Cognitive Architectures:
The Third Wave of Conversational Agents

Peter Voss
AGI Innovations Inc.
’AI is eating the World’

NL is key to AI
(Voice) Conversational AI is the new UI
...but NL is really hard

...there is a massive gap in current offerings

Current bots like Siri and Alexa are based on technology that is inherently unable to provide effective ongoing, interactive conversations.

This limits usefulness and adoption which creates user dissatisfaction and customer abandonment.
A survey of more than 7,000 consumers found customers’ top requests for AI bots is the ability to deal with more complex requests, and for greater personalization.

However, only 23% of providers said they were investing to improve personalization, and only 19% said they’re focused on enabling more comprehensive services.
Current Chatbot Technology does not...

- Have memory, or use context effectively
- Learn incrementally, interactively
- Understand complex sentences
- Manage ongoing conversation
- Reason, explain, or have common sense
# Aspects of Language

<table>
<thead>
<tr>
<th>Aspects of Language</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grammar Types</strong></td>
<td>Like can be a verb, adjective, noun, preposition, or conjunction.</td>
</tr>
<tr>
<td><strong>Concept Meaning/Selection</strong></td>
<td>The game ended in a tie, he is wearing a nice tie. Ted drew a bench towards the fireplace vs. Ted drew a bench by the fireplace.</td>
</tr>
<tr>
<td><strong>Phrases (verb + others)</strong></td>
<td>John stopped by the house this morning.</td>
</tr>
<tr>
<td><strong>Nominalizations</strong></td>
<td>Email is the buyer's file.</td>
</tr>
<tr>
<td><strong>Predicates</strong></td>
<td>I want to run a marathon. (Round: The data on file will be used for the project at hand, which is already under way.)</td>
</tr>
<tr>
<td><strong>Prepositional Phrases</strong></td>
<td>After 3 p.m., I will eat the apple on the table. (Phantom phrase: I waited for three days during this week; (on) Sunday I will take a hike.</td>
</tr>
<tr>
<td><strong>Determiners</strong></td>
<td>Basically, every other person is blonde. We teach them rules that the union is referring to.</td>
</tr>
<tr>
<td><strong>Noun Adjective Resolution</strong></td>
<td>Sally won unlimited offers of prize. Sally bought both extremely expensive diamond toe caps.</td>
</tr>
<tr>
<td><strong>Scanners</strong></td>
<td>Grab some green apples and oranges.</td>
</tr>
<tr>
<td><strong>Sizes</strong></td>
<td>Feels cheap; very expensive; excellent.</td>
</tr>
<tr>
<td><strong>Pronouns</strong></td>
<td>He sent her his resume. Tom walked his dog.</td>
</tr>
<tr>
<td><strong>Constructions</strong></td>
<td>Tom finished his research paper on his last night. He got a good grade on the paper. (Jim is in California. I will visit him soon. John bought &amp; eats cookies so I ate a few (k, n), I saw 6 fewer (k, n) than 10 cats. Order a large.</td>
</tr>
<tr>
<td><strong>Normalization/meaning</strong></td>
<td>ask over/invisi. vs. ask. require.</td>
</tr>
<tr>
<td><strong>Multiple Encoding</strong></td>
<td>email me! send, me an email!</td>
</tr>
<tr>
<td><strong>Data Types</strong></td>
<td>five-things in the afternoon. 1°, 10°, 15° lbs.</td>
</tr>
<tr>
<td><strong>Attributes</strong></td>
<td>Tape balancer.</td>
</tr>
<tr>
<td><strong>Entities</strong></td>
<td>The CEO and The Alliance Group purchased shares of Amazon. A car versus the car versus Jane's car versus cars.</td>
</tr>
<tr>
<td><strong>Compounds</strong></td>
