COMP41400 - Multi-Agent Systems

Question

Task 3:

```
rule +!light(string light, string state) {}
```

Why is this empty goal necessary?

Agent Speak

https://jason.sourceforge.net/jBook/SlidesJason.pdf

The main language constructs of AgentSpeak are:

- Beliefs
- Goals
- Plans

The architecture of an AgentSpeak agent has four main components:

- Belief Base
- Plan Library
- Set of Events
- Set of Intentions

Beliefs and Goals

Beliefs represent the information available to an agent (e.g., about the environment or other agents).

- `publisher(wiley)`

Goals represent states of affairs the agent wants to bring about (come to believe, when goals are used declaratively)

- Achivement goals: `!write(book)`

Or attempts to retrieve information from the belief base

- Test goals: `?publisher(P)`

Events and Plans

- An agent reacts to **events** by executing plans
- Events happen as a consequence to changes in the agent's beliefs or goals
- **Plans** are recipes for action, representing the agent's know-how
- An AgentSpeak plan has the following general structure:
  - `triggering_event : context <- body.`
  - the `triggering event` denotes the events that the plan is meant to handle
  - the `context` represent the circumstances in which the plan can be used

    - the `body` is the course of action to be used to handle the event if the context is believed true at the time a plan is being chosen to handle the event.
- AgentSpeak triggering events:
    - `+b` (belief addition)
    - `-b` (belief deletion)
    - `+!g` (achievement-goal addition)
    - `-!g` (achievement-goal deletion)
    - `+?g` (test-goal addition)
    - `-?g` (test-goal deletion)
- The context is logical expression, typically a conjunction of literals to be checked whether they follow from the current state of the belief base
- The body is a sequence of actions and (sub) goals to achieve

AgentSpeak Plans

```
+green_patch(Rock)
        : not battery_charge(low)
        <- ?location(Rock,Coordinates);
                !at(Coordinates);
                !examine(Rock).
```

```
+!at(Coords)
        : not at(Coords)
                 & safe_path(Coords)
        <- move_towards(Coords);
                !at(Coords).
```

Week 01

How can we judge if something is intelligent?

The Turing Test ? An **interrogator** communicates with a **human** and a **machine** using a teletype for at least 5 minutes. He then has to decide which participant is **human** and which is **machine**.

- When was the Turing Test proposed?:: 1950 in Turing's Paper: Computing Machinery and Intelligence.

Searle's Chinese Room ? A thought experiment where a non-Chinese speaker follows instructions to manipulate Chinese characters, responding to input in a way that appears intelligent. The person inside the room does not actually comprehend the meaning of the Chinese characters.

Searle argues that merely manipulating symbols according to a program does not constitute genuine understanding, and therefore computers executing programs cannot be said to truly think or have consciousness.

Traditional focus on a single intelligence…

- How to **model** and **reason** about the world?
- How to **act rationally** (decisions + plans)?
- How to **learn** from experience?
- How to **process and understand** speech and vision?

Knowledge is complex to capture accurately:

- The **Tactic Knowledge Problem**:: We often rationalize what we do *after* we do it.
- The **Dynamic World Problem**:: The world has changed *before* we decide what to do.
- The **Symbol Grounding Problem**:: How to map symbols to things.
- The **Uncertain World Problem**:: How to reason effectively with incomplete and uncertain knowledge.

Introduction to Multi-Agent Systems

Multi-Agend Systems (MAS) is a branch of {{Distributed Artificial Intelligence (DAI)}}.

What is a Multi-Agent System? ? A Multi-Agent System is a computer system that is composed of **multiple computational entities**, that **interact** with one another in order to **solve problems** that are **beyond their individual capabilities**.

- Multiple agents **embedded / situated** in some **environment**.
- **Coordination** among problem solvers, potentially with diverse **objectives and interests**.
- Understanding **teamwork**, **cooperation** and **coordination**.
- Exploring **conflict** and **competition**.

⇒ Socially socially model of computing

- Agents are rational actors / decision makers
- Social structures help coordinate activities for the greater good

What is an Agent? ? An encapsulated computer system, situated in some environment, and capable of flexible autonomous action in that environment in order to meet its design objectives.

