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**Refereed Article**

# Donald Michie:

# It Takes Two (At Least) to Tango

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**Abstract:** *At some stage discovery - whether of facts or of theories - hits the road-block of complexity. To deploy the needed divide-and-conquer strategy, both biological and artificial systems invoke inter-agent collaboration.*

*"Agents" in the neurobiological context can be interpreted as specialized subsystems of the human brain. Clinical material is reviewed to illustrate what happens when an agent goes missing.*

*Alternatively, "agents" can be specialized members of societies of* separate *organisms. An unusual case is instanced from a long-term Russian study of three species of Siberian wood ants.*

*Finally in discovery software, collaborations of "agents" re-appear as subgoal hierarchies generated by structured induction. In long-neglected work by Shapiro and co-workers, this interactive method was used to build a theory of a chess end-game for which no theory had ever been humanly achieved. Automatically rendered into a form both machine-executable (for prediction) and brain-executable (for explanation), the collaborative method delivered a complete and correct theory on both predictive and explanatory criteria. This surpassed the best that human experts had ever obtained for far simpler, indeed even for trivial, end-games.*

*It was the handful of procedures above the layer of primitive attributes that supplied the explanatory component. For the predictive function, full competence was manifested by a monolithic data-induced decision tree solely employing the same primitive attributes. Transparency was in that case wholly lost.*

(Abstract continued on next page)

*The explanatory superstructure is likened to the "presentation of self" functions of those parts of the brain associated with consciousness. The infrastructural layer is likened to the brain's diversified and densely populated automatized layer. In human discourse this two-layer structure is convenient, indeed necessary. It critically assists someone wishing to elicit from human subjects their explanations or justifications of unexpected behaviours. Recognition that users of inanimate systems may have a similar need for a transparent discourse layer is still lacking from software designs. Use of Muggleton and Michie's Duality Principle could bring these conveniences both to AI systems and to interactive software generally.*

*The paper closes by relating the Duality Principle to Turing's forgotten "Child Machine" project. In the closing section of his celebrated 1950 paper in* Mind, *he prescribed a staged approach to the construction of human-level intelligence. First: construct a generic learning system able to assimilate new facts and generalize new theories. Second: incrementally teach the upper and coach the lower layer, as one teaches and coaches a child. Relevance to the growing need for run-time transparency in commercial software is mentioned.*

## Publication and review history

This work was first presented at the Machine Intelligence 17 Workshop, held on July 19-21, 2000 at Bury St Edmunds, Suffolk, UK. Attendance at this workshop was based on invitations. Speakers at the workshop were invited to submit their articles for consideration in the forthcoming workshop volume. The subsequent publication and review history for the present article was as follows.

1. First version *published* by Linköping University Electronic Press on 21.12.2000 and permanently available at
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2. First version *accepted* after due refereeing and according to scientific journal standards by the Electronic Transactions on Artificial Intelligence (ETAI) on 27.3.2001. Authors were invited to revise their articles, if they so desired, based on comments by the reviewers.
3. Revised version *accepted* on 24.12.2001.
4. Revised version *published* by Linköping University Electronic Press on 31.3.2002 and permanently available at the same URL as mentioned above.
5. Revised version appears in Electronic Transactions on Artificial Intellligence, Volume 4 (2000), section B, pages 1–19. The section and the annual volume are made permanently available at
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6. Paper editions of the ETAI issue and the ETAI volume containing this artice *republished* by the Royal Swedish Academy of Sciences.

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