An Attempt to Generalize AI Part 13: Reflexive Outputs

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This is the thirteenth in a series of articles attempting an overview of how minds may work and how similar systems could be implemented in computers. Previous articles described a probabilistic hierarchy based on *patterns*. A pattern has a specification describing a set, or population, of *pattern instances*, distributed throughout a hierarchy containing the pattern instances of all the patterns. Each pattern's set of pattern instances is used to obtain statistical information for probabilistic predictions. Each pattern's population of pattern instances is to be described in a very general way, to provide a very general ontology. An exploratory relevance process has been described, to restrict the hierarchy to representing relevant features of the world. This article introduces a further way of providing relevance: reflexive outputs. Reflexive outputs are outputs that, instead of controlling devices in the "outside world", control the modeling system itself – making adjustments to the hierarchy to direct its modeling. An AI system could learn to make reflexive outputs in the same way that it learns to make other outputs, because the distinction between the system itself and the "outside world" is really artificial: Outputs affect the world and, if a system is able to learn how to make appropriate ones, it should not matter if part of the world being affected happens to be the system itself. Reflexive outputs are not being proposed as an alternative to the exploratory relevance process proposed previously, which is still the main process for providing relevance, but are intended to augment it. A philosophical consideration of reflexive outputs in relation to the "self" is also given.

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List of Abbreviations

AI	artificial intelligence
BERP	basic, exploratory relevance process
EFS	evaluation function score
ERP	exploratory relevance process

1 Introduction

This article is the thirteenth in a series about artificial intelligence (AI) and how our own minds might work. The first article, *An Attempt to Generalize AI - Part 1: The Modeling System*, is available at http://www.paul-almond.com/AI01.pdf.[1] The second article, *An Attempt to Generalize AI - Part 2: Planning and Actions*, is at http://www/paul-almond.com/AI02.pdf.[2] The third article, *An Attempt to Generalize AI - Part 3: Forgetting*, is at http://www.paul-almond.com/AI03.pdf.[3]

These three articles described a hierarchy based on *patterns*, which are sets of *pattern instances*, and were intended to give an idea of how humans may model the world, plan actions and discard information from the model when it is no longer useful. The fourth article, *An Attempt to Generalize AI - Part 4: Modeling Efficiency*, which is at http://www.paul-almond.com/AI04.pdf, suggested that pattern instances should be allowed to have *incompletely specified pattern inputs*, so that it would be practical for the hierarchy to be "pruned" by some process seeking to maximize its relevance.[4] This required a *completely* probabilistic hierarchy, an issue dealt with in the fifth article of this series, *An Attempt to Generalize AI - Part 5: A Completely Probabilistic Hierarchy*, which is at http://www.paul-almond.com/AI05.pdf.[5]

That made a process to provide relevance in the hierarchy feasible. The sixth article, *An Attempt to Generalize AI – Part 6: Measuring Relevance*, which is at http://www.paul-almond.com/AI06.pdf, described a back-propagation process for measuring relevance in the hierarchy.[6] The problem is made tractable by the way in which the *action selection process*, described in the second article, *An Attempt to Generalize AI – Part 2: Planning and Actions*, works. The seventh article, *An Attempt to Generalize AI – Part 7: A Basic, Exploratory Relevance Process*, which is at http://www.paul-almond.com/AI07.pdf, described the *basic exploratory relevance process* (BERP), which uses this measuring process to direct the growth and pruning of the hierarchy.[7]

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[1] Almond, P., 2010. *An Attempt to Generalize AI - Part 1: The Modeling System*. [Online] paul-almond.com. http://www.paul-almond.com/AI01.pdf or http://www.paul-almond.com/AI01.doc.

[2] Almond, P., 2010. *An Attempt to Generalize AI - Part 2: Planning and Actions*. [Online] paul-almond.com. http://www.paul-almond.com/AI02.pdf or http://www.paul-almond.com/AI02.doc.

[3] Almond, P., 2010. *An Attempt to Generalize AI - Part 3: Forgetting*. [Online] paul-almond.com. http://www.paul-almond.com/AI03.pdf or http://www.paul-almond.com/AI03.doc.

