Frontier Map and Cognition Futures

Embodied Intelligence + A Survey of Computational Models of Cognition

Jesse Parent B.S. - Assistant Scientist & Cognition Futures Group Lead
Orthogonal Research and Education Laboratory
EIW ‘21 Agenda

- Background
  - Where to Start? | “What happened to Cybernetics?”
  - Need for a map | FrontierMap: An Umbrella Project
  - Hybrid, Dev., Embodied | Cognition Futures & Developmental AI

- The Cognition Futures Project

- SurveyCogModel:
  A Survey of Computational Models of Cognition
  (Trajectories and Changes)
EC Researchers - Where to Start?

“What Happened to Cybernetics?”

- Norbert Wiener, et al
- Conant and Ashby
  - Every Good Regulator
- Gibsonian Information
  - Affordances...
  - (radical) embodied cognition
EC Researchers - Where to Start?

A vast, unstructured set of arenas and foci?

- A sea of popular conferences (NeurIPS, AAAI, Society for Neuroscience, ICLR)
- *What context am I missing - and how do I get it?*
- What should I study?

References that I don’t know

- Throwbacks and cycles (seasons) of interest
Need for a Map: FrontierMap

What is the minimal relevant information?

With an informed novice or intermediate skill level, what is the most efficient way to understand the contents of a field?

What information is most relevant to transfer learning (skill in one domain equals skill in another)?

We have observed this issue at the OpenWorm Foundation. What needs to be learned in biology, computation, or both in order to contribute in the community (code, academic research)?

Everything one needs to participate in physics -- Leo Susskind

OREL Presentation at csv.conf.v5 (2020)
FrontierMap: An Umbrella Project

OREL Presentation at csv.conf.v5 (2020)
Towards "Cognition Futures"

Cognition Futures is a new research team within Orthogonal Research and Education Laboratory (OREL). We focus on computational models of intelligent agents with emphasis on the developmental/evolution, embodied behavior, and allistasis of these systems. We are also interested in the historical and philosophical underpinning cognitive science, particular the epistemic trajectories that lead to current fields of academic inquiry. This will lead us to an understanding of why intelligent systems and associated algorithms look the way they do, and how they can be improved upon in the future.

**News**

- 10-26 “Trajectories of Cognition” accepted at Neuromatch 3.0
- 10-01 Greenlight to develop “Cognition Futures” subgroup within OREL
- 09-15 Cognition Study Group initiated
- 03-20 FrontierMap unveiled at csx.confex.com

**People**

- Jesse Parent (OREL Group Leader)
- Anson Lim (Western Michigan University)
- Bradley Alcaia (OREL PI)

**Projects**

**A Survey of Computational Models of Cognition**

Jesse Parent  
*(In Preparation)*

A tour of the existing landscape of modeling cognition, with a novel taxonomy and programming appendices & jupyter notebooks. This paper identifies existing themes and trajectories in computational models for cognition and suggests areas that are ripe for future researchers to explore. Associated educational materials are also in development.

**FrontierMap: A Trans-Disciplinary Learning Database**

Jesse Parent  
*(In Preparation)*

The Lay of the Land in Computation & Cognition: developing a set of visual maps, literature review, educational notes, and related material to serve as a set of primers to aid in researchers defining their research agendas.
Towards "Cognition Futures"

Hybrid AI

Embodied

Developmental
Towards “Cognition Futures”

Friston on Challenges & Problems
(IEEE Soft Robotics Podcast)

“What is the relationship between the brain and the body? The answer could be cast in terms of what is the nature of intelligence, where intelligence is an attribute of creatures or systems / agents that have brains. I think the answer to that can be found probably in cybernetics and certainly more recent formulations of things like the good regulator theorem in theoretical biology. “

“Understanding the form, nature, and structure of the generative models that we as people bring to the table and navigate our world”
A Survey of Computational Models of Cognition

Jesse Parent - Assistant Scientist & Cognition Futures Group Lead
Orthogonal Research and Education Laboratory
SurveyCogModel: Driving Questions - Fundamental

What are we trying to identify?

- In simple terms, map the technical and computational evolution of models of cognition.

Why?

- What has been tried, what has not. (Paradigms)

How?

- What questions can we center this investigation around?
- What to highlight and pay attention to when looking back at a vast history of approaches?
  - “What is the signal we’re differentiating from the noise?”
SurveyCogModel: Driving Questions - Refined

What are we trying to identify?

1. How did computational modeling of cognitive processes evolve?
   1. What languages and software were available that enabled or limited these models?
   2. What hardware enabled or limited these models?
   3. Paradigms & theories they support
2. What are existing taxonomies for discussing cognitive models?
   1. What are they lacking? What could be improved?
3. What developments in other fields influenced cognitive models?
   1. Neuroscience, "AI", "cognitive science", philosophy, linguistics, engineering & robotics, anthropology (?)

