The Agency: Methods of Logic in General Philosophy of Science

Vincent F. Hendricks
Department of Philsophy and Science Studies
Roskilde University
Denmark

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1 The Agency / Outline

1. 'Agent' comes from the Latin term *agere* meaning 'to set in motion, to do, to conduct, to act'.

2. 'Agency' means 'the acting of an agent' in particular in presence of other agents.

3. An agent may interact or negotiate with its *environment* and/or with *other agents*.

4. An agent may make decisions, follow strategies or methodological recommendations, have preferences, learn, revise beliefs ...

- **Bullet items 1–4 crudely recap the focal points for the methods of logic in philosophy of science.**

2 One Agent / One System

- **'First Generation Epistemic Logic'**

- Epistemic logic proceeds axiomatically. "An agent δ knows that A" is formalized as a modal operator in a formal language which is interpreted using the standard apparatus of modal logic.

- Which epistemic axioms, **T**, **K**, **D**, **4**, **5**, ..., are plausible for axiomatizing knowledge, belief, certainty and other attitudes?

- The ambition is that cataloguing the possible complete systems of such logics will for a picking of the most appropriate or intuitive ones (~**S4** – **S5**).

Figure 1: Inactive agency.

- **Problems**
  - Implausible axioms, logical omniscience ...
  - Inactive agents:
    * Epistemic-logical principles or axioms are relative to an agent or method which may or may not validate these principles.
    * The primary role of the methods in classical epistemic logic is to index the accessibility relation.
    * Indices on accessibility relations will not suffice for epistemological pertinence simply because

there is nothing particularly epistemic about being indices.

– **Staying static / What we want to know is how the agent has to behave in order to obtain knowledge**.

3 More Agents / More Systems

- In a multi-agent system each individual agent is considered to being in some *local state*.

- The whole system as the sum of the local agents is in some *global state*.

- The dynamics may be modelled by defining what is referred to as a *run* over the system which really is a function from time to global states.

- The system may be thought of as series of runs rather than agents.

- What is being modelled here are the possible behaviors of the system over a collection of executions.

Figure 2: Active agency.

- Knowledge is defined with respect to the agents' local state.

- Truth of a formula is given with respect to a point. If truth is relative to a point then there is a question of 'when' which opens up for the introduction of temporal operators.

- One may for instance define a universal future-tense operator such that a formula is true relative to the current point and all later points.

- Multi-modalities are next ...

4 More Agents / More Modalities

Dana Scott once noted:

> Here is what I consider one of the biggest mistakes of all in modal logic: concentration on a system with just one modal operator. The only way to have any philosophically significant results in deontic logic or epistemic logic is to combine these operators with: Tense operators (otherwise how can you formulate principles of change?); the logical operators (otherwise how can you compare the relative with the absolute?); the operators like historical or physical necessity (otherwise how can you relate the agent to his environment?); and so on and so on. [Scott 1970]

- Combined systems including
  - Alethic modalities
  - Tense modalities
  - Epistemic modalities

4.1 An Example: Modal Operator Theory

- A possible world is a pair consisting of an evidence stream ε and a state coordinate n, i.e., (ε, n), where $\varepsilon \in \omega^\omega$ and $n \in \omega$.

- Let $\varepsilon \mid n$ denote the finite initial segment of an evidence stream also called the *handle*.

- Let $(\varepsilon \mid n)$ denote the set of all infinite evidence streams that extend $\varepsilon \mid n$, also called the *fan*.

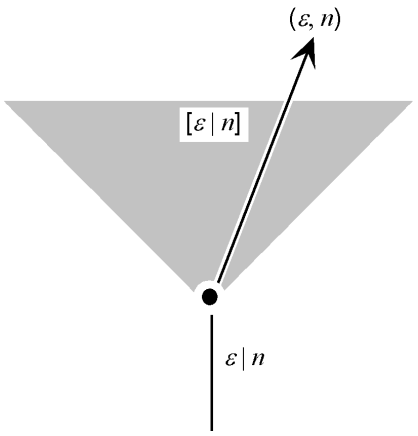

Figure 3: Handle, fan and possible world

- Define the set of all empirical hypotheses as

$$\mathcal{H} = P(\omega^\omega \times \omega).$$

So $h \in \mathcal{H}$ iff $h = \{(\varepsilon, n) \mid \varepsilon \in S, n \in N\}$ where $S \subseteq \omega^\omega$ and $N \subseteq \omega$.