- **Autonomous:** Control over internal state and own behaviour
- **Situated:** Experiences environment through sensors and acts through effectors
- **Flexible:** - Reactive: Respond in a timely fashion to environmental change - Proactive: Act in anticipation of future goals

Definition of Agency

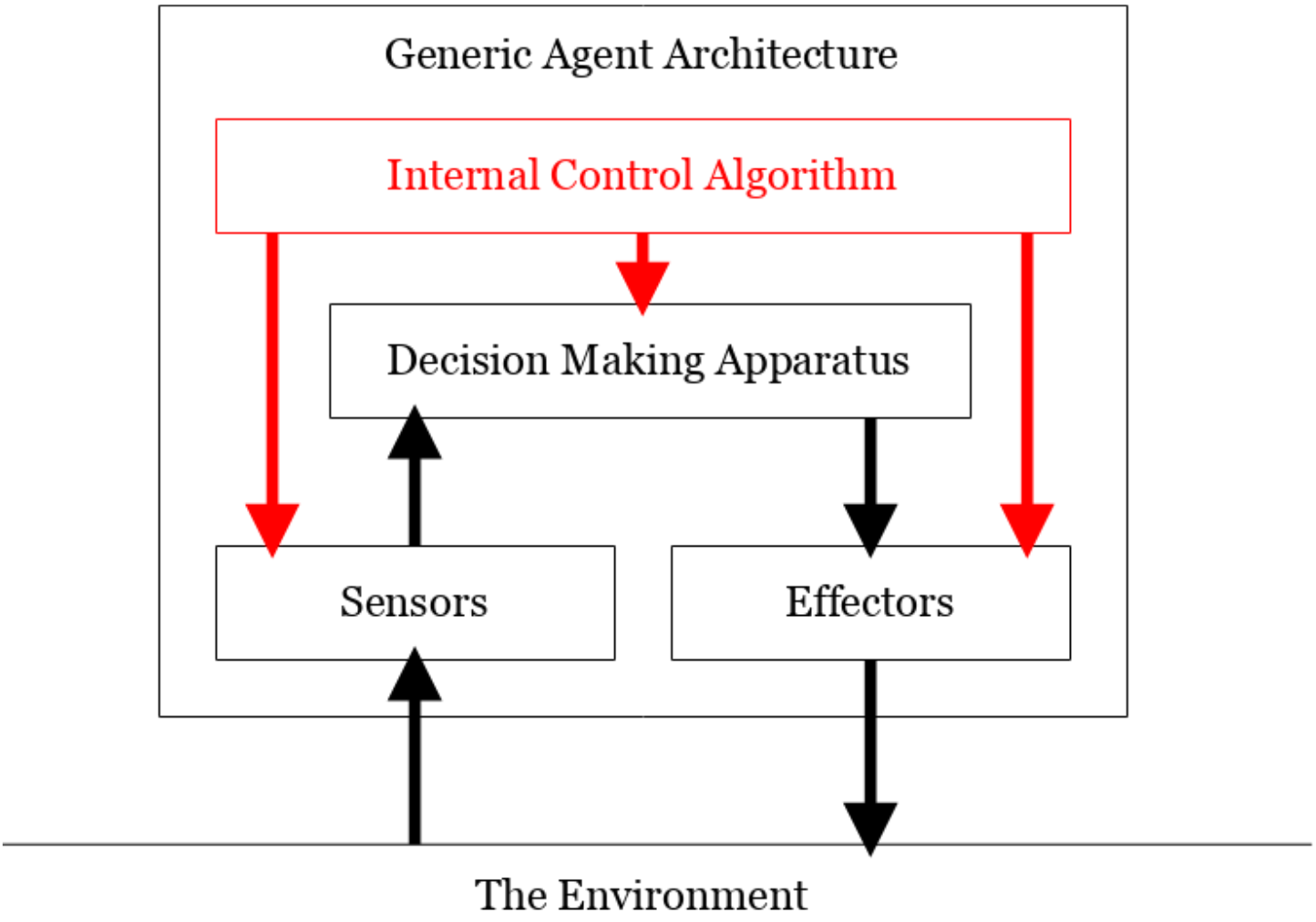
What are the agent attributes of **lower tier agency?** ?

- **Autonomy**: Agents operate without the direct intervention of humans or others and have some kind of control over their actions and internal state.
- **Social Ability**: Agents interact with other agents and (possibly) humans via some kind of agent communication language.
- **Reactivity**: Agents perceive their environment (which may be physical the world, a user via a graphical user interface, a collection of other agents, the Internet, or all combined), and respond in a timely fashion to changes that occur in it.
- **Pro-activity**: Agents do not simply act in response to their environment, they are able to exhibit goal-directed behavior by taking the initiative.

What are the Agent attributes of **upper tier agency?** ?

- **Mobility**: The ability of an agent to move around an electronic network.
- **Benevolence**: Is the assumption that agents do not have conflicting goals, and that every agent will therefore always try to do what is asked of it.
- **Rationality**: Is the assumption that an agent will act in order to achieve its goals and will not act in such a way as to prevent its goals being achieved, insofar its beliefs permit.
- **Intentionality**: An agent reasons about its activities through the application of mental notions such as beliefs, goals, obligations, commitments, intentions, …

Anatomy of an Agent ?



