COMPUTATION AS SOCIAL AGENCY: WHAT AND HOW

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Johan van Benthem, Amsterdam & Stanford, http://staff.science.uva.nl/~johan

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Turing's achievements, and what remains of them in the Arrow Airport Taxi Company.

Classical themes from the 'golden age'

Universal Machine can do any computation [basis for both practice and basic theory], *Church Thesis:* computation captured completely, *Turing Test*: computation also covers human cognition.

Current debates in US and Europe

Is the Turing model outdated, can we compute a larger class of functions/problems after all?

Logic and fine-structuring views of computation

The rise of programming languages. From computable functions to other levels of structure, say, 'algorithms'? Output and internal structure: *what* one computes vs. *how* one computes: *behavior*.

Modal logic: WHILE programs (Hoare), Dijkstra structured programming, C+, dynamic logic. Lambda calculus: LISP, functional programming. Divide keeps reemerging in modern versions.

The major challenge around 1980: distributed computation and process theory

Process Algebra (Milner, Bergstra & Klop): bisimulation, trace equivalence... no 'CT': [van Emde Boas on machine models]. [Sequential views also alive: μ-calculus, co-algebra of infinite streams.]

New computational paradigms still appearing

Multi-agent lines: computation as agency [1980s]: Halpern & TARK. 1990s: game semantics, linear logic, Abramsky in *Handbook of Philosophy of Information*. Telling detail: communication complexity. Andrew Yao rediscovered von Neumann-Morgenstern Theorem from game theory.

Life after Turing: facebook of logic and computer science

Scott & De Bakker, Kowalski, McCarthy, Dijkstra, Hoare, Pnueli, Milner, Emerson, & others:

Theme today: human metaphor for interactive computation, works both ways.

'Computer' from human to machine. Reverse trends ever since: social metaphors of computing, AI & cognition, agent societies of humans and machines, interactive foundations of computation.

Conquering daily life: conversation as computation

Example of the Muddy Children: updates solve the information puzzle, conversation has program structure, sequential and parallel. Dynamic-epistemic logics: again *what* and *how*, model events. Miller & Moss 2005: PAL^* is Π^1_1-complete. [But: complexity of logics ≠ complexity of tasks.]

Daily life strikes back: computation as conversation

Computing is action plus information. Methods can be programs (machine), or plans (human). Two basic features of conversation: *knowledge* [and belief], and multi-agent *interaction*. Suggests exploring transformations from standard algorithms to social procedures. Start with knowledge:

Epistemizing computational tasks

Graph Reachability: Given a graph $\boldsymbol{G}$ with two points x, y, does there exist a chain of arrows in $\boldsymbol{G}$ from x to y? Solvable in *Ptime* in size of $\boldsymbol{G}$ (Papadimitriou 1994). The *GR* algorithm performs two tasks: determining if a route exists, and giving an actual *plan* to get from x to y (see later).

Knowing you made it. You want to reach goal region ϕ, but have only limited observation. $\boldsymbol{G} = (G, R, \sim)$ now has arrows plus epistemic uncertainty links. Brafman, Latombe & Shoham 1993: robot with sensors inspects current node to see if it is in the goal region: $K\phi$. Su et al. on sensors inspired logic and epistemology.

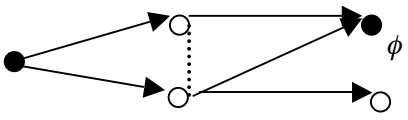
Recent cases of epistemizing: make knowledge explicit in auctions, voting, *social choice*.

Epistemization in general

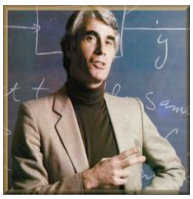
Systematic transformation can be studied as such, few general results known. (Turing himself?)

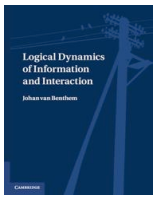
Knowledge programs. Not just epistemize specifications, also algorithms. 'Epistemic programs' (Fagin et al. 1995): test conditions depend on what the agent executing them knows about the facts, or other agents. Connections with imperfect information games. Two roles of knowledge interact:

Having a reliable plan. If we are to trust a plan, should we *know it to be successful*?



After one step, the agent no longer knows if moving *Across* or rather *Up* will reach the ϕ-point. What if we require that $[a_1]K[a_2]K\phi$, where $a = a_1;a_2$, etc.? What about more complex programs?