<td>The boys and girls competed together. Mr. and Mrs. Wilson.</td>
</tr>
<tr>
<td><strong>Conceptual Objects</strong></td>
<td>Quiet, KNITTING, cloth, window, 1967, etc. (v) going for hang gliding.</td>
</tr>
<tr>
<td><strong>Names (complex)</strong></td>
<td>Dr. Charles (Chip) Andrew Stamm, the North American Society for Sai Research.</td>
</tr>
<tr>
<td><strong>Negation</strong></td>
<td>I don't like white wine. Don't schedule any meetings on Friday. Which fruits are not rotten? Who has no availability?</td>
</tr>
<tr>
<td><strong>ADJ/ADV</strong></td>
<td>Birds in cages &amp; boxes, vs. Birds in cages and dogs.</td>
</tr>
<tr>
<td><strong>Tenses</strong></td>
<td>I will send the email. I sent it, are never as rare – are never plural.</td>
</tr>
<tr>
<td><strong>Correlative Constructions</strong></td>
<td>Graham Thomas III is tall,ecastilla, Dr. Koblesky, Mr. &amp; Mrs. Wilson. An accountant. Am, are, is, i, me, mine.</td>
</tr>
<tr>
<td><strong>Conjunctive Adverbs</strong></td>
<td>If we have a meeting over 3 hours, cancel my lunch.</td>
</tr>
<tr>
<td><strong>Causal Clauses</strong></td>
<td>Cameron turned the light off in the room. Now it is dark.</td>
</tr>
<tr>
<td><strong>Question/Inversion</strong></td>
<td>Why did Cameron turn off the light? (Because he was going to bed).</td>
</tr>
<tr>
<td><strong>Implication</strong></td>
<td>Close the door. Is the door closed?</td>
</tr>
<tr>
<td><strong>Emotional/Expr. Mood</strong></td>
<td>Location/interaction/goal/mood of user. Agent confusion, urgency, boredom.</td>
</tr>
<tr>
<td><strong>Genitives</strong></td>
<td>My first car's original engine's contributor.</td>
</tr>
<tr>
<td><strong>Relationships</strong></td>
<td>The teacher of my brother, Steve, is one. My favorite aunt lives in France.</td>
</tr>
<tr>
<td><strong>Temporal/Order</strong></td>
<td>Frank went to Sally's house. After that he returned home. Where is Frank?</td>
</tr>
<tr>
<td><strong>Spatial/Order</strong></td>
<td>I locked inside the closet behind the door of the house.</td>
</tr>
<tr>
<td><strong>Ownership</strong></td>
<td>John's party is 5 days after Christmas.</td>
</tr>
<tr>
<td><strong>Past</strong></td>
<td>Anna got flowers. She gave them to Jane. Who has the flowers?</td>
</tr>
<tr>
<td><strong>Superlatives</strong></td>
<td>The dogs are my favorite. The blue whale is the largest mammal.</td>
</tr>
<tr>
<td><strong>Synonyms/Anonyms</strong></td>
<td>Giving a hug is the same as hugging. The opposite of nocturnal is diurnal; sell-buy.</td>
</tr>
<tr>
<td><strong>Homonyms</strong></td>
<td>Flower/flour / flour.</td>
</tr>
<tr>
<td><strong>Analogy</strong></td>
<td>Carrot is to vegetable as apple is to what?</td>
</tr>
<tr>
<td><strong>Metaphor</strong></td>
<td>The world is an oven.</td>
</tr>
<tr>
<td><strong>Spelling Errors</strong></td>
<td>I needed the spelling corrector to correct the spelling. (Corrected to correct the spelling. The correct to the spelling.)</td>
</tr>
<tr>
<td><strong>Personal Pronouns</strong></td>
<td>We went to Texas to see family friends. After we arrived there, they greeted us. (Corrected to have been there).</td>
</tr>
<tr>
<td><strong>Exclamations</strong></td>
<td>It's A D in Redondo Beach. The one on Wednesday.</td>
</tr>
<tr>
<td><strong>Error Recovery</strong></td>
<td>Thank you so much! That's, oops, disgusting. My brother, please, want get a job.</td>
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Natural Language Understanding and Conversation is really hard!