[4] Almond, P., 2010. *An Attempt to Generalize AI - Part 4: Modeling Efficiency*. [Online] paul-almond.com. http://www.paul-almond.com/AI04.pdf or http://www.paul-almond.com/AI04.doc.

[5] Almond, P., 2010. *An Attempt to Generalize AI - Part 5: A Completely Probabilistic Hierarchy*. [Online] paul-almond.com. http://www.paul-almond.com/AI05.pdf or http://www.paul-almond.com/AI05.doc.

[6] Almond, P., 2010. *An Attempt to Generalize AI - Part 6: Measuring Relevance*. [Online] paul-almond.com. http://www.paul-almond.com/AI06.pdf or http://www.paul-almond.com/AI06.doc.

[7] Almond, P., 2010. *An Attempt to Generalize AI - Part 7: A Basic, Exploratory Relevance Process.*

The eighth article, *An Attempt to Generalize AI – Part 8: Forgetting as Part of the Exploratory Relevance Process*, which is at http://www.paul-almond.com/AI08.pdf, removed the need for the forgetting process in the third article, instead incorporating forgetting into the BERP, or any other exploratory relevance process (ERP).[8] This was done by modifying the relevance measurement process (RMP) to take account of obsolescence. This article also introduced *ghost pattern instances*. A ghost pattern instance is one that persists temporarily, after "removal" by the ERP, as a simple probability value, while it is still needed as a pattern input by other pattern instances. The incompletely specified pattern inputs introduced earlier are now ghost pattern instances. The ninth article, *An Attempt to Generalize AI – Part 9: Improving the Exploratory Relevance Process*, which is at http://www.paul-almond.com/AI09.pdf, discussed ways in which the sophistication of the BERP might be increased, giving an improved ERP.[9]

Functioning of the system requires pattern instances to be placed in the hierarchy on an ongoing basis, and pattern instances need to belong to patterns. A way in which this could work had been described in the first article, *An Attempt to Generalize AI - Part 1: The Modeling System*.[10] Other approaches, conforming to the same general idea, were discussed in *An Attempt to Generalize AI – Part 10: Alternatives for Pattern Instance Construction*, which is at http://www.paul-almond.com/AI10.pdf.[11]

The view of cognition in this series was related to dreaming in humans, with a suggestion for how it occurs in *An Attempt to Generalize AI – Part 11: Explaining Dreaming*, which is at http://www.paul-almond.com/AI11.pdf.[12]

The issue of ensuring relevance for patterns, rather than just for pattern *instances*, as had been considered in previous discussion of the BERP and other ERPs, was discussed

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[Online] paul-almond.com. http://www.paul-almond.com/AI07.pdf or http://www.paul-almond.com/AI07.doc.

[8] Almond, P., 2010. *An Attempt to Generalize AI – Part 8: Forgetting as Part of the Exploratory Relevance Process*. [Online] paul-almond.com. http://www.paul-almond.com/AI08.pdf or http://www.paul-almond.com/AI08.doc.

[9] Almond, P., 2010. *An Attempt to Generalize AI - Part 9: Improving the Exploratory Relevance Process*. [Online] paul-almond.com. http://www.paul-almond.com/AI09.pdf or http://www.paul-almond.com/AI09.doc.

[10] Almond, P., 2010. *An Attempt to Generalize AI - Part 1: The Modeling System*. [Online] paul-almond.com. http://www.paul-almond.com/AI01.pdf or http://www.paul-almond.com/AI01.doc.

[11] Almond, P., 2010. *An Attempt to Generalize AI - Part 10: Alternatives for Pattern Instance Construction*. [Online] paul-almond.com. http://www.paul-almond.com/AI0.pdf or http://www.paul-almond.com/AI10.doc.

[12] Almond, P., 2010. *An Attempt to Generalize AI - Part 11: Explaining Dreaming*. [Online] paul-almond.com. http://www.paul-almond.com/AI11.pdf or http://www.paul-almond.com/AI11.doc.

in *An Attempt to Generalize AI – Part 12: Pattern Relevance*, which is at http://www.paul-almond.com/AI12.pdf.[13]

This article will continue with the issue of relevance. The ERP discussed in previous articles should go a long way towards dealing with this issue, but it should be possible to do something else as well. By introducing special outputs that, instead of directing things in the outside world, are directed inwards, so that they affect the hierarchy itself, the system can use its own outputs, and its general, inbuilt tendency to learn to make the best outputs, to control the hierarchy and provide relevance in it. These special outputs, which I will call reflexive outputs, are the subject of this article.