Knowing a program

Know–that versus know–how. New issue: What does it mean to know a program, plan, or method? Attempted reduction to knowledge of effects, dependence on agent types (perfect recall).

Typical informational action: learning. From propositional knowledge goals to 'understanding'. When does an agent understand a program or plan? [What is understanding a mathematical proof?]

Philosophical analyses of knowledge may be relevant. Importance of possibly wrong beliefs and other information-driven attitudes, importance of program revision under new circumstances.

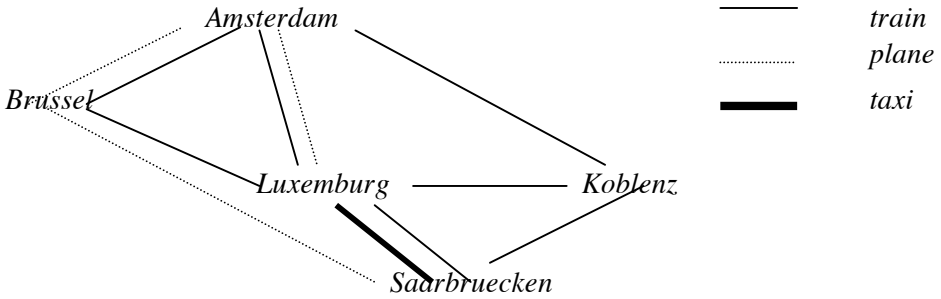
Aside: Various kinds of information are relevant, here not just semantic. Syntax and computing.

Next: Many-mind problems, multi-agent interaction. Gamification *of computational tasks: communication, sabotage*. *Systematic change in algorithms, from programs to logic of strategies*.

Gamifying algorithms

Reaching a goal comes with variants where *others* should not know. Many subtle algorithms are of social forms [security]. [See also Agotnes & van Ditmarsch 2009.] Much simpler case:

Reachability and sabotage. Consider Graph Reachability in the heart of Western Europe:



What if transportation breaks down, and a malevolent Demon starts disrupting the network? At every stage, let Demon first take out one connection. Now we have a two-player *sabotage game* to be solved. [Current experimental uses as a learning game in cognitive experiments.]

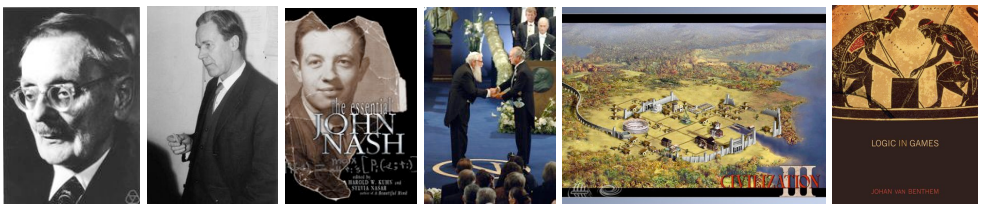
General transformation gamifying any algorithmic task to a *sabotage* game with more players. New logical languages defining these games, and players' strategies. How does *computational complexity* change? For sabotaged reachability, complexity jumps to *Pspace*-complete (Rohde 2005, like Go or Chess). [But cf. Sevenster 2006 on Scotland Yard games, and IF games.]

Issue: how does the graph search algorithm itself get 'sabotaged' into a game solution method?

Logic of reasoning about model change can be complex: sabotage modal logic is *undecidable*.

Gamification in general

General program: theory of epistemizing and gamifying algorithms. Links to general *game theory*. Many current contacts between logic, computer science, and game theory. Still larger Facebook:



How vs. *what* again: what are natural levels of fine-structure: when are two games equivalent?

Aside: practical *'gamification'*: who invented the term? Theory of this phenomenon wide open.

Foundational discussions, the three pillars of computation once more

Turing Test: what we need to understand is not 'computability', but *behavior*. And the real challenge is understanding behavior in diverse mixed societies of computers and humans.

Church Thesis: from unique 'what' to diversity of 'how'. Process equivalences for agent views. Computation as large family of different styles of behavior. Need base analysis of *social behavior*. A 'new Turing': social behavior, suitably conceived, as a universal model for computation?

Universal machine for agency as extended computation: does it exist at all, could it be Games?

References

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