The CLARION Cognitive Architecture: A Tutorial

Part 5 – Conclusion

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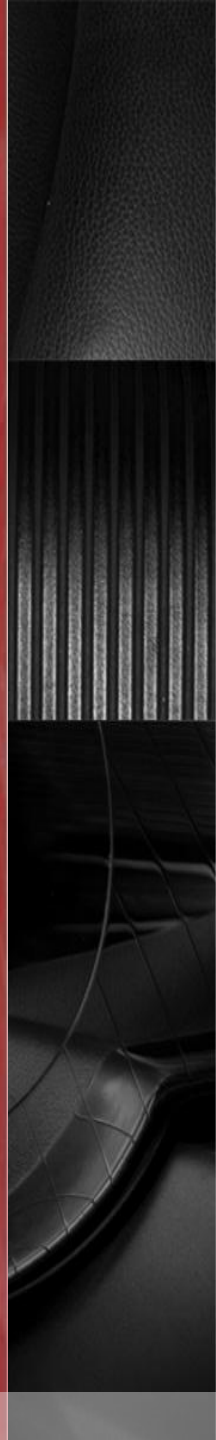


Why are Cognitive Architectures Important for Cognitive Science?

- To explore and explain psychological phenomena, we need psychologically-oriented cognitive architectures that are:
  - Cognitively-psychologically realistic "intelligent" systems.
  - Detailed cognitive theories that have been tested ("validated"), for example, through capturing and explaining psychological data.
- Cognitive Architectures help to shed new light on human cognition and therefore they are useful tools for advancing the science of cognition-psychology.
- Cognitive Architectures may serve as a foundation for understanding collective human behavior, along with social psychological phenomena --- beyond cognitive science.

Still Room for Grand Theories?

- Researchers in cognitive science are pursuing integrative approaches that explain data in multiple levels, domains, functionalities, and so on.
- Contrary to the claim that grand scientific theorizing have become a thing of the past and what remains to be done is filling in details.
- Because significant advances may be made through hypothesizing and confirming deep-level principles that unify superficial explanations across multiple domains.
- Cognitive architectures can be the basis of such unified theories.

Still Room for Grand Theories?

- In this work, we take an integrative approach in research:

  for example, combining strands of cognitive modeling (computational psychology), cognitive psychology, personality and social psychology, moral psychology, psychology of motivation, as well as sociological, anthropological, and political sciences, among others.

- Given the breadth of this work, there are many possibilities for extension, a lot of work still needs to be done, and a lot of resources would be needed

Comparisons:

Differences between CLARION 6.1 and other cognitive architectures

Differences between CLARION 6.1 and ACT-R 6 (based on ACT-R 6)

- CLARION makes a principled distinction between *explicit and implicit* knowledge/learning:
  - ACT-R does not directly capture the distinction and therefore the interaction between implicit and explicit processes;
  - ACT-R provides no direct explanation of *synergy* effects between the two types of knowledge/learning (e.g., Sun et al., 2005).

Differences between CLARION 6.1 and ACT-R 6 (based on ACT-R 6)

- ACT-R is not meant for *autonomous learning*, without a lot of a priori knowledge;
- It does not directly capture the psychological process of *bottom-up learning* as CLARION does.
- CLARION is capable of automatic and 'effortless' *similarity*-based reasoning, while ACT-R has to use cumbersome pair-wise similarity relations.
- CLARION has a general functional approximation capability (in its bottom level due to MLP), while ACT-R does not.

Differences between CLARION 6.1 and ACT-R 6 (based on ACT-R 6)

- In ACT-R, there is no built-in mechanism for *motivational* dynamics (as in CLARION) – goals are externally set and directly hand-coded.
- CLARION sets goals based on *drives*, allowing for the possibility of attending to multiple needs, as well as many other sorts of flexibility.
- ACT-R has some detailed *sensory-motor* modules.
  - CLARION implemented similar modules, but not in the current release.
  - CLARION has a keyboard and mouse plug-ins.
  - CLARION also has a remote communication plug-in to allow for connection between arbitrary front ends.

