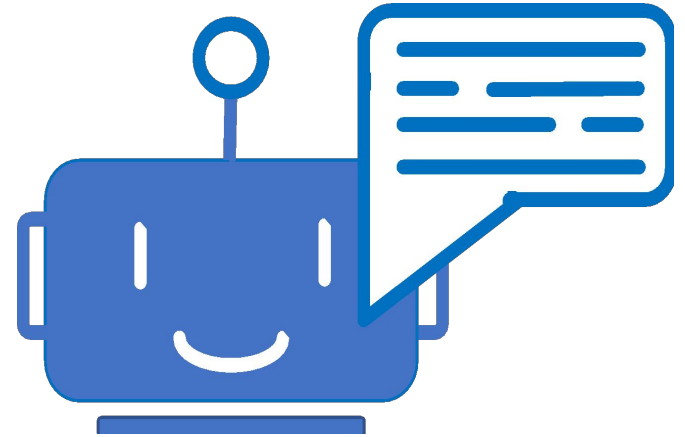# Let's talk, robots!
Dialogue Management in Human-Robot Interaction

Merle Reimann

Outline

1) Dialogue Management (DM)
   a) What is it and why do we need it?
   b) Rule-based approaches
   c) Probabilistic approaches
   d) Hybrid approaches

2) DM in HRI
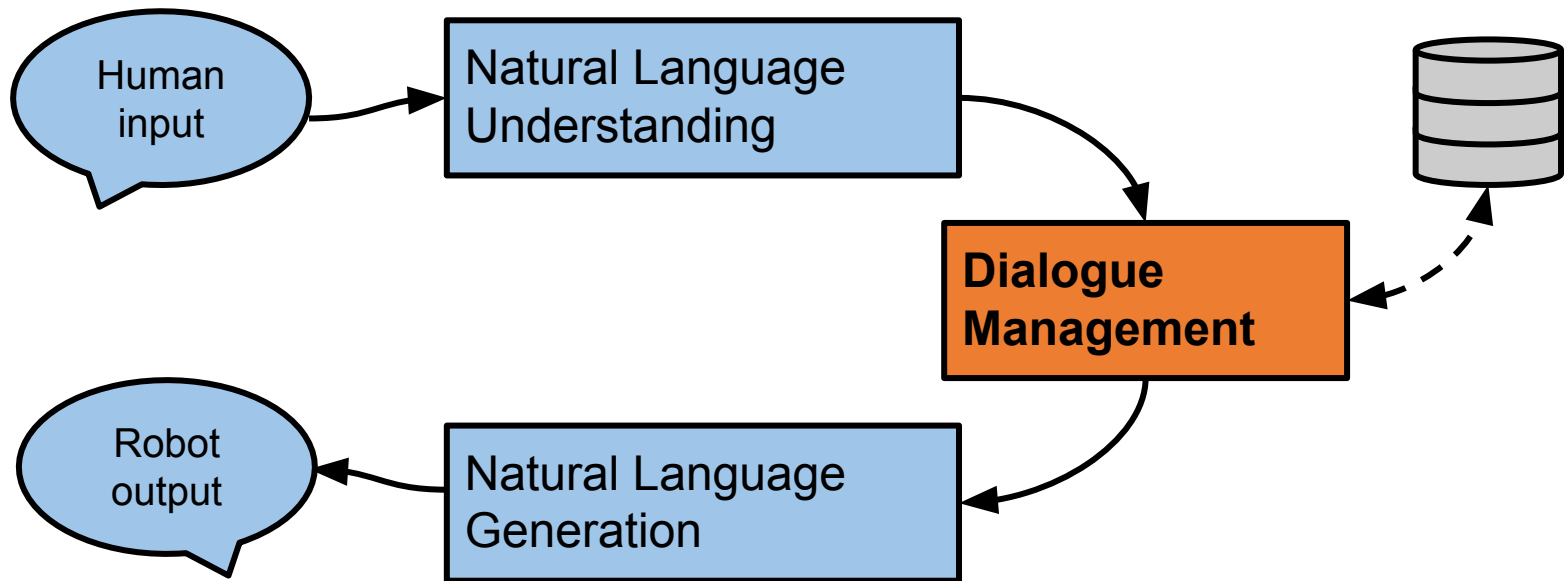   a) Challenges
   b) Robots
   c) DM
   d) Evaluation

What is DM?