Introduction to Agent-Based Modelling

What is Agent-Based Modelling? ? Agent-Based Modelling (ABM) is an approach to simulating systems that consist of a population of things that interact and where the behavior of the system emerges through those interactions. Things can be…

- Biological: People, Animals, Plants, Molecules, …
- Physical: Autonomous Vehicles, Satellites, …

How does Agent-Based Modelling work? ?

- Modelling **behavior over time**
- Time is modelled as a **logical (discrete) series of time points**
- Each agent performs **one action at each time point**
- The next time point is not reached until **all agents have completed executing**
- Actions are contextual, based on the current state of the agent / environment
- Actions update the state of the agent / environment.

Where is Agent-Based Modelling used? ?

- Non-Linear Complex Systems → Weather, Stock Market, Crowds
- Non-Markovian Systems → Swimming in a pool, selection without replacement
- Systems that exhibit emergent behavior → Ant colonies, Bird / Dish flocking behavior, traffic patterns

What is the Disease Progression SEIRD Model ?

- **Susceptible**: Can pick up the infection
- **Exposed**: Infected but not infectious

- **Infectious**:
  - Presymptomatic: No signs of infection
  - Mild/Severe/Critical: Degree of infection
  - Asymptomatic: No sign of infection
- **Recovered**: Survived infection
- **Dead**: Succumbed to infection

Week 02

Knowledge Representation & Reasoning

Types of Knowledge ?

- **Declarative Knowledge:** How to represent what we do? e.g. facts, concepts, objects, databases
- **Procedural Knowledge:** How to do stuff? e.g. rules, strategies, procedures
- **Meta-Knowledge:** Knowledge about Knowledge e.g. planning, modelling, tagging
- **Heuristic Knowledge:** Applied knowledge that is good but not guaranteed e.g. rules of thumb, insights
- **Structural Knowledge:** How to integrate / interrelate knowledge e.g. kind of, part of

Types of Reasoning ?

- **Deductive Reasoning:** Apply general theories (knowledge) to observations (observed facts) to infer new facts. *All men are mortal. Socrates is a man → Socrates is mortal.*
- **Inductive Reasoning:** Build general theories (knowledge) from observations (facts). *Cats and Dogs Breeds Classification Dataset.*
- **Abductive Reasoning:** Use general theories (knowledge) and incomplete observations to get the most plausible conclusion. *Learning to navigate a maze using Reinforcement Learning.*

Knowledge Representation Techniques ?

- Semantic Networks
- Frames
- Knowledge Graphs
- Expert Systems

Semantic Network:: Graph-based representation of knowledge. Using graphs to model relationships between concepts.

Frame-Based Systems:: A frame is a data structure for representing a stereotyped situation. A Frame consists of Facts / Data, Procedures, Default Values and other Frames / Subframes.

Knowledge Graphs:: Graph of data intended to accumulate and convey knowledge of the real world, whose **nodes represent entities of interest** and whose **edges represent relations** between these entities. Example: Resource Description Framework (RDF).

Expert Systems:: Focus on procedural knowledge. Rules describe how to infer knowledge from existing knowledge. Knowledge is encoded declaratively as propositions (facts) that can be true or false. Starts with **initial state** and combines general rules to derive **additional state information** from the current state. Examples: Shrdlu, Shakey.

Physical Symbol System Hypothesis

What does the Physical Symbol System Hypothesis state? ? The PSSH states that intelligence emerges from the manipulation of symbols according to specific rules (algebra, chess, formal logic).

What is the criticisms of the Physical Symbol System Hypothesis? ?

- Works for high-level intelligence (e.g. chess) but not on everyday cognitive tasks
- Not all symbol representations are meaningful
- Oversimplifies the complexity of human cognition → Chinese Room, no understanding required when manipulating symbols

Logic and Domain Modelling

Propositional Logic ?

- Deals with whole statements
- Binary (true/false) values
- Simple logical operators (AND, OR, NOT)
- Cannot analyze internal statement structure
- Limited reasoning capabilities

Predicate Logic ?

- Analyzes statement components
- Uses variables and quantifiers
- More complex logical operations
- Can handle nuanced truth conditions
- Deeper logical reasoning

Practical Reasoning

- **Physical Stance**:: Domain of physics and chemistry. Concerned with mass, energy, velocity, chemical composition → Predicting where a ball will land based on trajectory.
- **Design Stance**:: Domain of biology and engineering, concerned with purpose, function and design → Predicting that a bird will fly when flapping its wings, because that is what wings are for.
- **Intentional Stance**:: Domain of software and minds, concerned with belief, thinking and intent → Predicting the bird will fly away because it knows the cat is coming and is afraid of being eaten.

What does building a decision model involve? ?

- Selecting **mental attitudes** and formalize their relationship
- Designing **mental state architecture** and **decision-making algorithm**

Taxonomies on mental attitudes ?

