EPL680: Lecture 2
Cognitive Programming roadmap

OVERVIEW

- Reminder of the CP vision (from lecture 1)
  - Characteristics
  - Typical applications

- High-level road map on how to get there
  - Foundations and high-level architecture of CP
  - Main challenge problems to be addressed

Characteristics of Cognitive Systems

- What are Cognitive Systems?
  - Realization of Cognition/Intelligence in-silico.
    - Artificial Intelligence!!!

- What intelligence exactly?
  - Cognition refers to:
    - Common sense intelligence,
    - Everyday intelligence ,
    - Natural intelligence,
      - Not formal, scientific intelligence!

- What Artificial Intelligence exactly?
  - Early or Old AI
  - Human-level AI
  - Simple AI

Characteristics of Cognitive Systems

- **Systems that are Cognitively Compatible with humans**
  - **Compatible in both directions.**
- **Systems whose operation has a strong correspondence with Cognitive Processes**
  - **Informed by Cognitive Psychology**

The Cognitive Systems Vision

Cognitive Systems = Automated Cognition

- Automation of information/knowledge processing a la (comparable) to the human mind
  - Similar/comparable to the Phenotype behavior (Turing test)?
  - Similar/comparable to Genotype operation (Connectionist Network)?

- This information processing operation of the mind is called:
  - Thought/Inference/Reasoning
- Normally characterized as Logical:
  - Logical Thought/Inference/Reasoning

- Natural Language can play a special role in Cognitive Systems as it forms the medium on which this process of Thought/Inference/Reasoning is consciously conceptualized by the mind
  - Natural Language (words, phrases, stories) as part of a programming basis for Cognitive Systems

The Cognitive Systems Vision

Cognitive Systems = Automated Cognition

- The task is then to formalize this phenomenon of cognition/operation of the human mind – c.f. formal theories of nature e.g. gravity, electromagnetism etc.

- Formalize means to describe this in strict terms under classical mathematical logic
  - The Central Dogma of (hard) Science
    - Aristotle defines science – επιστήμη - as any study that is governed by well defined rules of inference such as those in his όργανον (as opposed to governed by myth and rhetoric)
  - Computer Science follows this dogma
    - Theory of Computation and Computers are build on formal logic.

- Hence we need to describe Logic (Logical Reasoning) in Logic!
  - It should be straightforward!
  - It is NOT! Why?

The Cognitive Systems Vision

Formalizing Human Reasoning

- Hence we need to describe Logic (Logical Reasoning) in Logic!
  - It should be straightforward! It is NOT! WHY?

- Because human common sense logic is different from formal logic
  - Formal logic is appropriate for human scientific reasoning!
  - Common sense reasoning or Natural Intelligence is informal.
    - I.e. cannot be captured by formal logic!
  - We are thus asked to "Formalize the Informal"

- Natural reasoning is flexible, default – risky, defeasible and revisable.
  - Given the available information it has enough to risk making a conclusion

- What is then the logic for formalizing ordinary human thought that people use in their everyday life?
  - What is the logical nature of common sense reasoning?

How do Cognitive Systems differ from others?

- **No strict, rigid, "recipe-type" computation as in conventional programs/systems – including AI and Agent systems.**
- **Flexible with limited information about the problem**
  - **Emphasis is not on optimized solutions but on persuasive solutions**
- **Fallible but are able to recover from their errors.**
  - **Turing: "… an infallible machine cannot also be intelligent."**
- **Have different Logical Foundations**
  - **Defeasible Reasoning vs Strict, Rigid Reasoning**
  - **Non-classical logic – "away from truth is all models/possibilities"**
- **Yet, they need to be constructed over "rigid machines"!**

The Cognitive Systems Vision

Formalizing Human Reasoning

- What is the logical nature of common sense reasoning?
  - Psychology: It is NOT mathematical formal logic
    - From empirical investigation of human reasoning
    - See follow up lecture for details.
  - Artificial Intelligence: It is NOT mathematical formal logic
    - Non-monotonic Reasoning/Logics (NMR/L)
    - BUT this should still be based on Classical Formal Logic
      - Keep notions of truth and possible models
      - New Logics build on top of underlying formal logic
    - Examples on NMR/L: Default Logic, Autoepistemic Logic, Circumscription, Negation as Failure, Belief Revision Logics, …
    - See follow up lecture for details.
  - There was/is a school of thought that claims that "humans ought to reason/think in the form of formal mathematical logic".
    - As this is the only correct form of reasoning – ορθώς σκέπτεσθε.
    - Driven by the central dogma of science!