(I have mentioned reflexive outputs in previous articles, where I referred to them as "prioritization control outputs";[14] however this article will discuss them within the context of the AI approach in this series of articles.)

[13] Almond, P., 2010. *An Attempt to Generalize AI - Part 12: Pattern Relevance*. [Online] paul-almond.com. http://www.paul-almond.com/AI12.pdf or http://www.paul-almond.com/AI12.doc.

[14] Almond, P., 2007. *Planning as Modelling: A New Version*. [Online] paul-almond.com. Available at: http://www.paul-almond.com/PlanningAsModellingNew.pdf or http://www.paul-almond.com/PlanningAsModellingNew.doc. pp.1-5, pp.12-15.

2 The Existing Approach to Relevance

What follows is a description of the existing way in which the hierarchy of pattern instances is made relevant. This is actually the same description that was given in the previous article, *An Attempt to Generalize AI – Part 12: Pattern Relevance*.[15] Readers familiar with the methods of attaining relevance may want to go directly to the next section, Section 3: Reflexive Outputs, on page 9.

Two forms of the hierarchy can be considered.

- The **conceptual hierarchy** is the hierarchy of all pattern instances. The conceptual hierarchy could never be represented in a computer, as it is infinite.
- The **actual hierarchy** is that part of the conceptual hierarchy which is represented in a computer. It consists of a selection of pattern instances.

Because the states of some of the pattern instances in the actual hierarchy are dependent on inputs/outputs that have yet to occur, they can only be known about probabilistically. This is achieved by propagating probabilistic information through the hierarchy in logic application and statistics application.

The existing approach to relevance assumes that there is a set of patterns which are to be used, and it deals with how to connect pattern instances of those patterns into the hierarchy. The idea is to represent only relevant parts of the conceptual hierarchy in the actual hierarchy.

A *basic exploratory relevance process* (BERP) has been described in *An Attempt to Generalize AI – Part 7: A Basic, Exploratory Relevance Process*,[16] though more sophisticated kinds of *exploratory relevance process* (ERP) could also be used. In the BERP, each pattern instance is assigned a relevance value. Pattern instances are continually added to the actual hierarchy, and they need to be connected to the ones that are already there. Pattern instances are also continually removed from the hierarchy, and the chance that a pattern instance avoids being removed at any time depends on its relevance: Low-relevance pattern instances are likely to be removed more quickly. The result will be an actual hierarchy that becomes denser where it has high-relevance, growing into high-relevance regions, and less dense where it has low-relevance.

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[15] Almond, P., 2010. *An Attempt to Generalize AI - Part 12: Patterns and Relevance.* [Online] paul-almond.com. http://www.paul-almond.com/AI12.pdf or http://www.paul-almond.com/AI12.doc. pp.7-8.

[16] Almond, P., 2010. *An Attempt to Generalize AI - Part 7: A Basic, Exploratory Relevance Process.* [Online] paul-almond.com. http://www.paul-almond.com/AI07.pdf or http://www.paul-almond.com/AI07.doc.

The BERP, and other ERPs, require a way of assigning relevance values to all the pattern instances. This is done by the *relevance measurement process* (RMP), a relevance back-propagation process described in *An Attempt to Generalize AI – Part 6: Measuring Relevance*.[17] This starts by assigning relevance externally to particular, important, bottom-level pattern instances corresponding to future inputs, and then back-propagating this relevance through the hierarchy according to the degree of effect that pattern instances are having on pattern instances with already known relevance values. The particular, important, bottom-level pattern instances get their importance from the way in which the system's actions are planned: the *action selection process* described in *An Attempt to Generalize AI - Part 2: Planning and Actions*.[18] The action selection process involves selecting an output value, when one is required, by trying the different possibilities and propagating probabilistic information through the hierarchy in each case, as if the output had occurred with the relevant output value. An evaluation function score (EFS) is continually computed from recent inputs, and encoded as bottom-level pattern instances, and the desirability of a particular output value can be determined by looking at the prediction for the pattern instances that will be used for future input of the EFS. It is these pattern instances which are the particular, important, bottom-level ones which are assigned relevance externally, and from where relevance is back-propagated, in the RMP.