- **Informational Attitudes:** knowledge, beliefs, emotions
- **Pro-Attitudes:** desires, goals, obligations, intentions
- Any mental state architecture should contain at least one mental attitude from each class

What is practical reasoning?:: Practical reasoning is a matter of weighting conflicting considerations for and against competing options, where the relevant considerations are provided by what the agent desires / values / cares about what the agent beliefs → Figuring out what to do.

Practical reasoning consists of two activities ?

- **Deliberation**: Deciding what we want to achieve
- **Means-end Reasoning**: deciding how to achieve it

The Belief-Desire-Intention (BDI) architecture ?

- **Beliefs**: Current state of the environment
- **Desires**: Ideal future state of the environment → Drive agent's activities and are satisfied when agent beliefs that it has achieved them
- **Intentions**: Subset of the desires that the agent commits to → Achieved through application of means-end reasoning

Role of Intentions in Practical Reasoning ?

- Intentions pose problems for agents who need to determine ways of achieving them
- Intentions provide a "filter" for adopting other intentions, which must not conflict
- Agents track the success of their intentions and are inclined to try again if their attempts fail
- Agents believe their intents are possible
- Agents do not believe they will not bring about their intentions
- Under certain circumstances, agents believe they will bring about their intentions
- Agents need to intend all the expected side effects of their intentions → side effect or package deal problem

Means-End Reasoning

What is Means-End Reasoning?:: The process to work out plans that will be used to achieve intentions.

- **Means:** how to achieve something (the plan)
- **Ends:** what we want to achieve (the intention)

A plan is a specific set of sequence of actions that the agent should perform to achieve its ends.

Means-End Reasoning Strategies ?

- **Planners**: automatic programming - plans are created on demand to achieve each end as it arises → e.g. STRIPS (Shakey)
- **Plan Libraries**: procedural programming - (partial) plans are written in advance and are selected based on current ends → e.g. AgentSpeak(L)
- **Hybrid Systems**: combined approach - planning is used where no suitable pre-existing plan exists → e.g. Hierarchical Task Network
- **Reactive Plan**: plans are collections of reactions that define what action to perform in each state → e.g. Teleo-Reactive Programming

What is planning? ? Transforming some initial state into a desired goal state through the application of a set of actions.

What are planners? ? Planners are software systems that can automatically create plans.

- Input: current state, goal state and available set of actions
- Output: sequence of actions (the plan)

STRIPS

What is STRIPS?:: A search-based approach to planning that overcomes the frame problem by distinguishing between theorem proving and planning using **states** and **operators**.

- **States:** represented as a set of formulas. A set of facts and inference rules.
- **Operators:** action routine descriptions that define valid potential transitions between states.

The BDI Agent Control Loop

BDI Agents implement the following algorithm ?

- **Perceive:** Gather sensor data and update beliefs
- **Reason:** Update Desires & Intentions based on modified beliefs
- **Act:** Execute 1 or more actions based on the current intentions of the agent

Commitment Strategoes

The following commitment strategies are commonly discussed in the literature of rational agents:

Commitment Strategies ?

- **Blind Commitment:** continue to maintain an intention until the agent beliefs it has been achieved. Also called fanatical commitment.
- **Single-minded commitment:** continue to maintain an intention until the agent believes it has been achieved or it is no longer possible to achieve that intention.
- **Open-minded commitment:** maintain an intention as long as it is still believed possible.

Week 3

Agent-Oriented Programming

Agent-Oriented Programming:: Based on the idea of programming agents as mental entities.

Week 4

Agentification:: Developing software / hardware that integrates with agents and non-agent systems → agentifier: like an interface

Alternatively to agentification, we can introduce the idea of an environment.

EIS:: Environment Interface Standard

Agents & Artifacts Model:: Environments are workspaces containing artifacts that agents create, share, use, adapt for their work.

Agents & Artifacts Basic Concepts ?

- **Agents**: Autonomous goal/task-oriented entities. Create and co-use artifacts for supporting their activities.
- **Artifacts**: Non-autonomous function-oriented entities. Modelling the resources and tools used by agents.
- **Workspaces**: Grouping of agents and artifacts. Shared space in which agents interact.

Artifact Model Features ?

- Based on concepts **use** and **observation**
  - Triggering execution of operation by acting on artifact usage interface
  - Perceiving **events** or **properties** (beliefs)
- Artifacts are controllable and observable things

Categories of Artifacts ?

- **Personal Artifacts**: Designed to provide functionalities for a single agent use
- **Social Artifact**: Provides global functionalities (communication, coordination, organization)
- **Boundary Artifacts**: Interfaces to represent external systems (DB, GUI, web service)

CArtAgO

What is CArtAgO?:: Platform / infrastructure implementing the Agents & Artifacts Model → Runtime environment for executing artifact-based environments.