Cognitive Programming

Automating Human Reasoning

- From Cognitive Psychology we have a notion of human reasoning (information processing by the mind) called COMPREHENSION
  - Used mainly in the context of natural language but not only.

COMPREHENSION will form the central notion of computation in Cognitive Programming

- Comprehension is the link and integration of the explicit information in a stimulus (e.g. a piece of text) with stored information or knowledge in the mind/brain
  - First we recognize the stimulus and then we may process it further by further integration with Common Sense Knowledge in our mind.

Foundations of Cognitive Programming

The central role of Comprehension in CP

- **Central hypothesis of Cognitive Programming:**
  - **Comprehension is the process that unlocks our Natural Intelligence captured in Natural Language and hence comprehension could be a basis of intelligent computation.**

- **So what is Comprehension?**

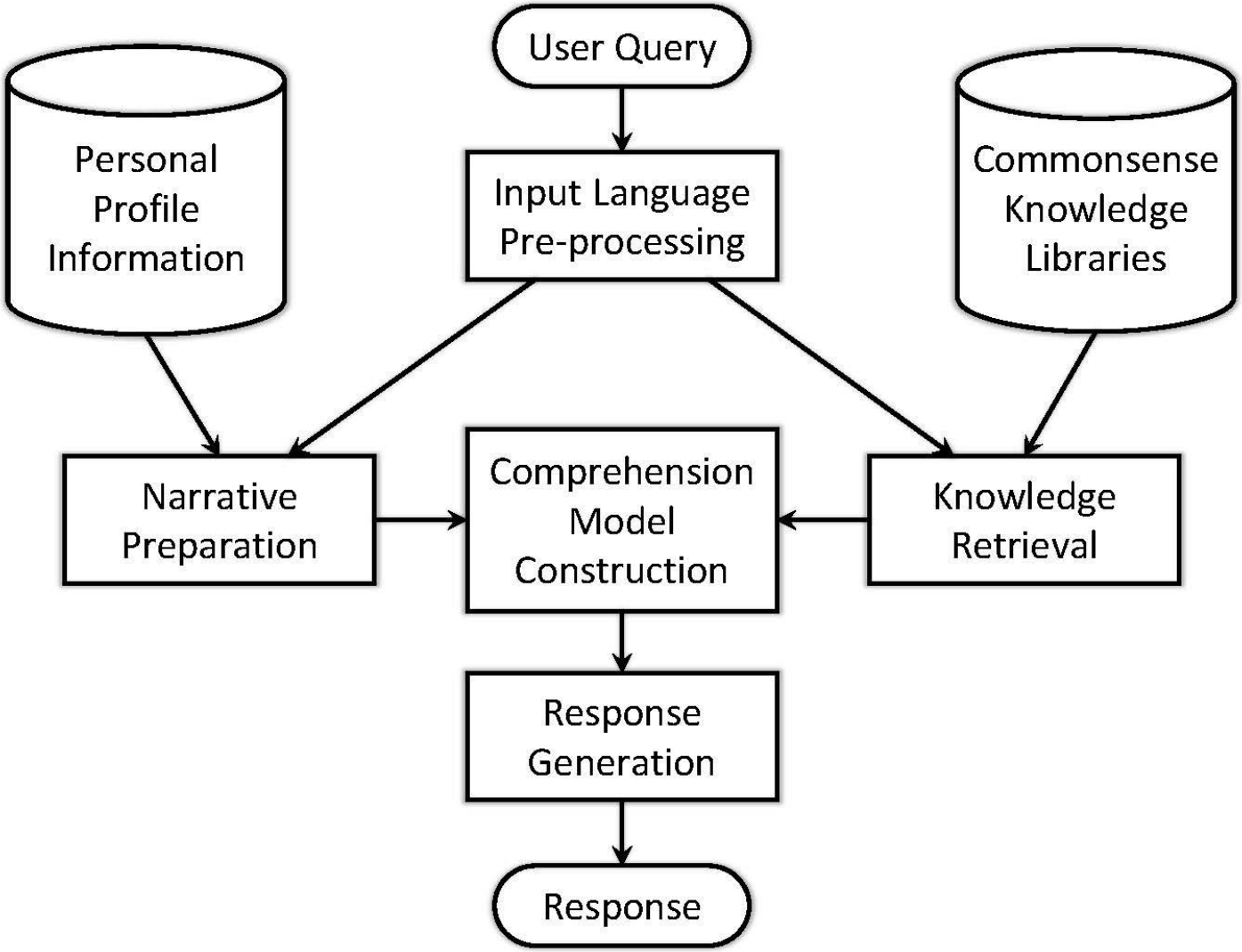
  How does Cognitive Psychology comprehend Comprehension?
  - **"It is the link between the explicit language input in text and the implicit world knowledge of humans – their common sense knowledge."**

