Pavlovian, Skinner and other behaviourists contribution to AI

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1. Abstract

A version of the definition of intelligent behaviour will be supplied in the context of real and artificial systems. Short presentation of principles of learning, starting with Pavlovian's conditioned response (reflex) through reinforced response and operant conditioning of Thorndike and Skinner will be given. Some tools of artificial intelligence that act according to those principle will be presented. An attempt will be made to show how some simple rules for behaviour modifications can lead to a complex intelligent behaviour.

Contents

- Pavlov -a Nobel price winner Pavlov[1906]
- Intelligence
- Learning: visions of main behaviourists
- Biological learning –resume
- AI and animal learning
- Critics and propositions for solution
- Conclusions

2. Intelligence. Desription

1. Abilities to:
   - reasoning
   - imagination
   - insight
   - judgement ⇒ Binet test, IQ test
2. Three fundamental cognitive processes:
   - abstraction
   - learning
   - dealing with novelty .

3. Ability to profit from experiments ⇒ ability to behave adaptively, to function successfully within particular environments.

3. Learning

Adaptive changes of behaviour = learning

Behaviour is considered intelligent when it can be seen to be adaptive.

Critics: there are many behavioural changes that one would like to call learning although they are not at all adaptive.

We call behaviour intelligence only when we see how that behaviour is adaptive.
$\Rightarrow$ intelligence is in the eyes of the observer [Brooks 1991]

Principle of learning

4. Biological (animal) learning

- Stimuli–response associations make the behaviour unstable (depends on the place, initial position A_0).
- Stimulus–approach associations make the behaviour stable (the goal stimulus S_0 can be approached from many directions, places $A_i, i = 1, 2, ...$)
- Place–approach associations make the behaviour stable (more advanced learning: it requires the ability to use a configuration of stimuli to identify a place to approach).
- Response chain makes the behaviour unstable (more than a simple $S - R$, single stimulus S_0 triggers a whole sequence of responses: $R_0, R_1, R_2, ...$).
- Stimulus–approach chain makes the behaviour stable (sequence of stimuli:$S_0, S_1, S_2, ...$ are approached in order).
- Place–approach association can be also linked in chains (the same stimuli ($landmarks$) can be used many times to locate different places).

- $S-R-S'$ associations, where S and S' are situations, one can make inference that if it is in S and performs response R it will end up in S' (it is a form of expectation learning and correspond to Tolman's postulate about animals' learning).
- $S-R-S^*$ associations, where a stimulus S is followed by a response R with a reinforcement, stimulus, S^* (S^* gets more intense as a goal is approched).
- $S-S'$ associations are examples of the classical conditioning of Pavlov's dog (in which the bell has been associated with food which in turn activates salivation) =stimulus–substitution theory of conditioning$\Rightarrow$ Hebb's theory.

Balkenius [1994] Skinner, 1999 , Sahrkey and Ziemke[1999]

5. AI and animal learning

How to match relevant animal learning theories with AI research:

- Rule based systems are very often similar to S-R associations.
  Example: look-up tables (LUT) in both AI and control.
  (Notice some inputs may be not stored)
- Samuel's checkers program , 1959, is similar to reinforcement learning described by a set of $S - R - S^*$ associations.
- Most AI planning systems, based on acquisition of knowledge about the world, make use of representations similar to $S - R - S'$ associations of the form:

$$precondition \times action \rightarrow outcome$$

  where the outcome of one rule is the precondition for the next. Planning is a search for a sequence of rules that leads from the start to the goal.

Recent critics:

- Classical AI systems lack generalization capabilities: complete systems cannot be made from studies of isolated modulus.
- Classical AI systems lack robustness and cannot perform in real time, and run on sequential machines.
- Classical AI systems are goal based and organized hierarchically; their processing is done centrally.
- Real world differs from virtual ones: it has its own dynamics. Virtual world has states with complete information on them, they are static.
- The frame problem appears, i.e. how models of parts of the real world can be kept in tune with the real world as it is changing, and how to determine which changes in the world are relevant to a given situation without having to test all possible changes.

6. Suggested solutions

- Complete system (agent) must possess the architecture:
  1. with direct coupling of perception to action,
  2. with dynamic interaction with the environment,
  3. with intrinsic mechanisms to cope with resource limitations and incomplete knowledge,
  4. with decentralized processing,
- Complete system has to be the autonomous agent (self-sufficient agent, equipped with the appropriate learning mechanism, with its own history, adaptive),
- Complete system has to be the situated agent (it acquires information about its environment only through its sensors and interacts with the world on its own),
- Complete system has to be embodied (it must interact with its environment, is continuously subjected to physical forces, to energy dissipation, to damage, to any influence in the environment).

7. Neural network architecture embedded in robot

Robot

Example: Learning rule of Hebb to modify the weights w_{ij} of an artificial neural network (ANN)

$$w_{ij}(t+1) = w_{ij}(t) + \eta o_j a_i$$

where η is the so-called learning rate, o_j the output of the node (PE) j, and a_i the activation of the node i.

8. Conclusions

Complete system = system equipped with AI

- Complete system is behaviour based, not goal based.
- Complete system includes sensors and effectors.
- Sensory signals (stimuli) should be mapped (relatively) directly to effector motors (responses).
- Complete system is equipped with a large number of parallel processes connected (only loosely) to one another.

This leads to embodied cognitive sciences and to embodied intelligence introduced by Rodney Brooks [1991] and the subsumption architecture.

Since complete (i.e. intelligent) systems are behaviour based the behaviourists contributions are obvious.

Acknowledgement. The first author (W.K.) would like to thanks Mrs. and Mr. A. Adamkiewicz for the inspired discussions on psychology during his stay in their Dom na Łąkach in Izby, Beskid Niski Mountains, in the summer 2003. The help of Dr. Piotr Gołąbek in collecting materials used in the preparation of the paper is highly acknowledged.