According to Traum and Larsson (2003):

1) Updating the dialogue context

2) Providing context dependent expectations for interpretation

3) Coordinating other modules

4) Deciding the information to convey and when to do it

Human input → Natural Language Understanding → Dialogue Management

Dialogue Management → Natural Language Generation → Robot output

Dialogue Management

Complexity

- task
- flexibility
- initiative (system, user, both)

most important tasks

- encapsulates the logic
- largely responsible for user satisfaction

Why is it difficult?

Situated grounding
"Can you grab the blue cup that is next to the red block?"

Repair and Corrections
"When are we meeting for dinner today?"
"We are meeting at 6… no, at 7:30."

Repetition
"My favourite animals are bumblebees."
"Sorry, I wasn't listening. What did you say?"
"I just said that I like bumblebees. They are cute."

Confirmations
"Did I understand it correctly that your favourite word is gobbledygook?"
"Yes, that's correct."

Clarifications
"What do you want to have for dinner?"
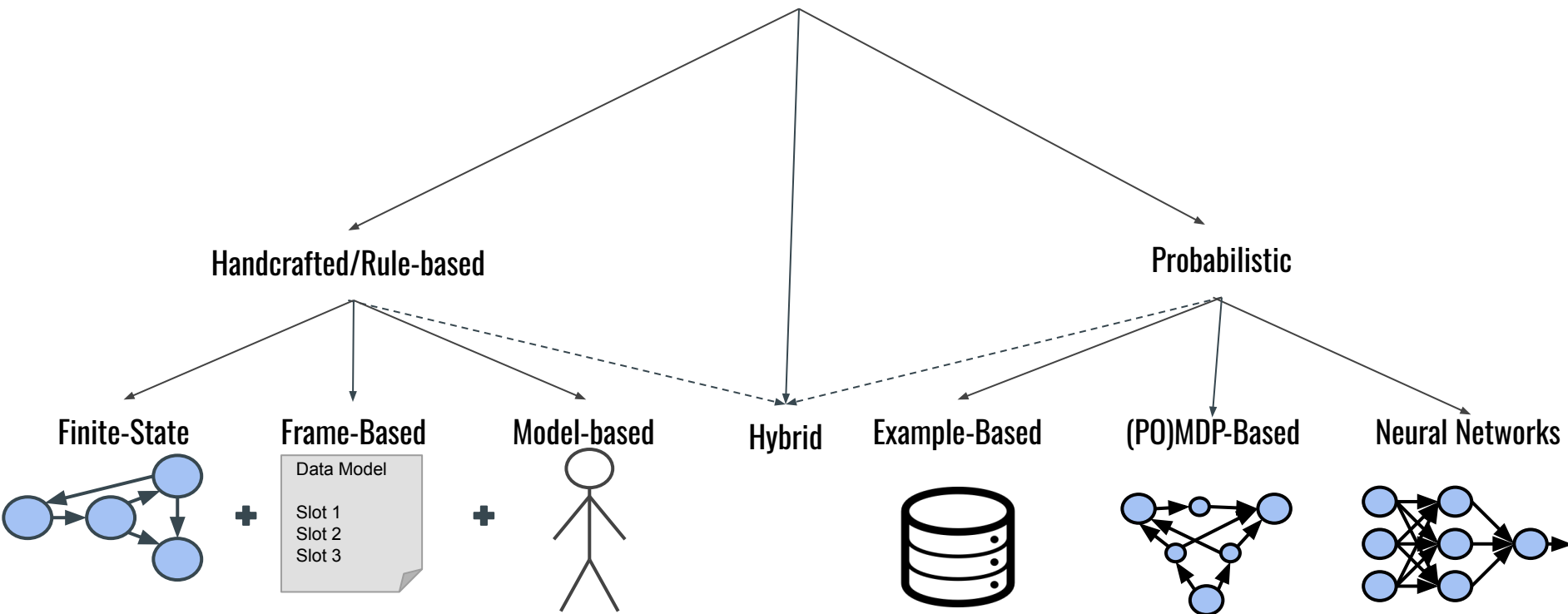"Pasta would be nice."
"What kind of pasta?"
"I was thinking about spaghetti aglio e olio."
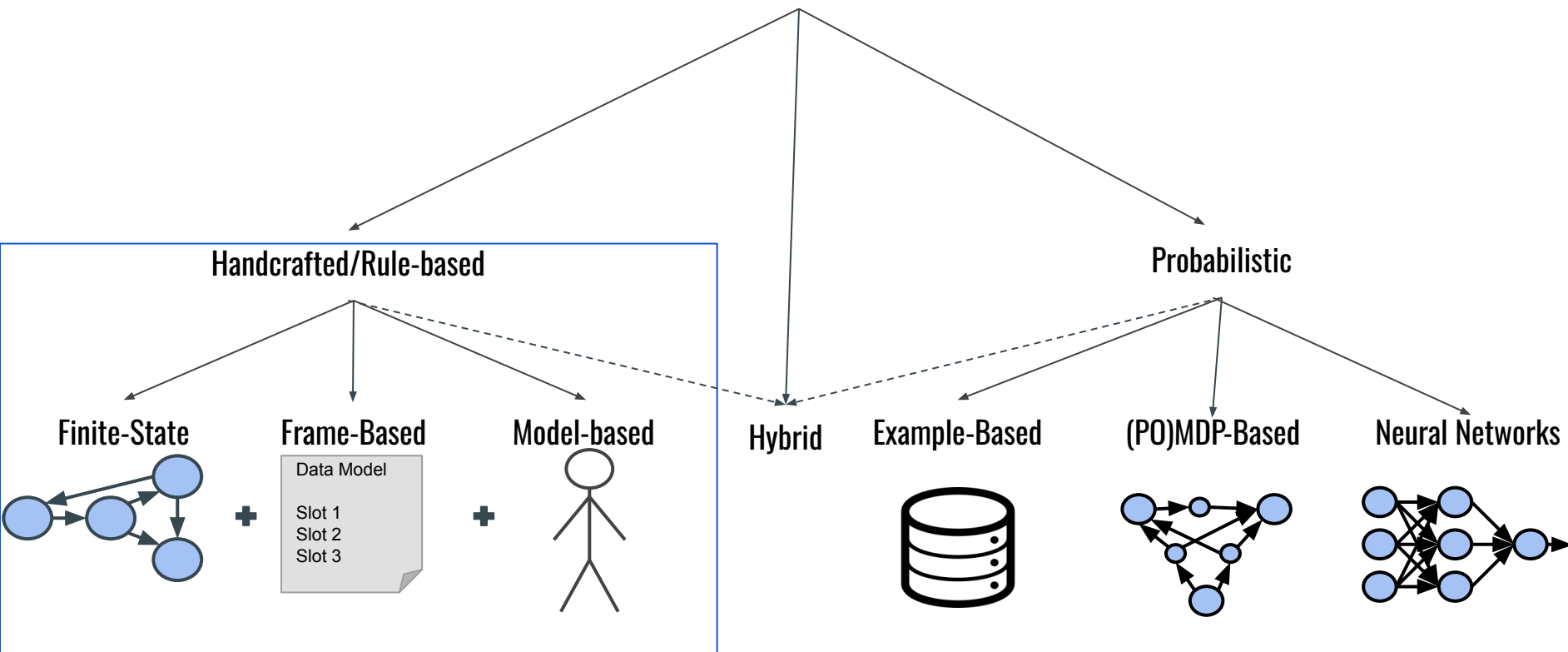
Sorry what did you say?

- Non-understanding
  - Missing data
  - Ambiguity
- Possible strategies
  - Ask for repetition
  - Ask for rephrasing
  - Make an assumption and rely on corrections

DIALOGUE MANAGEMENT

Handcrafted/Rule-based

Probabilistic

Finite-State

+

Frame-Based

Data Model

Slot 1
Slot 2
Slot 3

+

Model-based

Hybrid

Example-Based

(PO)MDP-Based

Neural Networks

Rule-Based Approaches

DIALOGUE MANAGEMENT

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Neural Networks

Finite State Machines

- Highly structured tasks
- System initiative
- Restricted user input
- User's actions determine the transitions between the system responses that constitute the nodes of the finite state machine