Week 5

What is interaction?:: Sharing of information / tasks between nodes within some distributed system to achieve some common goal.

Types of Interaction in MAS ?

- **Shared Resources**: interaction is achieved through shared resources that allow both implicit and explicit sharing of data.
- **Message-oriented**: interaction is achieved by transmission of discrete messages between nodes.

Coordination Languages (Tuple Spaces)

- **What is a tuple?**:: Immutable ordered list of 1 or more values.
- **What is a tuple space?**:: Shared memory consisting of multiple tuples that may be interacted with by one or more processes (agents).

Tuple Space Operations ?

- Creating (Out Operation): `Out("Rem", 48)`
  - Adds tuple to tuple space, must be unique
- Reading (Rd Operation): `Rd(string:name, int:age)`
  - Template (parameters as vars)
  - Matches template and returns one matching tuple (non deterministic)
- Deleting (In Operation): `In(string:name, int:age)` - Same as reading, but removes matched tuple

Shared Resource Interaction

Benefits of Shared Resource Interaction ?

- **Extensibility**: all agents communicate via shared space
- **Good for sharing large quantities of data**
- **Broatcast**: Supports 1:m communication
- Easy to **monitor and manage system activities**

Drawbacks of Shared Resource Interaction ?

- **Loss of Privacy**: Information is (potentially) public
- **Information Overload**: Bad design can lead to large quantities of data

Agent Communication Languages

What is message-based interaction?:: Explicit form of interaction where the agents interact using Message Transport Services.

Core Concepts of Speech Act Theory ?

- **Locutionary Act**: The actual utterance and its literal meaning In software: The act of sending a message
- **Illocutionary Act**: The intended meaning or purpose behind the utterance In software: The contents of the message
- **Perlocutionary Act**: The effect the utterance has on the listener In software: The effect of the message

What are the Five Main Types of Speech Act Theory? ?

- **Assertive:** Statements that represent facts or beliefs
- **Directive:** Attempts to get the listener to do something
- **Commissive:** Commitments to future actions
- **Expressive:** Expressions of feelings or emotions
- **Declarative:** Utterances that bring immediate changes to reality

What are the 5 identified categories of Illocutionary Acts? ?

- representatives
- directives
- commissives
- expressives
- declaratives

Searle's Theory ? Speech acts can be decomposed into 2 core components:

- A performative verb (e.g. request, inform)
- Propositional content (e.g. the window is closed)

What are Agent Communication Languages (ACLs) ? A format for representing contents of a message: performative + content. ACLs define a set of performatives and and associated meaning (semantics) for them. Semantics define how messages affect mental state.

What ACLs are there?

- 1994 - Knowledge Query and Manipulation Language (KQML) → developed for expert systems interaction
- 2000 - Foundation for Intelligent Physical Agents (FIPA) ACL

KQML and KIF

- **KSE**:: Knowledge Sharing Effort → concept for knowledge sharing, which requires a common language. KSE defined a common language.
- **KQML**:: Knowledge Query and Manipulation Language. Language for message formatting and message handling protocols.
- **KIF**:: Knowledge Interchange Format. Language for expressing message content.

How do KQML and KIF relate?:: KQML is an outer language that defines communicative verbs or performatives. KIF is a language for expressing message content. KIF is central to KQML as it provides the common language for expressing information (knowledge). Agents must agree in advance what things mean → must have shared ontology.

What are KQML faciliators:: A special class of agents that perform useful communication services, like forwarding / routing messages, matchmaking, mediation, translation, registry.

What KQML faciliators exist? ?

- **Point-to-point protocol**
- **Subscribe**
- **Broker**
- **Recruit**
- **Recommend**

KQML Criticism ?

- No defined transportation mechanism
- Set of performatives is large and ad hoc
- Lacked the class of performatives: commissives → not possible to communicate commitment to actions. W/o that, it is difficult to implement multi-agent scenarios.
- Weak semantics of performatives → different implementations of KQML not interoperable

FIPA ACL

FIMA = Foundation of Intelligent Physical Agents.

What is FIPA:: Official standards body for multi-agent systems. Standardizes concept of an agent and underlying machinery. Promotes interoperability between technologies and systems.

FIPA ACL Structure ?

- 20 performatives in FIPA ACL
- Housekeeping → Sender, Reply to, Reply-with, In-Reply-With
- Content → Actual content of the message
- Language → The language in which the content is written
- Ontology → The ontology in which the message needs to be interpreted

FIPA Interaction Protocols ?