[17] Almond, P., 2010. *An Attempt to Generalize AI - Part 6: Measuring Relevance*. [Online] paul-almond.com. http://www.paul-almond.com/AI06.pdf or http://www.paul-almond.com/AI06.doc.
[18] Almond, P., 2010. *An Attempt to Generalize AI - Part 2: Planning and Actions*. [Online] paul-almond.com. http://www.paul-almond.com/AI02.pdf or http://www.paul-almond.com/AI02.doc.

3 Reflexive Outputs

3.1 The Idea of Reflexive Outputs

Reflexive outputs are like normal outputs except that, *instead of affecting things outside the modeling system, they affect the modeling system itself*, controlling the actual hierarchy. Reflexive outputs can focus the actual hierarchy on particular features of the world, causing the actual hierarchy to represent or not represent a given part of the conceptual hierarchy. The idea is that the right combination of reflexive outputs could provide relevance in the hierarchy, by making it represent those parts of the conceptual hierarchy most important for making the predictions that are needed.

3.2 Why Reflexive Outputs Would Work

Reflexive outputs are special in terms of *what they do* – affecting the system itself – but they are not special in terms of *how they are made*. They are made in the same way as other outputs.

No special mechanism is required for the making of reflexive outputs. With the action selection process, as previously described, the system automatically learns to make the outputs that best improve its situation.[19] Reflexive outputs would just be a special case of this, and the system would just learn to make suitable reflexive outputs as part of learning to make all its other outputs. If the system learned that making reflexive outputs in a certain way improved its situation, then it would tend to continue doing this.

Reflexive outputs make sense if we realize that at a basic level, any distinction between the system itself and the "outside world" is artificial. Parts of the model may make such a distinction, giving rise to the "self": the part of the model that relates the system's future outputs to previous inputs/outputs, and is therefore describable in terms of concepts such as "intentionality", but this is an emergent property of the hierarchy. The basic workings of the hierarchy – the way that pattern instances work and propagate information – and the workings of the action selection process make no such distinction. At a basic level, there is no difference between the system and the outside world. The model just represents the world, which includes the system itself, and the system's outputs are selected to manipulate the world in such a way as to obtain the most favorable evaluation function scores, and whether such manipulation of the world happens to affect the system itself is, at a basic level, irrelevant.

If there are special outputs which can affect the hierarchy itself, then the hierarchy can learn to make suitable outputs of this kind which cause prediction of high EFS values,

[19] Almond, P., 2010. *An Attempt to Generalize AI - Part 2: Planning and Actions*. [Online] paul-almond.com. http://www.paul-almond.com/AI02.pdf or http://www.paul-almond.com/AI02.doc.

just as it would do with any other output. An output of this kind would affect a predicted EFS by reducing the uncertainty in the system's predictions of the future, allowing it to be better at planning its actions, so that it can achieve a better outcome.

3.3 Analogies

3.3.1 Analogy 1: Indirect Manipulation of the System

Suppose the AI system were installed in a robot which had dials on the exterior case. These dials can be used to change the actual hierarchy in the modeling system. A human engineer could come along and use those dials to adjust the modeling system, so as to adapt it to some situation. The dials might somehow alter the settings of the actual hierarchy inside the machine, either causing it to become denser or less dense in particular regions, or altering some more general settings in the ERP. A useful adjustment of the dials would be one which caused the uncertainty in the hierarchy's predictions of pattern instances corresponding to future EFS input – the pattern instances involved in the action selection process – to be reduced.

Now, suppose the robot has arms and hands and can manipulate its own dials itself. It could do exactly the same as the human engineer, and it would not need any special learning process to do so: The robot is only using its outputs to manipulate reality, as usual, and the fact that the reality being manipulated now includes a dial on its case is irrelevant.

The idea of a robot using arms and hands to manipulate dials on its own exterior may seem slightly comical, and it is unwieldy and inefficient. If we wanted the robot to be able to do this, instead of doing this, we could link some of the robot's outputs directly to servomotors that move the dials. We could go still further, however. Ultimately, we could just link some of the robot's outputs directly to the systems they were supposed to be affecting in the hierarchy. These outputs would now be reflexive outputs.