-> Efficient in terms of accuracy and cost

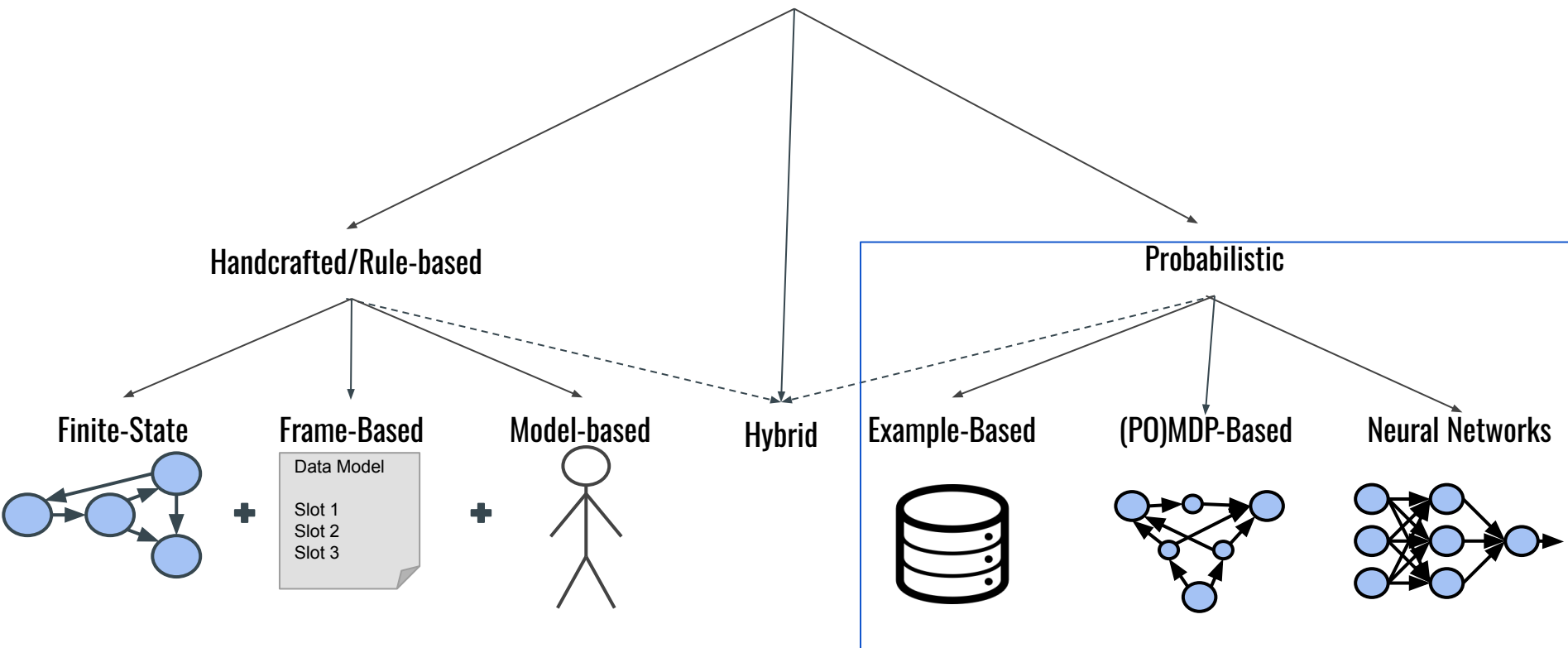-> Lack of versatility and poor domain portability

Frame-Based Approaches

- Extends FSM-approach
- Do not have a predefined dialogue path but use a frame structure
  - one slot for one piece of information
  - the system can capture several slots at once
  - information can be provided in any order
- Allows for more mixed initiative interaction

Model-Based Approaches

- Adds a model to the frame-based approach
  - Context model
  - User model
  - Grounding state
- Model influences the selection of the next dialogue action

Statistical Approaches

DIALOGUE MANAGEMENT

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Probabilistic

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Data Model

Slot 1
Slot 2
Slot 3

Model-based

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Example-Based

(PO)MDP-Based

Neural Networks

Goal of Statistical Systems

- Build systems that exhibit more robust performance
- Improved portability
- Better scalability
- Easier adaptation to the task
- Handing of unseen data