- Propose Protocol
- Query Protocol
- Request Protocol
- Cancel Meta-Protocol
- Subscribe Protocol
- Recruiting Protocol
- Brokering Protocol
- Request When Protocol
- English and Dutch Auctions, (Iterated) Contract Net

Message-Oriented Interaction

Communication Channels are used to route messages

- Asynchronous and private 1:1 communication
- Transport independent
- Build on standards

Message-Oriented Interaction Benefits ?

- Well suited to internet scale applications
- Communication can be direct and (less) public

Message-Oriented Interaction Drawbacks ?

- Requires Agent Discovery mechanism
- Knowledge level interaction → not good for large scale data transfer
- Difficult to monitor because decentalized

Week 5

Coordination

What is Coordination?:: The process by which an agent reasons about its local actions and the (anticipated) actions of others to try and ensure that the community acts in a coherent manner.

Why coordinate? ?

- Preventing anarchy or chaos
- Dependencies between agents' actions
- Need to meet global constraints
- No individual has sufficient competence, resources or information to solve the entire problem
- Efficiency

Types of Coordination ?

- **Task sharing**: A problem is decomposed into subproblems and allocated to different agents
  - **Assigned dynamically** at run-time based on agents **capabilities**
- **Result sharing**: Agents share information relevant to their subproblems - **Proactively:** agent sends information to others - **Reactively:** Agent sends information in response to a request

---

Week 7

Contract Net

What is Contract Net?:: A protocol for task sharing.

What are the key stages of Contract Net? ?

1. **Recognition:** Agent recognizes it has a problem it wants help with
2. **Announcement:** Agent announces task with specification
3. **Bidding:** Agents decide whether they wish to bid for the task
   - If agent bids, it submits tender with conditions on which it can execute task
4. **Awarding:** Agent chooses between bids & decides who to award the contract to
5. Expediting

Negotiation

What is negotiation?:: The process of several agents searching for an agreement. Reaching consensus.

One-to-One Negotiation

Monotonic Concession Protocol

What is the Monotonic Concession Protocol?:: A negotiation framework in which two agents reach agreement.

How does Monotonic Concession Protocol Work? ?

- In **first round** both agents make **initial proposal**
- In **subsequent rounds** each agent can make either a **concession** or **stick** with their current proposal. **Concession**: Proposal that is better for the opponent than own previous proposal.
- Keep going until either **agreement** is reached or **conflict** arises

What are the Possible Outcomes of the Monotonic Concession Protocol? ?

- **Agreement**: Agent makes proposal that is better for the opponent than the opponent's own proposal (or as good as)
- **Conflict**: No agent concedes → worst possible outcome

Multilateral Concession Protocol

Similar to monotonic concession protocol, but as many-to-many negotiation.

How does the Multilateral Concession Protocol work? ?

- Many-to-Many negotiation
- **Protocol**: Each agent must message the N other participants (or centralized resource is used)
- **Conflict**: Nobody concedes
- **Agreement**: One agent makes a proposal that everyone likes at least as much as their own proposal
- **Concession**: Unclear what happens

One-to-Many Negotiation (Auctions)

What are the parties of an auction? ?

- **Auctioneer**: goal is to allocate the goods to one of the bidders and desires to maximize the prize
- **Bidders**: Desire is to minimize the prize.

English Auctions

How does the English auction work? ?

1. Auctioneer starts a round by specifying the current minimum price (reserve price)
2. Bidders propose bid > current minimum prize
    - Bidders who don't want to bid do not submit a proposal
3. Auctioneer compares proposals and selects the best - Accepts best bid, rejects others - If no better bid has been found, the item is awarded to the agent with the highest bid from the previous round - If agents make the same bids, a resolution strategy is required (e.g. first bid received)

English auction dominant strategy:: Successively bid small mount more than highest current bit until valuation reached, then withdraw.

English auction is susceptible to… ?

- **Winners course**: Winner is the one who overvalues the goods and may end up paying more than its worth
- **Shills**: Artificial raising of bidding price by auctioneer through bogus bidders

Dutch Auctions

How does the Dutch Auction work? ?

1. Auctioneer starts round specifying a high bid > expected sale price
2. Bidders agree / disagree with the valuation
    1. No bidder agrees → auctioneer lowers price
3. First bidder to accept the current price is winner
4. If price reaches a reserve level with no bids, the item is withdrawn

Dutch auction dominant strategy:: None.

Dutch auction is susceptible to… ? Winners curse

First-Price Sealed-Bid Auctions

How does the First-price Sealed-bid Auction work? ?

- One shot auction
- Single round, where bidders submit sealed-bid of the good
- Goods are awarded to agent that made highest bid

First-price Sealed-bid Auction dominant strategy:: Bid less than true value.

Vickrey Auctions

How does the Vickrey Auction work? ? The highest bidder wins the auction but pays the second-highest bid amount instead of their own bid → encourages to bid more genuinely.

Distributed Planning

Distributed Planning Models ?