3.3.2 Analogy 2: Obtaining a Better View

For another idea of what would be going on with reflexive outputs, we can imagine a system that manipulates its environment to get a better view. Suppose a robot needs to make some decision, and what is down a corridor in front of it is relevant to this decision. However, the robot cannot see down the corridor because some crates are stacked up in the way. If we considered the robot intelligent, we would not be surprised if it moved the crates to obtain a better view down the corridor: to reduce the uncertainty in the information it has about what is down there, and ultimately, the future. We would regard an intelligent system manipulating the world to obtain a "better view" as something expected.

Now suppose that the part of the world being manipulated to obtain a better view is the AI system itself, that instead of moving crates to see what is down the corridor, the

system can adjust parts of itself to see what is in the future. We should regard this as normal behavior, no different from any other kind, and requiring no special learning process or justification.

4 A Philosophical View of Reflexive Outputs

We will now look at what is happening when reflexive outputs are made. This is a bit more philosophical, because it relates to the more general issue of the "self", and things can be viewed in different ways.

4.1 View 1: Reflexive Outputs are the "Self" Controlling the Hierarchy

We normally think of the "self" as controlling the making of outputs – as initiating action in the world. For example, with the sentence "John kicked the ball" most people would have some idea that there is some person, some "self", called John, in a brain somewhere and this self decided to kick the ball. If we are taking this view, we could view reflexive outputs as the "self" manipulating the hierarchy that is running it. This seems to fit in well with our experience. Just as we can decide what to do in the "outside world" – kicking balls, picking things up, etc – we seem to be able to decide what to focus our minds on. With such a view, the experience of deciding to do something in the outside world and the experience of deciding to concentrate on something are very similar, differing only in terms of whether the outputs are directed inwards.

One issue with such a view might be that some actions seem to take place subconsciously, raising the whole issue of what the "self" means here, but that issue already exists when we apply this view to conventional actions anyway. We might say that some actions can be made subconsciously, or that there is some subconscious component to planning, but it seems intuitively meaningful to us to think of the "self" as *doing* things, even with this issue.

I have said that we might associate our experience of deciding to concentrate on something with reflexive outputs. This is not automatically the case. In the kind of system being discussed in this series of articles, there is no "self" separate to the modeling system: The "self" is merely part of the representation of the world in the hierarchy, being the representation of that part of the world that very strongly relates to future behavior, which is similar to the kind of view previously proposed by Metzinger.[20] This means that the "self" is itself derived from what the rest of the hierarchy is doing. The "self" might be having an experience of deciding to concentrate on something, and this might be caused merely by the ERP arranging the hierarchy in a particular way, the

[20] Metzinger, T., 2003. *Being No One: The Self-Model Theory of Subjectivity*. Cambridge (MA): MIT Press. Metzinger, T., 2009. *The EGO Tunnel: The Science of the Mind and the Myth of the Self*. New York: Basic Books.

experience then being derived from it. On the other hand, if reflexive outputs are in use it would make sense to say that at least some experience of deciding to concentrate on something, or some component of such experience, is explainable in terms of the "self" acting with the same degree of validity with which we would say that the "self" does anything. What I am really saying here is that we need to be careful not to run away and start making over-generalized statements relating experience to lower level processing.

4.2 View 2: Actions just seem to be initiated by the "self", but the "self" is just part of the model.

The view of the mind being taken in this series of articles is one in which what we think of as the "self" is actually part of the model in the hierarchy: "You" are generated by your brain's modeling system to explain your actions, and therefore predict your future actions, just as anything else is modeled to explain and predict things. In this view, the "self" has no qualitatively special status, though it would differ from other objects in the model in various matters of degree.

It could be argued that when we think that the "self" is initiating action, this is not really the case: that the "self" participates in this process only as an object in the model, and that the model itself initiates any action, the "self" being put together just to make sense of what is happening.

It should be noted, however, that even in this view, the "self" should not be viewed as completely passive. It would have to be having some effect on the outputs to justify its inclusion in the model at all. The issue here may be that the way in which it is having this effect is not necessarily what people think of when they talk about the "self" doing things. If the "self" is regarded as "doing things" when it influences a modeling system to produce a particular output, then the model of an umbrella in your brain is similarly "doing things" when it influences you to reach out and pick it up before going outside. The entire model could be said to be directing your actions and doing things. We might, however, regard part of the model, the "self" as different by a matter of degree, in its extreme effects on what you do.

