicle body and the same lateral/contralateral links to the sensors but reverse the sign of influence from positive to negative, new behaviours can be observed.

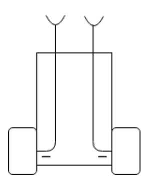
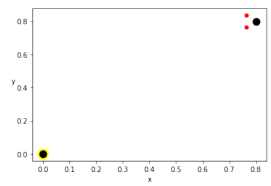
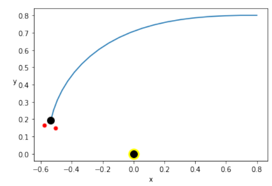


Figure 7: The Lover Vehicle

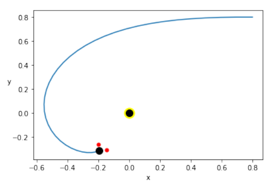
In a similar set up to Vehicle 2a, Vehicle 3a's sensors will now have an inhibitory effect on the motors. This vehicle will speed up in places of little stimulus and slow down when in the vicinity of the source.



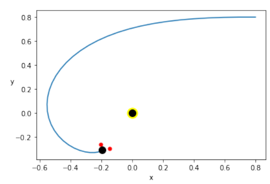
(a) Step 0: Initial Position



(b) Step 1



(c) Step 2: Having come to a halt



(d) Step 3: Final Position: Admiration

Figure 8: The movement of Vehicle 3a over a Set Time Step.

As we can see in Figure 8 Vehicle 3a comes to a halt when close to the light source. To summarize this behaviour one could say it rushed to find its stimulus and then came to an eternal rest, in open admiration of the discovered stimulus. This earned Vehicle 3a the title of the Lover.

2.4 The Explorer - Vehicle 3b

With contralateral connections (Figure 9) this vehicle will still slow down when close to the source but if it comes to rest will be pointing away from the source.

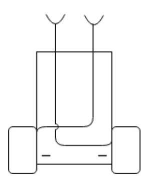
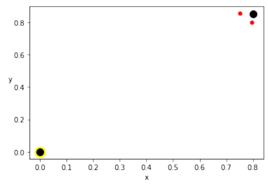
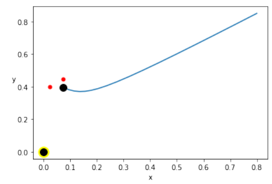


Figure 9: The Explorer Vehicle

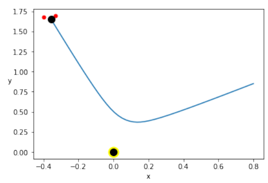
This vehicle might not stay for very long at the source - with the introduction of a bias weight on the motors (in place of environmental perturbations) we can see in Figure 10 that the vehicle slows down as it approaches the source, as if to examine it. After its examination is complete, with some help it can move off again in search of newer sources of light. These characteristics and behaviours gave it the name of Explorer.



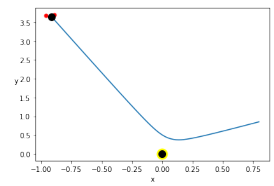
(a) Step 0: Initial Position



(b) Step 1



(c) Step 2



(d) Step 3: Off in search of new Sources

Figure 10: The movement of Vehicle 3b over a Set Time Step.

As Braitenberg puts it, both vehicles 3a and 3b like the light but in different ways. Vehicle 3a loves the light in a more permanent eternal sense, content with its resting place next to the source, whereas Vehicle 3b is intrigued by the source and perhaps it is that new found curiosity that speeds it away in search of other stimuli.

2.5 One and Two-Eyed Photo-Taxis

By "lesioning" our vehicle and removing its ability to have multiple sensory inputs (in this instance both motors were connected to the the left sensor) we can observe it tracing a path unlike the previous vehicles (Figure 11).

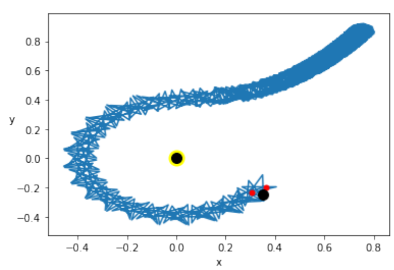


Figure 11: One-Eyed Photo-Taxis W/out Bias

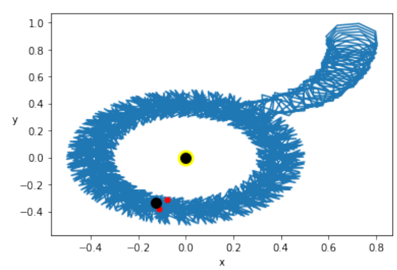


Figure 12: One-Eyed Photo-Taxis with Bias

Figures 11 and 12 show one-eyed photo-taxis without and with a bias (respectively) on both motors. We can see that they do achieve photo-taxis as they tend towards the source however they will enter an endless loop as both motors get excited at the same rate by the one sensor. The vehicle spins on its axis continuously whilst tracing out a path around the light and will stay content in its orbit around the stimulus.

3 Active Perception

Active perception allows for a new view on behavioural studies as a study of modeling and control strategies for perception (Bajcsy, 1988). Modelling here refers to models of sensors and processing modules and their interactions. And control strategies are created to find a sequence of steps to minimize a loss function whilst gathering as much information as possible (Bajcsy, 1988). This can be seen as quite a heavy tie to active inference, or the free energy principle (Friston, 2010); A process theory of the brain and that living creatures will infer their actions as a way of minimizing their (expected) free energy (Çatal, Verbelen, Nauta, De Boom, & Dhoedt, 2020). The question we want to answer here however, having seen the behaviours of the various Braitenberg vehicles, is what level of brain complexity is required in order to generate the desired behaviours.

3.1 Cheap Design

The cheap design principle is an idea from embodied cognition and AI (Pfeifer & Bongard, 2006). This principle refers to the low complexity of the neural controller of an organism when compared to its observed behaviours (Montafar, Ghazi-Zahedi, & Ay, 2015). The Braitenberg vehicles could be argued to have been built with this cheap design principle in mind. Braitenberg observes how an external viewer might call the vehicles' behaviours complex were the internal wirings hidden and even goes on to link these behaviours to animal neural structures. This link to complex behaviours is a common theme and explored also (Pfeifer & Bongard, 2006) where the behaviours of ants as they walk are examined. Montafar et al. make the point that the fact that the most complex human-body structure, the brain, accounts for on average 2% of the bodys mass but requires 20% of our entire energy consumption (due to the vast amount of electrical signals constantly being fired around) is support of the presence of cheap design even in biological systems.

4 Conclusion

In this paper we have shown instances of Braitenberg's simple vehicles and attempted to explore some of the rich behaviours they display and with a comparison of the two-eyed photo-taxis machine against its inhibited one-eyed counterpart. As Friston (Karl) asks: To what extent a machine, significantly tuned to its environment, really needs cognition. And with active perception as a lens of looking at these artificially intelligent machines we can see simple creatures display complex behaviours and show a different way of designing artificial intelligence.

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