  - **EXAMPLE: "Arrange dinner for my wedding anniversary"**
    - **Normally, people celebrate their wedding anniversary**
      - **Wedding anniversary "associates with/implies" Celebration**
      - **Wedding anniversary "supports an argument for" Celebration**
    - **Normally, a wedding anniversary is celebrated with one's spouse**
      - **{Dinner Celebration, Wedding Anniversary} "associates with/implies" Dinner_with_Spouse**
      - **{Dinner Celebration, Wedding Anniversary} "supports an argument for" Dinner_with_Spouse**

  - **Comprehension Model: {Celebration, Dinner with wife, Romantic Dinner, Vegetarian Restaurant, NO DOTS!!!}**

Cognitive Programming

General Architecture of Cognitive Systems



The central problems of Cognitive Programming?

- How do we formalize Comprehension?
  - What is the logical nature of human reasoning?
- **How do we represent Common Sense Knowledge?**
  - **As the Internal (execution) Language of the CP framework.**
- **How do we access from stimuli Common Sense Knowledge?**
  - **Natural language as the interface (programming) language of the CP framework**
- **How do we reason with Common Sense Knowledge?**
  - **Computational models of comprehension.**
- **How do we learn or acquire Common Sense Knowledge?**
  - **Build the CP libraries used in the execution of a Cognitive Program.**

Common Sense Knowledge drives Cognitive Programming!

- How do we represent Common Sense Knowledge?
  - As detailed rules or loose associations?
  - In one all-encompassing whole or in individual (context specific) parts?
- How do we access from stimuli Common Sense Knowledge?
  - Through a context that the stimulus gives? How is this determined?
  - By indexing a context-particular part of the knowledge or by splicing at runtime/thinking time such a context-specific knowledge set?
- How do we reason with Common Sense Knowledge?
  - What is a "correct" conclusion/inference?
  - Want correctness or goodness, persuasiveness of solutions?
  - What is the programming semantics of Cognitive Programming?
- How do we learn or acquire Common Sense Knowledge?
  - Unsupervised learning through experience, e.g. data mining over text corpora?
  - Nurturing, teaching, training, …?
  - Hand coding of the knowledge (c.f. Cyc from Cycorp Ltd)?

Common Sense Knowledge for CP

- Is it COMMON to all?
  - Mostly, yes.
  - But could differ at places, depending on experience
    - What differs?
      - Its content – the actual association of concepts?
      - Strength of association?

- Enhanced with "local common knowledge" specific to the user(s).
  - Local knowledge about our home.
  - Local knowledge about our habits at home

- Example
  - Bob: "We heard the phone but could not answer it"
  - Ann: "Is John awake?"

What is the essential problem of designing and building Cognitive Systems in CP?