This project is mostly designed to cover questions #1 and #2, where as #3 is perhaps more covered by the Cognition Study Group, but #3 is mentioned as it completes the picture of how cognition models evolved.
Formative Concepts

- Embodiment and the 3/4Es
- “The Cognitive Revolution”
- Symbolic vs Connectionist vs Hybrid
  - Winters & Summers of AI
  - “The Bitter Lesson” – Rich Sutton
- Notable features
  - Models of Development & Cognition
  - Allostasis & Regulation
  - Cybernetics (EGRT), Free Energy, Complexity

What has changed?

What should change?
Formative Concepts - and evolutions?

Embedded theories are increasingly challenging traditional views of cognition by arguing that conceptual representations that constitute our knowledge are grounded in sensory and motor experiences, and processed at this sensorimotor level, rather than being represented and processed abstractly in an amodal conceptual system. Given the established empirical foundation, and the relatively underspecified theories to date, many researchers are extremely interested in embodied cognition but are clamoring for more mechanistic implementations. What is needed at this stage is a push toward explicit computational models that implement sensorimotor grounding as integral to cognitive processes. In this article, six authors from varying backgrounds and perspectives address issues concerning the construction of embodied computational models, and illustrate what they view as the critical current and next steps toward mechanistic theories of embodiment. The first part has the form of a daisy between two fictional characters: Ernest, the “experimentist,” and Mary, the “computational modeler.” The daisy consists of an interactive sequence of questions, requests for clarification, challenges, and (attractive) answers, and touches the most important aspects of grounded theories that should inform computational modeling and, conversely, the impact that computational modeling could have on embodied theories. The second part of the article discusses the most important open challenges for embodied computational modeling.
Mapping Cyborg Cognition Futures: From Partitioned Pasts to a Symbiotic Century

Jesse Parent1,2

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Abstract

Where should researchers focus their efforts within the vast frontier of civilization's increasing virtual, augmented, and enhanced manner of living? We offer Mapping Cyborg Cognitive Futures as a set of lenses to help identify fruitful areas of investigation, holistic context, and ethical & design dependencies for this horizon. Hybrid artificial-intelligence (AI) and advances in neuro-inspired and cognitive computation may afford greater intra-agent capabilities. Advances in brain-computer interfaces, human-robot and human-computer interaction, and developing robustness of virtual and augmented realities create new environments and new means to engage and interface within them. Uncharted territories and emerging manners of interaction will provoke unprecedented ethical challenges, warranting forethought and consideration of downstream impact. As the challenges of the 21st century approach with increasing pace, this big picture, multifaceted vantage point aids investigators by offering more efficient explore-exploit mitigation and relevant literacy in emerging issues.

realm. Two macro categories (B. potentials and limits of living systems; C. life's relation to mind, machines, and culture?) pertain to this project, with specific goal #12 “Evaluate the influence of machines on the next major evolutionary transition of life” setting the stage (Bedau et al., 2000).

We introduce three complementary lenses by which to triangulate future trajectories of the space in which biological and artificial life may come together. While Theseas operated via switches and relays as his cognitive infrastructure, received low-dimension sensory data through rudimentary embodiment, and maneuvered within a simplistic (yet artificially and intentionally constructed) environment, we consider the contemporary trajectories of these factors. We investigate seek to map out factors influencing cognitive capacities in intelligent agents; the mesh-points of interacting with our material world, hybrid, or completely virtual realities; as well as the ethos and designs that may shape these new mediums within which new forms of potentially sym-
More from our lab

Stefan Dvoretskii
Modelling Neural Development with Braitenberg Vehicles

Bradly Alicea
Approaches to Developmental Embodied Neurosimulation
## 2021 INTERNATIONAL WORKSHOP ON EMBODIED INTELLIGENCE

### LUNCH TIME BREAK-OUT SESSIONS (12-1pm GMT)

**25 March 2021**

### SESSION 1: Biohybrid, Cyborg, Human in the loop

- Chair: Luca Scimeca
- Co-Chair: Florence Leong
- Technical Support: Leoni Costi

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<td>Rafael Hostettler</td>
<td>Roboy 3.0 - Open-Source musculo-skeletal telepresence system</td>
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<td>Ilana Nisky</td>
<td>Human-in-the-loop design for tele-operated robot-assisted surgery</td>
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<td>Kieran Gilday</td>
<td>Dexterous Manipulation and the Passive Hand</td>
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<td>Mini Saaj</td>
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### SESSION 2: Open Crazy Topics

- Chair: Perla Maiolino
- Co-Chair: Grzegorz Sochacki
- Technical Support: Peter Miles

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Thank You & Our Team

Dr Bradly Alicea,  
Jesse Parent,  
Anson Lim,  
Daniela Cialfi

And OREL & DevoWorm groups for support & Discussion