- **Centralized Planning**: Single (master) agent responsible for creating a plan for the workers (slaves) Master maintains models of workers capabilities
- **Distributed Planning**: Group of (master) agents cooperate to form centralized plan and assign plan to workers (possibly themselves)
- **Distributed Plans**: Agents cooperate by forming individual plans and coordinate activities along the way AgentSpeak(L) way

Stages of Partial Global Planning ?

- Each agent generates short-term plans themselves
- Agents exchange information to determine where plans interact
- Agents alter local plans to better coordinate their activities

Other Forms of Coordination

- **Joint Intention**:: Shared goal between agents that are collectively responsible for working together to achieve that goal.
- **Coordination by Mutual Modelling**:: Agent maintains an internal model of other agents and tries to model the behavior of other agents. Adapts its own behavior based on those predictions / expectations.
- **Norm & Social Law**:: Norm is an established and expected pattern of behavior → no penalties for breaking, but social exclusion / negative reputation. Social Law is enforced by some authority → penalties for breaking.

Organizational Patterns

What organizational Patterns exist? ?

- Hierarchy
- Market
- Network

Hierarchy Pattern

What is the Goal of the Hierarchy Pattern?:: Coordinate the flow of resources or information by controlling and directing it via some central point.

How does the Hierarchy Pattern work? ?

- Each agent controls sub-hierarchy (statically defined)
- Agents at lower levels are dependent on agents at higher levels
- Interactions are hardcodet into system implementation
- Managers agents control, coordinate and optimize sub-hierarchies

What is the Hierarchy Pattern good for?:: Closed systems, information agents and management of communication networks.

Hierarchy Pattern Key Infrastructure Agent Roles ?

- **Controller**: Monitor and orient performance of (sub-) system
- **Interface Agents**: Communication between system and 'outside world'

Market Pattern

What is the Goal of the Market Pattern?:: Facilitate exchange between self-interested agents.

How does the Market Pattern work? ?

- Heterogeneous agents: diverse services and competencies
- Agents compete to perform tasks leading to the satisfaction of own objectives
- Interaction through communication and negotiation
- Fixed negotiation rules
- Payoff immediate

What is the Market Pattern good for?:: Open systems, e-commerce, virtual enterprises.

Market Pattern Key Infrastructure Agent Roles ?

- **Identification**: Registration of society members
- **Matchmaker**: Tracks needs and services of agents, mediates matching
- **Banking**: Defines ways to exchange goods, determines profit and fairness of exchange

Network Pattern

What is the Goal of the Network Pattern?:: Facilitate collaboration between self-interested agents that have a mutual goal.

How does the Network Pattern work? ?

- Agents trade freedom for guarantees regarding security and trustworthiness

- Services may be traded for rewards (e.g. prestige)
- Relationships dependent on communication patterns and social norms
- Coordination achieved through mutual interest
- Coordination is governed by rules and sanctions

What is the Network Pattern good for?:: Open systems in which security and trust are essential.

Network Pattern Key Infrastructure Agents ?

- **Matchmaker**: Tracks needs and services of agents, mediates matching
- **Gatekeeper**: Accepts and introduces new agents to market and informs new agents of possibilities of the market
- **Notary**: Registers collaboration contracts between agents
- **Monitoring Agents**: Trusted third parties keep track of execution of collaboration contracts

---

Week 8

A {{Multi-Agent System}} is a computer system that is composed of {{multiple computational entities}}, that interact with one another in order to solve problems that are {{beyond their individual capabilities}}.