-> Model construction and parameterization are dependent on expert knowledge

-> Training data must be correctly labeled for the learning process

-> Size of currently available annotated dialogue corpora is usually too small to sufficiently explore the vast space of possible dialogue states and strategies

-> Real-world data collection is costly and time consuming

Corpus creation

- Human-agent dialogues
  - Wizard-of-Oz
  - Autonomous systems
  - Mix of both
- Human-human dialogues
 - Task-oriented
  - Chat-based
- Simulations

-> explicitly modeling the variability in user behaviour

Example-Based Approaches

- Specific case of corpus-based modelling
  - Finds dialogue examples that are similar to the current dialogue example
  - Best example is then selected from the candidate examples by calculating similarity
- Limited to data that is in the corpus

(Partially Observable) Markov Decision Processes ((PO)MDPs)

- Have to handle uncertainty

- Often combined with reinforcement learning

- Map history of observations on dialogue actions
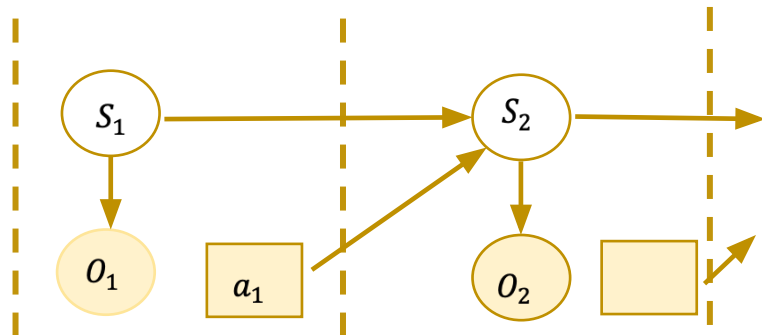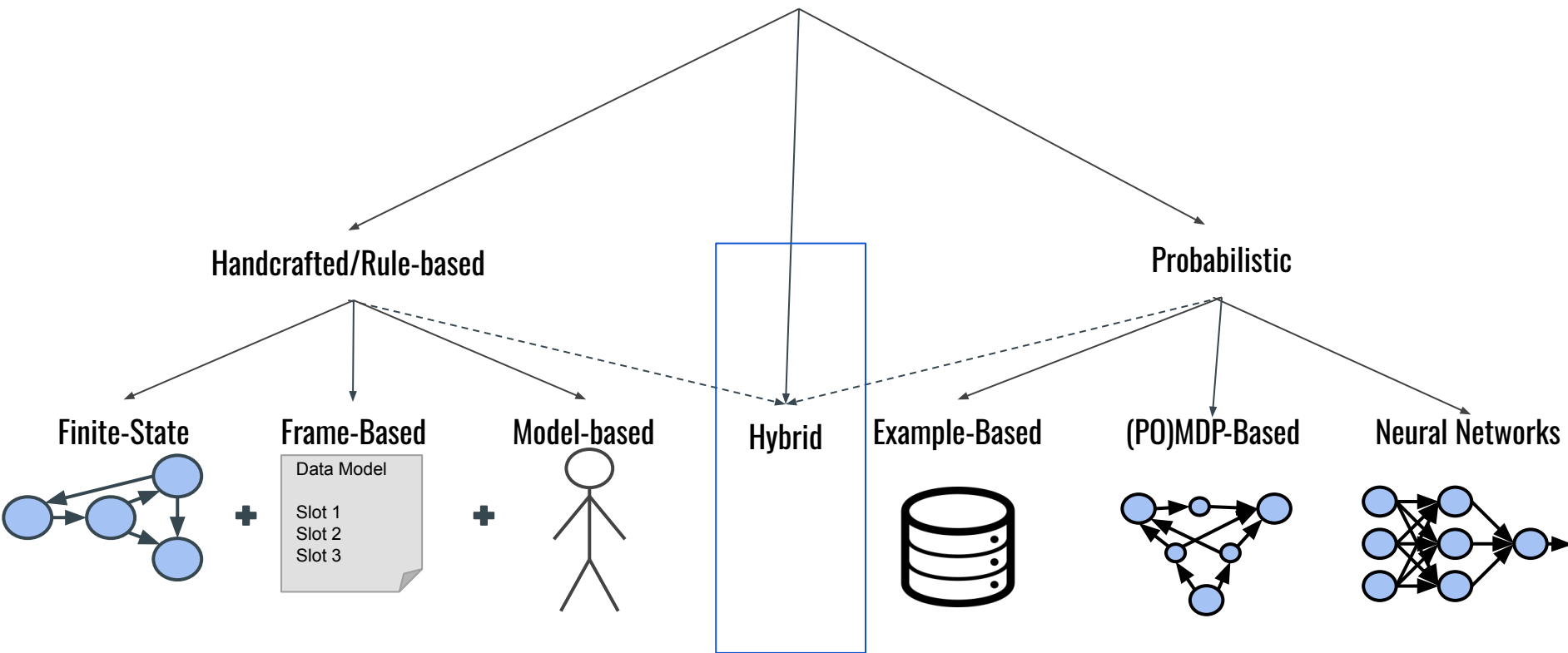
End-to-End Approaches

