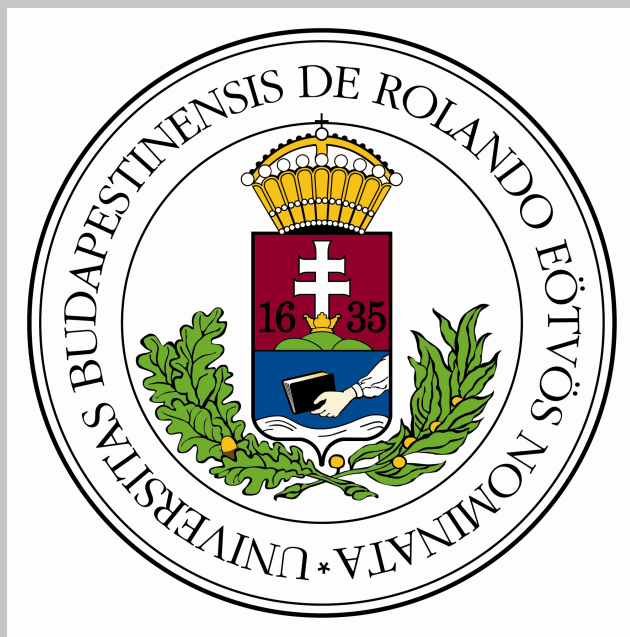


AVM: Data structures for the Cognitive Science of Religion

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1. Computational Foundations of Cognition

“[C]ognition is computation. This hypothesis permits the rigorous analysis of cognition – even at its most abstract – through a formal characterization of cognitive calculation. But computation is a rich notion that can be formalized in many ways. So the fundamental hypothesis of cognitive science – cognition is computation – immediately gives rise to the fundamental question of human **cognitive architecture**: just what *type* of computation is cognition?” (Smolensky & Legendre, 2006, vol. I, p. 5, emphases are original).

1st approximation: our working assumption is that *computation consists of*

- Representations or data structures,
- Operations “manipulating” these data structures,
- Overall architecture, built up of those operations.

2nd approximation: “representations” and “manipulations” can be distributed, embodied, embedded, etc.

AIM: to understand the data structures and algorithms in our mind/brain.

Data structures: numbers, character strings, graphs, feature matrices, distributed activation patterns, etc.

Algorithms: rewrite rules, symbol manipulating programs, differential equations, activation spreading, etc.

PROPOSAL: as data structures, let us use

<i>type</i>	
ATTRIBUTE.1	<i>value.1</i>
ATTRIBUTE.2	<i>value.2</i>
ATTRIBUTE.3	<i>value.3</i>

AVMs = attribute-value matrices

a.k.a. **[typed] feature structures**, widespread in linguistics (HPSG, LFG, some Construction Grammars, etc.) since the 1980s.

2. Cognitive Science of Religion

AIM: to understand the religious concepts in the human mind/brain.

The **building blocks** of the mental representations in [religious] cognition:

•Entities:

- *Ontological categories*: human, animal, plant, object, artifact... (Keil, 1989).
- *Agentive* vs. *non-agentive*. – *Intuitiveness* vs. *counterintuitiveness* (Boyer, 1994).
- *Epistemic modality*: real, culturally postulated, fictive, hypothetical, counterfactual... (Biró, 2012)

•Actions, events:

- *Thematic roles*: AGENT, PATIENT, RECIPIENT, INSTRUMENT, ... (Lawson & McCauley, 1990).
- *Intuitiveness* vs. *counterintuitiveness* (Boyer, 1994).
- *Tense-and-modality*: past, present, future, wish, precept, prohibition, etc.
- *Epistemic modality*: real, culturally postulated, fictive, hypothetical, counterfactual... (Biró, 2012)

•Folk theories applied to ontological categories.

•Etc.: properties, locations, time, amounts, etc.

GOAL: to model these building blocks using some formalism.