- **Understanding computationally the nature of human reasoning/thought/inference – of Comprehension**
  - **Forming computational models of cognition - of Comprehension**
- **Finding the heuristics/optimizations that the brain has evolved in its operation of cognition and thought – of Comprehension**
  - **Particularly, in its use of Natural language as a reasoning language - for Comprehension**
- **Automatically acquiring the (common sense) world knowledge on which cognition – Comprehension - is based.**

Comprehension – Illustrative examples

- **Example 1: Text: "The doorbell rung" or Audio:** 
  - **Inference: "Someone is at the door"**
    - **CSK: Normally, a doorbell is rung by somebody.**
      Normally, people who ring wait at the door.
  - **Inference: "This someone does not have the keys"**
    - **CSK: Normally, a doorbell is rung by somebody.**
      Normally, people who ring wait at the door.
  - **Inference: "This someone does not live here"**
    - **CSK: Normally, …**
  - **Inference: "This someone is my flatmate, Bob"**
    - **Local knowledge: Normally, Bob forgets his keys.**
      Normally, he comes back from work at this time.
- **Next input: Text/Audio: "Police, …"**
  - **Revision of Inference: "It is not Bob"; Explanatory Inference:**

Comprehension – Illustrative examples

- **Example 2 – a two sentence conversation:**
  - **Bob: "We heard the phone but could not answer it"**
  - **Ann: "Is John awake?"**

- **Inference by Ann: "John is awake"**
  - **Normally, if one hears the phone is awake**
  - **Normally, a phone is heard by people inside the house**
  - **Normally, "we" implies many - Grammatical Knowledge**
  - **Local knowledge: At home there is Bob and John**
    - **Inference: "Many is Bob and John"**

- **Note the qualitative nature of CSK and CS Reasoning.**
  - **Not mathematical.**
  - **Not explicitly quantitative!**

- **Combines: Grammatical, Spatial and Naïve Arithmetic Knowledge.**

- **Bob: "Penny, is already here."**
  - **Revision of inference by Ann: "John is asleep"**
    - **Local knowledge: "John does not wake up before 9am."**

Comprehension in Application Problems

- **Cognitive Web Search Assistant**
  - **“Fast way from London to Manchester not public transport”**
  - **“Survey paper on cognition”**
  - **“A recipe for success at work”**
    - **“How to be successful at work?”**

  - **By comprehending the query through common sense knowledge, we can focus the search according to the indention of the user.**
    - **By posing a new query constructed from the comprehension inferences**
      - **“London to Manchester by plane or car”**
      - **“Flights London to Manchester”**
      - **“Scientific survey paper on cognition**

  - **With local knowledge:**
    - **“Arrange dinner with Giuseppe and family”**
    - **“Giuseppe and family arrive on Thursday. Search for restaurants & music”**
      - **‘restaurant (Putney OR Hammersmith) “gluten-free” –Italian’**
      - **’25th July evening “live jazz” inner London’**

Comprehension in Application Problems

- **Cognitive Home Assistant**
  - **What is an appropriate corpus of Common sense knowledge?**
    - **Background general common sense knowledge**
      - **Opening windows freshens the house**
      - **Opening all windows causes a draft in the house**
      - **Opening windows on a windy day dirties house**
    - **Background specific common sense knowledge**
      - **Configuration of the specific house – rooms and windows**
    - **Local knowledge of needs and preferences of the user**
      - **Policy that depends on a good comprehension of the instruction of the user under the current comprehended situation.**
- **Specify in the form of informal rules, a part of the relevant common sense knowledge for a home assistant**

Cognitive Systems – Applications – From lecture1

- **Cognitive Home Assistant**
  - Behaves similarly to a human assistant – a butler!
  - NOT build by detailed programming of actions to be performed under conditions:
    - WHEN Temp < 20 THEN Turn_on_heating
    - WHEN Temp = 23 THEN Turn_off_heating

    What happens when temperature is bigger than 23? Or at 20° we say we are cold?
    What happens when there is a sick child in the house with fever?
    What happens when we have a party with the house full of people?

  - Build by instructing it about our needs/desires and our preferences amongst them:
    - Keep home warm but economize.
    - John has a fever today.
    - We are having a party tonight with 10 people.

    using common sense knowledge about home living and personal information of the specific human user (and home).

- **Similarly, Trip and Hotel Assistant**
  - In terms of purpose of trip (business or pleasure), alone/with family, interests, etc.

- Define a high-level instruction language for these Cognitive Assistants?