- Extensive amounts of training data required

- Little direct control

- Very high flexibility

- For example LLMs
  - No understanding
  - Prediction of the next word based on current one (+ previous ones)

Hybrid Approaches

Hybrid approaches to DM

- Hybrid approaches to DM combine statistical and rule-based approaches
- Try to reduce the amount of dialogue data required by incorporating expert domain knowledge into DM

Examples

Example 1: Museum Guide
You want to create an artificial museum guide that tells the user about the exhibition. You do not think that it makes sense to tell every user about every aspect of the exhibition.
You have:
- Very little data
- A lot of experience with designing exhibitions
- A short user questionnaire to ask for user preferences

-> Model-Based Approach

Example 2: Judgmental Pizza Agent
You want to create an agent that asks a user for their pizza preference. If their favourite pizza is the same as yours, the agent reacts with a "Good choice", otherwise it'll make a judgmental comment.
**You have:**
- A lot of data
- A long list of possible pizza answers

-> FSM Approach

Example 3: Another Museum Guide
Same as 1.
You have:
- A lot of data
- A system to record user reactions during the interaction
- Less experience with exhibition design

-> (PO)MDP Approach

Other options are possible!
It just depends on what you value as important and how much you are willing to invest.
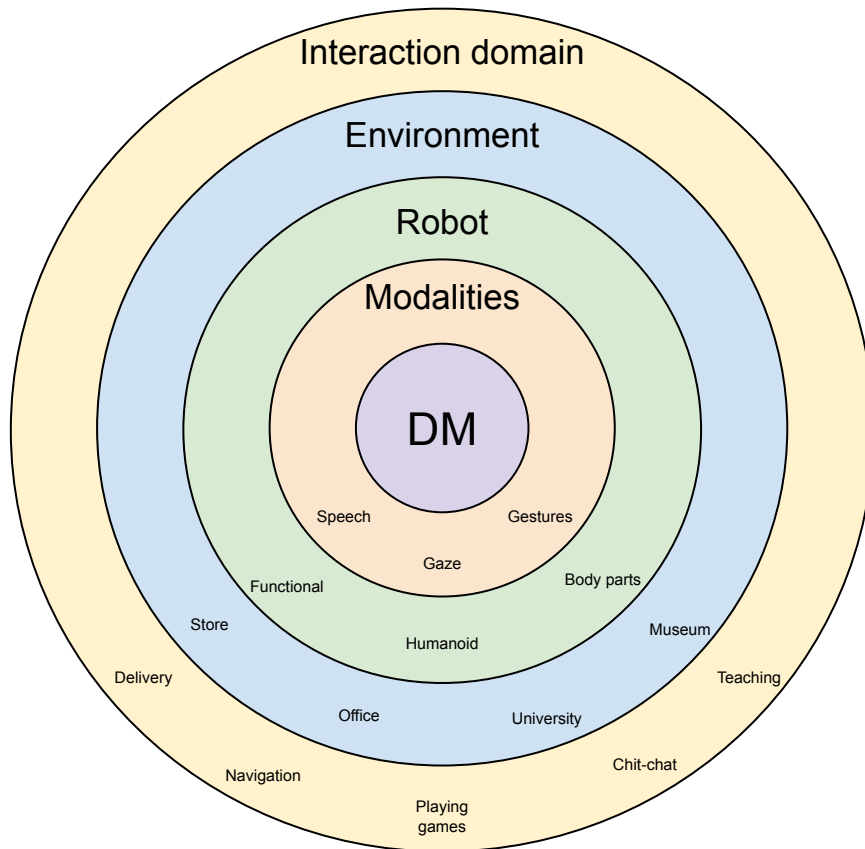
DM in HRI
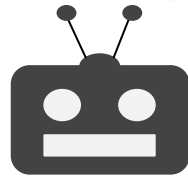
Challenges