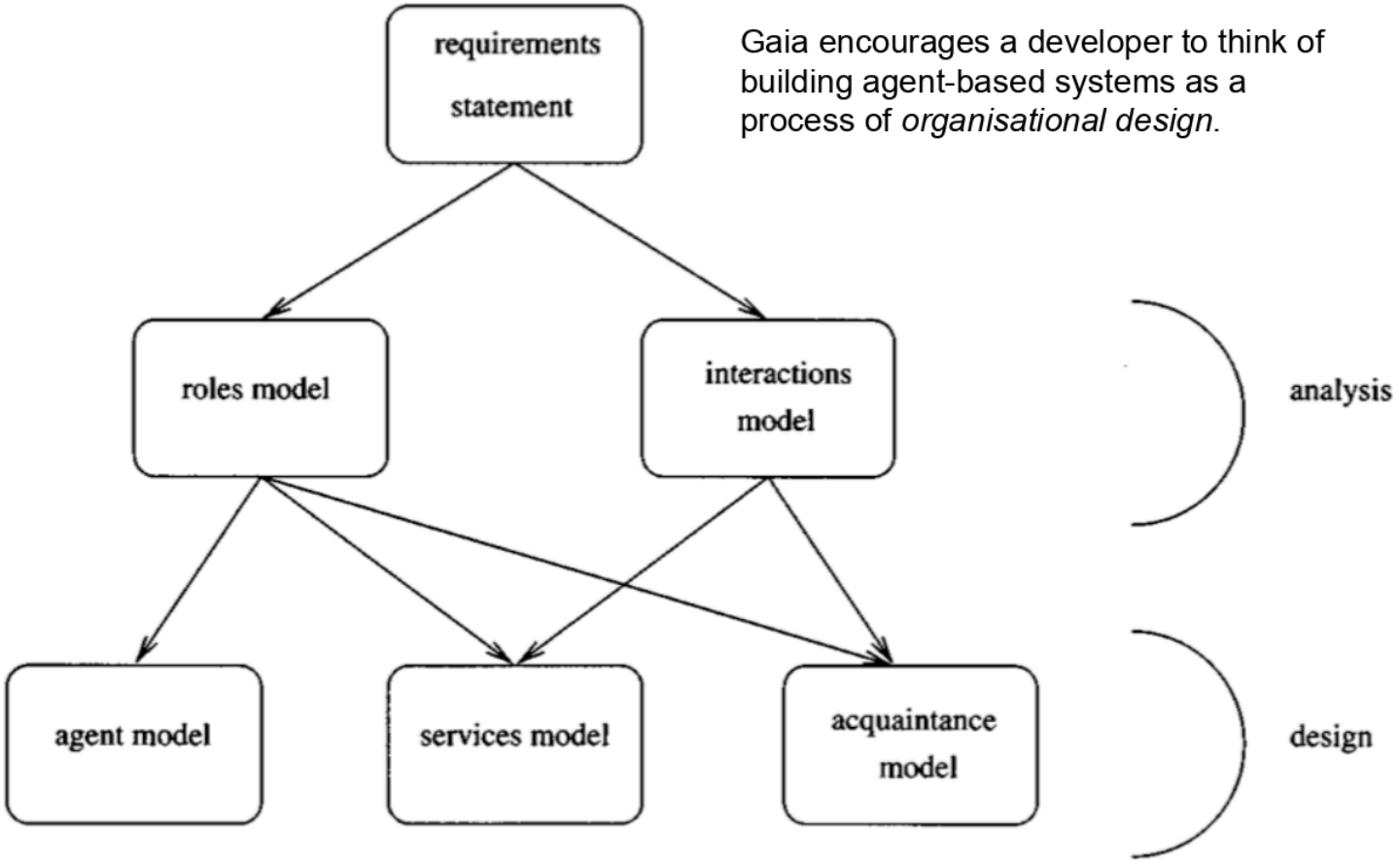
A {{Microservices-based System}} is a computer system that is composed of multiple services that interact with one another to deliver a set of business processes that {{span multiple individual services}}.

Week 10

GAIA

What is GAIA?:: Methodology for agent-oriented analysis and design. The Gaia methodology is both general, in that it is applicable to a wide range of multi-agent systems, and comprehensive, in that it deals with both the macro-level (societal) and the micro-level (agent) aspects of systems.

Explain the GAIA Process ?



Describe the Gaia Roles Schema ?

Role Schema:	*name of role*
Description	*short English description of the role*
Protocols and Activities	*protocols and activities in which the role plays a part*
Permissions	*"rights" associated with the role*
Responsibilities	
Liveness	*liveness responsibilities*
Safety	*safety responsibilities*

- **Liveness Responsibilities**: Those that, intuitively, state that "something good happens".
- **Safety Responsibilities**: Those that, intuitively, state that "nothing bad happens.

What happens during the GAIA Analysis Process? ?

1. Identify roles in the system (Unelaborated role model)
2. Identify and document associated protocols to each role (Protocol model)
3. Using the protocol model, elaborate the roles model (Elaborated role model)
4. Iterate 1-3 and refine models

What happens during the GAIA Design Process? ?

1. Create Agent model → aggregate roles into agent types
2. Develop Service Model by examining the activities, protocols and safety and liveness properties of each role
3. Develop Acquaintance Model from the Interaction Model and Agent Model

What are the GAIA Domain Characteristics? ?

- Agents are coarse-grained computational systems, each making use of significant computational resources
- Maximizes some global quality measure, but may be sub-optimal for system components → not intended for systems that admit possibility of true conflict
- Makes no assumptions about delivery platform → heterogeneous agents with different languages, architectures, techniques
- Supports development of closed systems: static structure in relationships and abilities of agents with few agent types < 100

Prometheus

What are the phases of Prometheus ?

1. **System specification**: Identify basic functionalities of the system
2. **Architectural design**: Identify system overview diagram - document agents, events and data in AUML
3. **Detailed design**: Develop internal structure of each agent and how it will achieve task within system