A useful research strategy, as I learned it in linguistics:

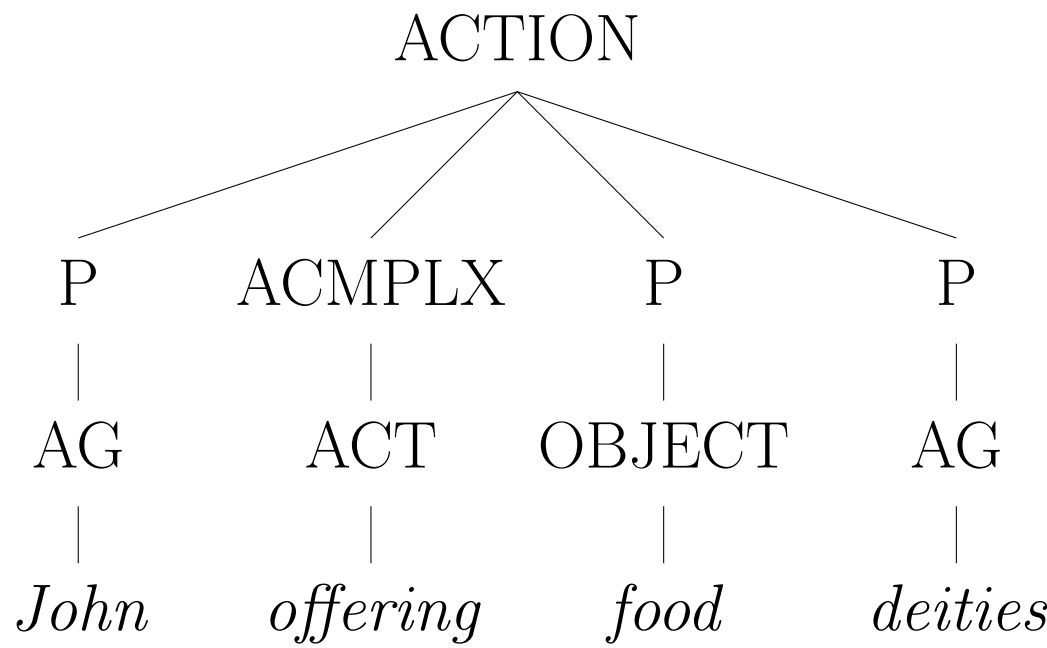
- Develop some formalism, such as context-free grammars or AVMs.
- Describe as many [cultural, religious,...] phenomena with this formalism, as possible.
- Gradually refine the formalism: revise it, restrict it, and embed it in a larger theory.

3. Context-free grammars (CFGs) and trees

Inspired by Chomskyan syntax in the 1980s, Lawson and McCauley (1990) develop a *context-free grammar* (1) as the model of the human **Action Representation System**. With it, specific actions – including *religious rituals* – can be represented as trees (2):

ACTION → P ACMLPX P*
P → AG QUALITY*
P → OBJECT QUALITY*
AG → *John, Steve, Zeus, Snow White, deities,...*
OBJECT → *cow, food, flower, stone,...*
ACMLPX → ACTION QUALITY*
ACT → *offering, giving, eating, seeing,...*

(1) Some of the formation (production) rules.
in the Lawson–McCauley CFG formalism.



(2) Tree representation of the ritual
“John offering food to the deities”.

Entities represented as atomic elements (terminals) in CFG. Main thrust: represent *rituals* as **actions**.

4. AVMs: attribute-value matrices

In linguistics, context-free grammars were introduced to account for the **linear order of the constituents**, e.g., of the words in a sentence. To more efficiently account for further phenomena, such as agreement, the CFG formalism has been generalized and modified, giving rise to alternatives. Many of these alternatives, including **unification grammars**, employ *attribute-value matrices*.

In fact, Lawson and McCauley (1990)’s analysis focuses not on the linear order of the participants in a ritual, but on the **thematic roles** they fill. **These can be more perspicuously expressed using AVMs:**

GIVING-action		② state-of-affairs		① human	
AGENT	John ①	THEME	crop	NAME	“John”
PATIENT	food	PROPERTY	good	ONTOLOGICAL CATEGORY	human
RECIPIENT	deities	TIME	next year	AGENCY	+
TIME	now	MOOD	volitive	EPISTEMIC MODALITY	real
GOAL	②	...		GENDER	male
				AGE	...