- High variability

- ASR affects DM
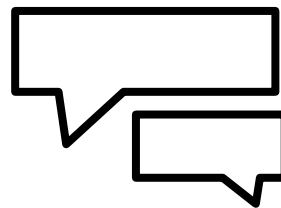
- Novelty

- User frustration

Robot Appearances

- Various robot types used for conversations
  - Mainly humanoid and functional
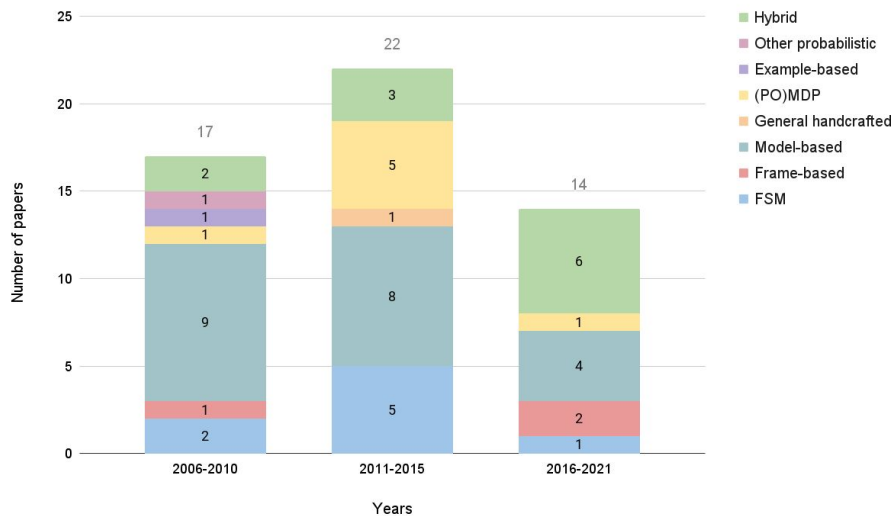 - Other types: Body parts, Artifact, Android
- Sets expectations

Unclear	Android	Artifact	Body parts	Functional	Humanoid
1	4	4	10	15	19

0   20   40   60
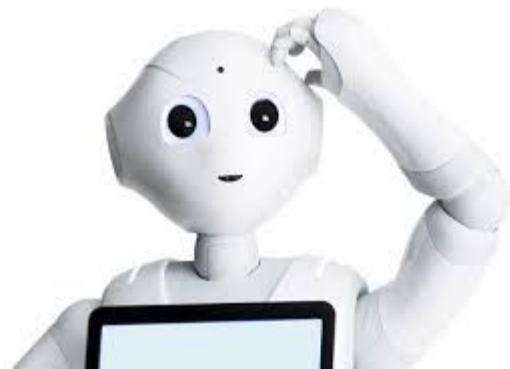
Dialogue Management

- Still often handcrafted
  - Control
  - Task-based interactions
  - Conversation as a tool
- Moving towards hybrid

Evaluation

- Subjective metrics
    - User satisfaction/frustration
    - Perception of the robot (e.g. Godspeed questionnaire)
    - Naturalness
- Objective metrics
    - Number of turns
    - Task success rate

Take home message

- Numerous dialogue management approaches exist
- Handcrafted approaches allow for control but limit flexibility
- Probabilistic approaches are less controllable but have a higher flexibility
- Hybrid approaches combine handcrafted and probabilistic approaches
- Robots make DM challenging due to their situatedness and embodiment
- Evaluation of DM (in HRI) can include both subjective and objective metrics
- Which DM approach to choose is highly dependent on what you want to do and on the data you have