Similarities between CLARION 6.1 and ACT-R 6 (based on ACT-R 6)

- ACT-R and CLARION often use different implementations to represent similar ideas:
  - Components/modules/subsystems in CLARION are similar to modules in ACT-R.
  - Productions in ACT-R are similar to top-level rules in CLARION.
  - Eval modules in ACT-R are similar to fixed rules in CLARION.
  - Chunks in ACT-R and CLARION are similar (although ACT-R does not use distributed representations)
  - CLARION borrowed BLA
  - Buffers in ACT-R are equivalent to queues in CLARION

    (an implementation feature for asynchronous operation).
- CLARION and ACT-R often account for different tasks, although there have been some overlaps also.

Differences between CLARION 6.1 and Soar 9.3 (based on Soar 9.3)

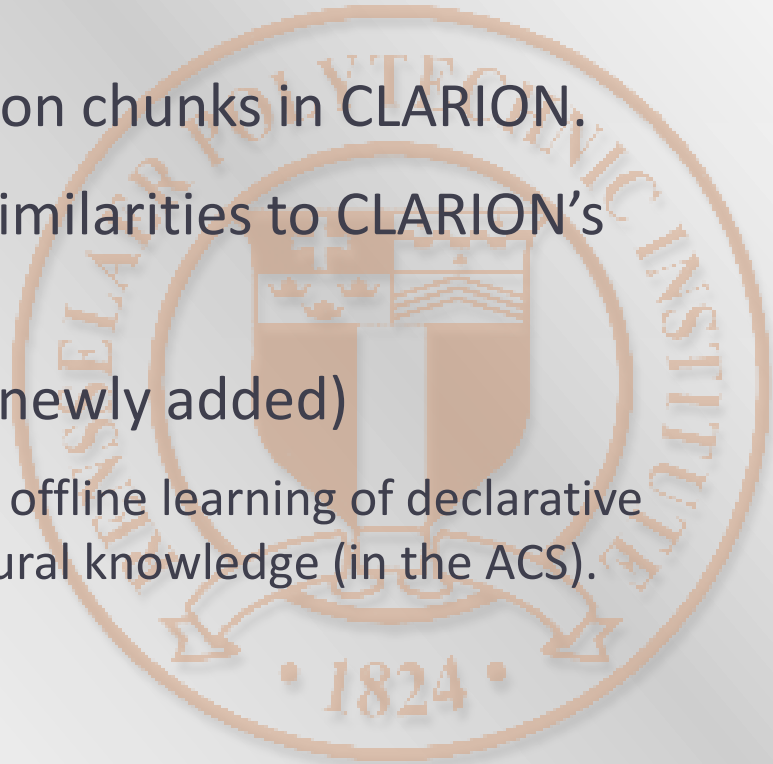
- In Soar there is a single representation of permanent knowledge (productions), whereas CLARION allows for *multiple* representational forms for both *declarative and procedural* knowledge (implicit or explicit).
- Soar makes no distinction between *explicit and implicit* knowledge. In Soar, there is no built-in modeling of the psychological process of the interaction and *synergy* between explicit and implicit processes.
- Soar implements a separate *long-term memory*, whereas CLARION assumes all knowledge is in the same (short- and long-term) memory (of a variety of types).

Differences between CLARION 6.1 and Soar 9.3 (based on Soar 9.3)

- CLARION can apply multiple, complementary *learning* mechanisms, Soar traditionally uses a single learning mechanism, i.e., chunking (but RL is being added).
- Soar makes no distinction between *explicit and implicit* learning.
- Soar uses a single mechanism for generating goals (automatic subgoaling). In CLARION goals can be generated using various (meta-cognitive) mechanisms to incorporate facets of contextual (sensory) information as well as motivational factors (drive activations).