- An empirical hypothesis h is said to be *true* in world (ε, n) iff

$$(\varepsilon, n) \in h \text{ and } \forall l \in \omega : (\varepsilon, n + l) \in h.$$

4.1.1 Multi-Modalities

1. The **singular future** operator, Fh, is true in world (ε, n) iff at some time in the future it will be the case that h:

   (ε, n) validates Ph iff $\exists k < n : (\varepsilon, k)$ validates h.

2. The **universal past** operator, Hh, is true in world (ε, n) iff for all times in the past it was the case that h:

   (ε, n) validates Hh iff $\forall k < n : (\varepsilon, k)$ validates h.

3. The temporal modalities G and P are definable in a similar manner.

4. The **temporal necessity** operator, $\boxdot h$, is true in world (ε, n) iff for all times it is the case that h:

   (ε, n) validates $\boxdot\, h$ iff $\forall k \in \omega : (\varepsilon, k)$ validates h.

5. The **universal necessity** operator, $\Box h$, is true in world (ε, n) iff in all worlds it is the case that h:

   (ε, n) validates $\Box h$ iff
   $\forall (\tau, m) \in \mathcal{W} : (\tau, m)$ validates h.

6. The **empirical necessity** operator, $\boxminus h$, is true in world (ε, n) iff in all worlds in the world fan it is the case that h:

   (ε, n) validates $\boxminus h$ iff
   $\forall (\tau, m) \in [\varepsilon \mid n] : (\tau, m)$ validates h.

- A discovery method δ is a function from finite initial segments of evidence to hypotheses:

$$\delta : \omega^{<\omega} \longrightarrow \mathcal{H}.$$

- A the discovery method δ discovers h in the limit in (ε, n) iff

$$\exists k \forall n' \geq k \forall (\tau, n') \in [\varepsilon \mid n] : \delta(\tau \mid n') \subseteq h.$$

- The convergence modulus for discovery method δ is given

$$cm(\delta, h, (\varepsilon, n)) =$$
$$\mu k \forall n' \geq k \forall (\tau, n') \in [\varepsilon \mid n] : \delta(\tau \mid n') \subseteq h.$$

- Knowledge based on discovery:

(ε, n) *validates* $K_\delta h$ *iff*

1. $(\varepsilon, n) \in h$ *and* $\forall l \in \omega : (\varepsilon, n + l) \in h$,

2. $\forall n' \geq n, \forall (\tau, n') \in [\varepsilon \mid n]$:

   (a) $\delta(\tau \mid n') \subseteq h$,

   (b) $(\tau, n') \in \delta(\tau \mid n')$.

- Note that by definition the agents are inherently active since there will be no knowledge if the method doesn't conjecture!.

- The method may in addition be subject to various methodological recommendations, program commands or strategies imposing epistemic behavior.
  - Infallibility
  - Consistency
  - Perfect memory
  - Timidity
  - ....

- Which axioms are valid for these definitions of knowledge are sensitive to the methodological recommendations imposed on methods!

4.2 Other multi-modal paradigms

- Dynamic epistemic and doxastic logic
- Action logics and belief revision
- Action and deontic logics
- Logics of information
- Public annoucement logics
- Preference logics
- Logics of games and strategies

5 More Agents / More Abilities

- Agent diversity (different agents, different abilities)
  - Perfect memory, consistency, conservatism, timidity, infallibility ...and other methodological recommendations or strategies for learning, winning, revising ...

- Social software
  - Studies of the procedures of society whether elections, conferences etc. as analogous to computer programs to be analyzed by similar logical and mathematical tools.

- Knowledge modelling
  - Common knowledge
  - Implicit / explicit knowledge
  - Graded knowledge
  - Knowledge interaction and transmissibility of information
- Division of epistemic labour (philosophy of science, epistemology, social science)
  - Agent diversity
  - Agent cooperation

The short end of a long story yet to be told ...