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<td>He will send the email. He almost sent it.</td>
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<tr>
<td>Adj. resolution/ Compounds</td>
<td>Television &amp; movie stars vs royalty &amp; movie stars.</td>
</tr>
<tr>
<td>Co-reference</td>
<td>Jim is in California. I will visit there soon</td>
</tr>
<tr>
<td>Implied concepts</td>
<td>John brought a dozen cookies. I ate a few.</td>
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<td>Relationships</td>
<td>The teacher of my brother, Steve, is Jane. My favorite aunt lives in France.</td>
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<tr>
<td>Compatitives/ Conditionals</td>
<td>If the meeting is more than 3 hours, cancel my lunch</td>
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Natural Language Understanding and Conversation is **really** hard!

My sister’s cat Spock... is pregnant.

Remind me to speak with Jane.
Remind Jane to speak to me.
Can you remind me what Jane said?
The Experts Agree...
To build better computer brain, we need to look at our own.

My view is to throw it all away and start again.

Current AI methods are statistically impressive but individually unreliable.


– Sept’2017, Geoffrey Hinton – AI Pioneer

– Feb’2017, DARPA
The Third Wave of AI
1) Traditional Logic Programming
2) Neural Nets - Big Data
3) Cognitive Architecture

Common Structures of many Cognitive Architectures

- Declarative Learning
- Declarative Long-term Memory
- Procedure Learning
- Procedural Long-term Memory
- Procedure Learning
- Short-term Memory
- Goals
- Action Selection
- Perception
- Action

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Cognitive Architecture

“...hypothesis about the fixed structures that provide a mind... and how they work together – in conjunction with knowledge and skills embodied within the architecture – to yield intelligent behavior in a diversity of complex environments."
3) Cognitive Architecture

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A Highly Integrated Cognitive Architecture

Knowledge & Skills

- Parsing
- Learning
- Memory
- Inference
- Language Generation
- Context

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A Highly Integrated Cognitive Architecture

User specific

App specific

Core Knowledge & Skills

Existing apps benefit from Core improvements!

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Chat-Bot Technology

User Input → ML Categorizer → Isolated, Hand-Crafted Custom Program

- Ontology Specification
- Keyword Extraction
- Logic Flow & Error handling
- Custom ‘NLG’
- API calls (optional)

Output

Skill 1

Skill n

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Integrated Cognitive Core

- Uses Common Ontology
- Deep Parsing & NLU
- Generic Flow Control
- Generic NLG Functionality
- API calls (optional)
- Custom Skill Requirements
Intelligent Interactions

- Understanding:
  - Meaning and implications of words
  - Entity resolution

- Memory:
  - Short-term memory & context
  - Conceptual long-term memory

- Adaptivity:
  - Unsupervised, one-shot learning
  - Real-time skill learning

- Reasoning:
  - Disambiguation & Questions Answering
  - Explaining answers & actions

- Conversation Management:
  - Conversation Context & Goals
  - Disambiguation & Meta-Cognition

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Some Core Functionality

Parsing:
• Uses context/history, and reasoning to disambiguate parses
• Uses ontology/memory, hypernyms, hyponyms, synonyms, tense, etc.
• Does deep parse, including complex clauses & multiple commands

Skill/Parameter Selection:
• Utilizes semantics, and generic pragmatics (e.g. question as command)
• Deep parse maps instruction parameters, including date & other units
• Allow for interruptions and run-on sentences

Skill Execution:
• Automatic disambiguation, clarification
• Generic Natural Language Generation (NLG)
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Some Built-In Skills

- Question Answering
- Learn Preferences/ Defaults
- Scheduled Actions
- Reminders & Alerts
- Lists and Notes
- Calendar management
- Messaging
1. **Narrow AI** (1\textsuperscript{st} & 2\textsuperscript{nd} Wave)
   Frozen, *External* Intelligence

2. **AGI** (Cognitive Architectures)
   Adaptive, *Internal* Intelligence

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What is Human Intelligence?

The ability to solve novel problems in the real world
What does Intelligence require?

- General learning ability
- Real-time, interactive learning
- Self directed learning
- Dynamic goals and context
- Transfer learning/ generalization
- Abstract reasoning/ language
How does Machine Learning shape up?

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How do Cognitive Architectures shape up?

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How do Cognitive Architectures shape up?

☑ General learning ability
☑ Real-time, interactive learning
☑ Self directed learning
☑ Dynamic goals and context
☑ Transfer learning/ generalization
☑ Abstract reasoning/ language
Universe of AGI Tasks

DL / ML
GOFAI

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The ‘Narrow AI’ Trap

Generality

AGI

Narrow AI

Competence

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AGI Innovations Team – Unicorn Training

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Thank You

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Why the Big Players are highly unlikely to succeed in Advanced NL Conversation

• Their strength, focus, and expertise is in Big Data/ML
• They have huge incentives to incrementally improve ML
• They think like engineers, not cognitive psychologists
• VCs, academia, careers/salaries, media, etc. almost exclusively promote statistical approaches
• Advanced NL Conversation cannot be solved by statistical methods, it will require something like a cognitive architecture

“Electric light bulbs did not come about from the continuous improvement of the candle ...“ – Oren Harari
PVA: Corporate vs Private

Amazon

Google

Apple

MSFT

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User pays for service.
Own agenda.
Owns data.
Operates other PVAs

Corporation’s agenda.
Limited coverage & knowledge of user.
Limitations of ML/DL

- Narrow, Hand-crafted Applications
- Needs a lot of tagged Data
- Long training time
- Poor unsupervised learning
- No incremental learning
- No transfer learning
- Opaque data and operation
- Very limited NLU
Limitations of ML/DL

- No STM or dynamic context
- No conceptual reasoning
- Only provides statistical results
- No dynamic goals or planning
- No meta-cognition
- Very limited ‘understanding’
- Cannot operate within real-time constraints
- Cannot integrate multiple modules