Similarities between CLARION 6.1 and Soar 9.3 (based on Soar 9.3)

- Soar's temporary knowledge (attributes and values) is similar to (micro)features (dimension-value pairs) and chunks in CLARION.
- Operators in Soar are similar to action chunks in CLARION.
- Soar's working memory has many similarities to CLARION's working memory.
- Soar also has an episodic memory (newly added)
  - CLARION can use episodic memory for offline learning of declarative associations (in the NACS) and procedural knowledge (in the ACS).



Psychological Justifications and Implications of CLARION

- R. Sun (2013). ***Anatomy of Mind***. Oxford University Press, New York.
- R. Sun (2002). ***Duality of the Mind***. Lawrence Erlbaum Associates, Mahwah, NJ.
- R. Sun (1994). ***Integrating Rules and Connectionism for Robust Commonsense Reasoning***. John Wiley and Sons, New York.

Psychological Justifications and Implications of CLARION

- S. Hélie and R. Sun (2010). Insight, incubation, and creative problem solving: A unified theory and a connectionist model. *Psychological Review, 117(3)*, 994-1024. (re NACS)
- R. Sun, P. Slusarz, and C. Terry (2005). The interaction of the explicit and the implicit in skill learning: A dual-process approach. *Psychological Review, Vol.112, No.1, pp.159-192*. (re ACS)
- R. Sun, E. Merrill, and T. Peterson (2001). From implicit skills to explicit knowledge: A bottom-up model of skill learning. *Cognitive Science, Vol.25, No.2*, pp.203-244. (re ACS)
- R. Sun (1995). Robust reasoning: Integrating rule-based and similarity-based reasoning. *Artificial Intelligence. Vol.75, No.2*, pp.241-296. (re NACS)

Technical Details of CLARION

- R. Sun (2003). *A Detailed Specification of CLARION 5.0. Technical Report*.
  - Addendum 1: The enhanced description of the motivational subsystem.
  - Addendum 2: The enhanced description of similarity-based reasoning.
  - Addendum 3: The properties of the CLARION-H implementation.
  - Addendum 4: Q and A.
- → CLARION 6.0 Technical Book, in preparation; will be published by OUP
- A simplified description of CLARION 5.0, written by a student as a project report (which only provides some general ideas, but very readable):
  - A Simplified Introduction to CLARION 5.0. Technical report. 2004.