An AVM pair for the **action/event** “John offering food to the deities now, for the sake of good crop next year”

AVM representing the **entity** “John”

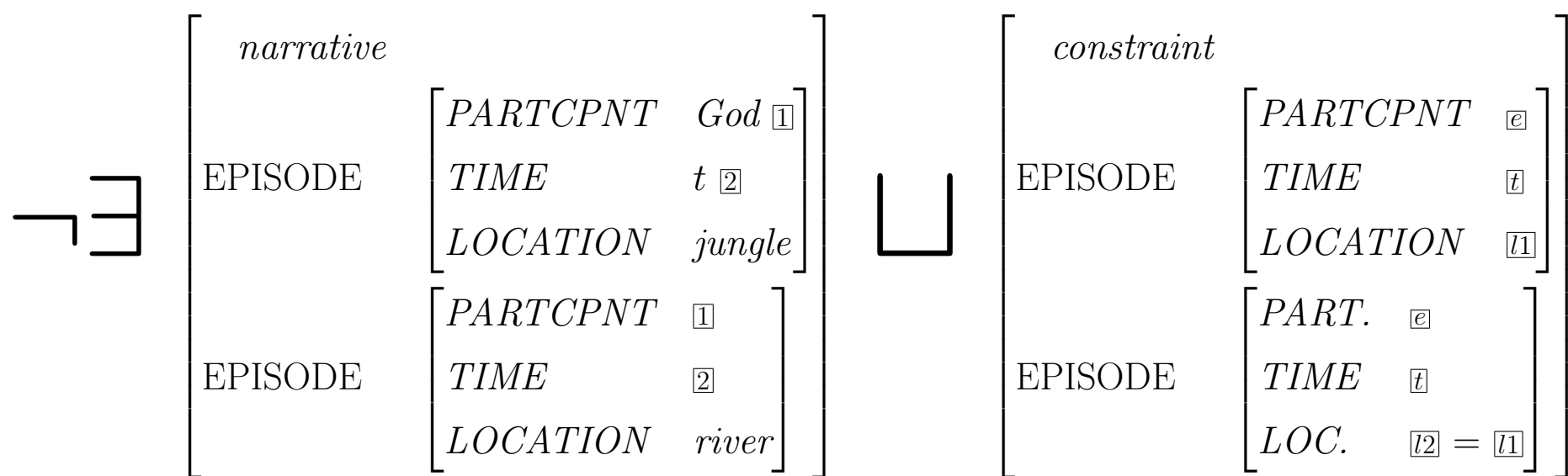
5. Complex religious system

Thus far: representing knowledge about **entities** and **actions/events**, both *real* and *culturally postulated*. Entities include: counterintuitive agents, objects with supernatural power, artifacts with religious significance. Actions, events and states-of-affairs include: rituals, prohibitions, mythological and eschatological events, etc. **Mythology** and **scriptures**: a series of culturally postulated past events, prohibited and prescribed actions.

Cultural and religious knowledge modeled as a set of AVMs: cult. postulated entities and actions.

AVM formalism also introduces:

+ **Unification:** a representation is *counterintuitive* if it cannot be unified with a constraint provided by some folk theory.



+ **Co-indexation**, aka. **reentrant structures**: such as ① in section 4, is a tool for expressing identity, which connects various structures in this complex system. Example: the deity ④ appearing in a narrative (past tense event) is the same entity as the recipient ④ of a sacrifice (a GIVING-action, *precept* modality).

6. Summary

Conclusions:

- *Attribute-value matrices* (AVMs) shown to be an effective **descriptive tool** as a **data structure** in formal-computational models of cultural and religious cognition.
- Enabling a uniform framework for representing and manipulating real and culturally postulated entities, actions and narratives, hard and soft constraints... — and hopefully much more.

Moreover, thanks to the decades-long expertise in computational and theoretical linguistics with AVMs,

- AVMs come with strong mathematical foundations,
- AVMs come with extensive literature on their computational implementations.

NEXT: *describe more and more phenomena, in order to refine the formalism.*

TOWARDS A UNIFIED FRAMEWORK OF HUMAN (HIGHER) COGNITION:

I believe, if a formalism adequately describes two very different domains of human (higher) cognition (such as linguistics and religion, or culture in general), then its general cognitive adequacy – as a horizontally integrating theory (Smolensky & Legendre, 2006) – can be further corroborated.

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