If we take such a view, the idea of the "self" directing reflexive outputs fades away, and we no longer think in terms of the "self" deciding to manipulate the modeling system running it. This, however, is no different to the way we would be treating any other claim of the "self" acting.

Another issue here is that some people might take a particularly hard-line version of this view in which they say that the "self" does not exist.

4.3 Which view is correct?

How do we deal with the difference between these two views, and which one should we prefer? I suggest that neither view is the right one or the wrong one. Instead, each view

is at a different level. The “self” in the first view may seem to fade away when examined closely, but practically anything seems to fade away when examined closely, so this should hardly concern us. Whatever view we take of reflexive outputs at any time should be consistent with the view that we take of outputs in general, and that view can be decided on according to what kind of discussion we are having. Sometimes we may want to discuss this at the level of the “self” doing things, and in those situations, it would be consistent to think of reflexive outputs as the self manipulating the system. At other times, we may be looking more deeply at the system, and just viewing things in terms of the hierarchy of pattern instances, and in those situations the “self” may not be relevant to an explanation of outputs.

Some people may say that the second view is right, and that the first view is wrong. Even those people, I think, when they are not doing cognitive science or philosophy, would use the same language as everyone else in discussing their actions.

5 Complications with Implementation

I have given a description of the general idea of reflexive outputs, here, but I have not discussed in any detail how they would work. I think it is going to be difficult, at this stage, to get very far with that. The obvious difficulty with getting reflexive outputs to work is how you map specific reflexive outputs onto the hierarchy of pattern instances. It would be absurdly impractical to have each reflexive output to control addition or removal of a single pattern instance.

One approach may be to associate reflexive outputs with specific, high-level patterns, so that they can make these patterns more or less influential on what is happening with the hierarchy. The idea here is that control of a small number of high-level patterns could have a significant effect on the hierarchy. The exact way in which this works would depend on the way the hierarchy is implemented and the relationship between patterns and pattern instances.

Another approach might be for reflexive outputs to control general settings in the ERP. For example, they might globally control the rate at which pattern instances are pruned or added.

6 Conclusion

The hierarchical model in the modeling system developed in this series of articles can be considered in two different forms: the *conceptual hierarchy*, which is the hierarchy of all pattern instances, and the *actual hierarchy*, which is that part of the conceptual hierarchy which is represented in a computer.

It is important to ensure that the actual hierarchy consists of that part of the conceptual hierarchy that is relevant. The basic exploratory relevance process (BERP), as well as more sophisticated exploratory relevance processes (ERPs) have been proposed in previous articles to provide this relevance.[21]

This article introduces a further way of providing relevance: reflexive outputs. Reflexive outputs are outputs that, instead of controlling devices in the "outside world", control the modeling system itself – making adjustments to the hierarchy to direct its modeling. An AI system could learn to make reflexive outputs in the same way that it learns to make other outputs, because the distinction between the system itself and the "outside world" is really artificial: Outputs affect the world and if a system is able to learn how to make appropriate ones, it should not matter if part of the world being affected happens to be the system itself. Reflexive outputs are not being proposed as an alternative to the ERP proposed previously, which is still the main process for providing relevance, but are intended to augment it.

Reflexive outputs could be considered with regard to the self in two different ways. In one way, reflexive outputs would be considered as the "self" "deciding" how to organize the modeling system. In the other way, the "self" would be recognized as just an object in the modeling system itself, and would not be viewed as "making" reflexive outputs, or any outputs at all. Neither of these should be viewed as the "correct" view. They are merely views taken at different levels.

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[21] Almond, P., 2010. *An Attempt to Generalize AI - Part 6: Measuring Relevance*. [Online] paul-almond.com. http://www.paul-almond.com/AI06.pdf or http://www.paul-almond.com/AI06.doc.
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Almond, P., 2010. *An Attempt to Generalize AI - Part 7: A Basic, Exploratory Relevance Process*. [Online] paul-almond.com. Available at: http://www.paul-almond.com/AI07.pdf or http://www.paul-almond.com/AI07.doc [Accessed 17 June 2010].

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