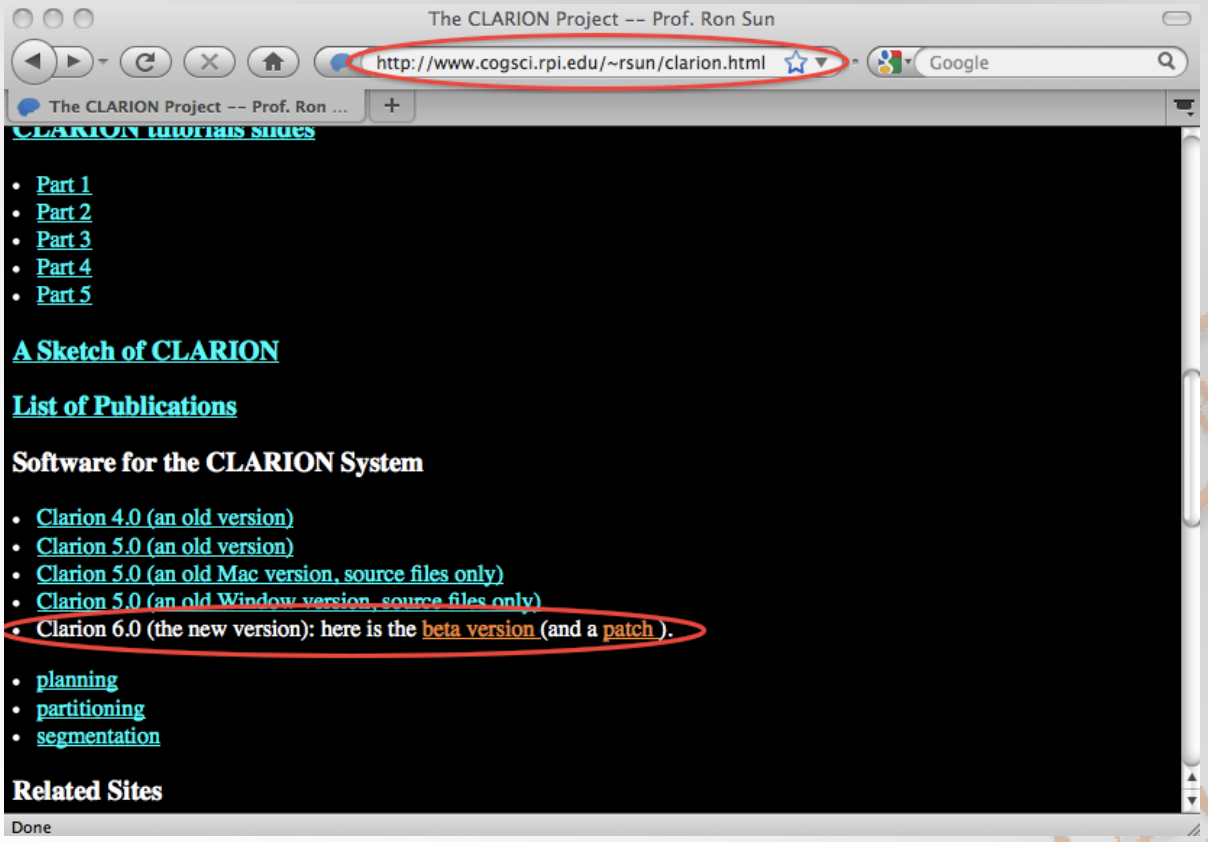
Conclusion: What is CLARION?

- CLARION is a comprehensive theory of the mind ("cognition" as broadly defined).
- CLARION is a conceptual framework for analyzing cognition-psychology (various functionalities and tasks).
- CLARION is a computational framework for simulating psychological data.
- CLARION is a computational framework for facilitating building intelligent systems. (?)
- CLARION is a set of programming tools for simulation/modeling:
  - Java packages [CLARION 5.0, CLARION 6.0]
  - C# assembly [CLARION 6.1]

Conclusion: What is CLARION?

- Significant progress has been made in advancing the research on cognitive architectures beyond the narrowly defined notion of "cognition"
- through incorporating motivation, meta-cognition, emotion, personality, and so on.
- Nevertheless, there is obviously still a long way to go to fully capture integrated, functioning biological and social "personhood",
- which results from the sum total of the genetic, sociocultural, and other factors, through the close relationship between the biological being and the physical and social words one finds self in ---their interaction and co-evolvement (as hypothesized in our ecological-functional approach; Sun, 2002 Erlbaum book; Sun, 2012 NIP).

Downloading The CLARION Library



- Go to http://www.cogsci.rpi.edu/~rsun/clarion.html
- Click on the highlighted link to be taken to the page to download version 6.0.5 and the most recent patch

The CLARION community

- Email clarion.support@gmail.com to:
  - Be added to the mailing list for updates on major releases.
  - Contact to get answers to support questions for the 6.1 (C#) release.
  - Send notice of any issues/bugs.
  - Submit feature/enhancement requests
- A new website and logo
  - All documentation and guides moved there
  - A forum where members of the CLARION community can:
    - Get support on and discuss simulation development
    - Submit bug reports and feature requests
    - Share custom components, simulations, agent/world configurations, etc.

The CLARION Cognitive Architecture

Thank You.

Questions?

Resources:

clarion.support@gmail.com

http://www.cogsci.rpi.edu/~rsun/clarion.html

http://sites.google.com/site/clarioncognitivearchitecture