EASE - EVERYDAY ACTIVITY SCIENCE AND ENGINEERING

Discovering and Exploiting the „Manifolds“
of Human Problem-Solving for Robots

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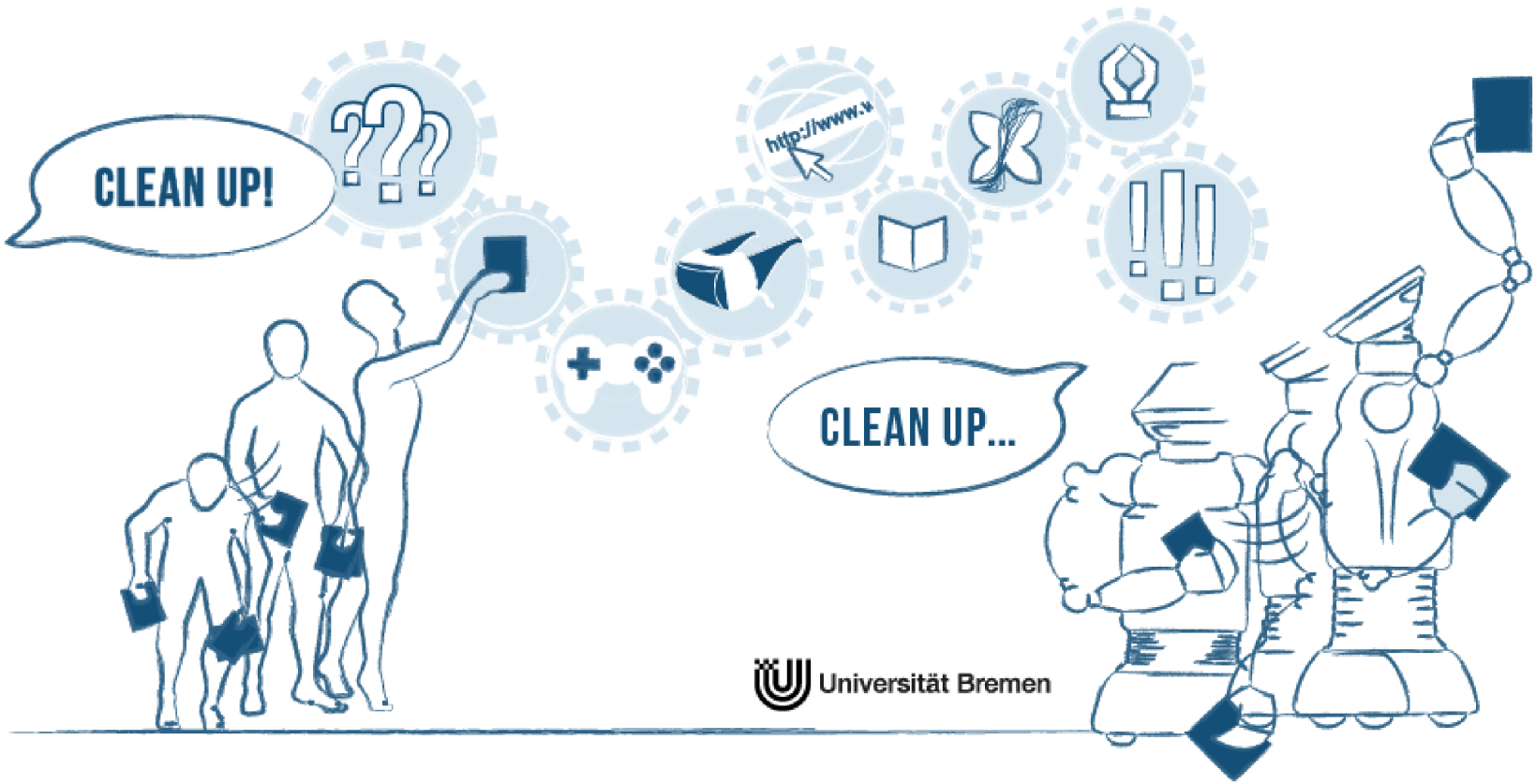
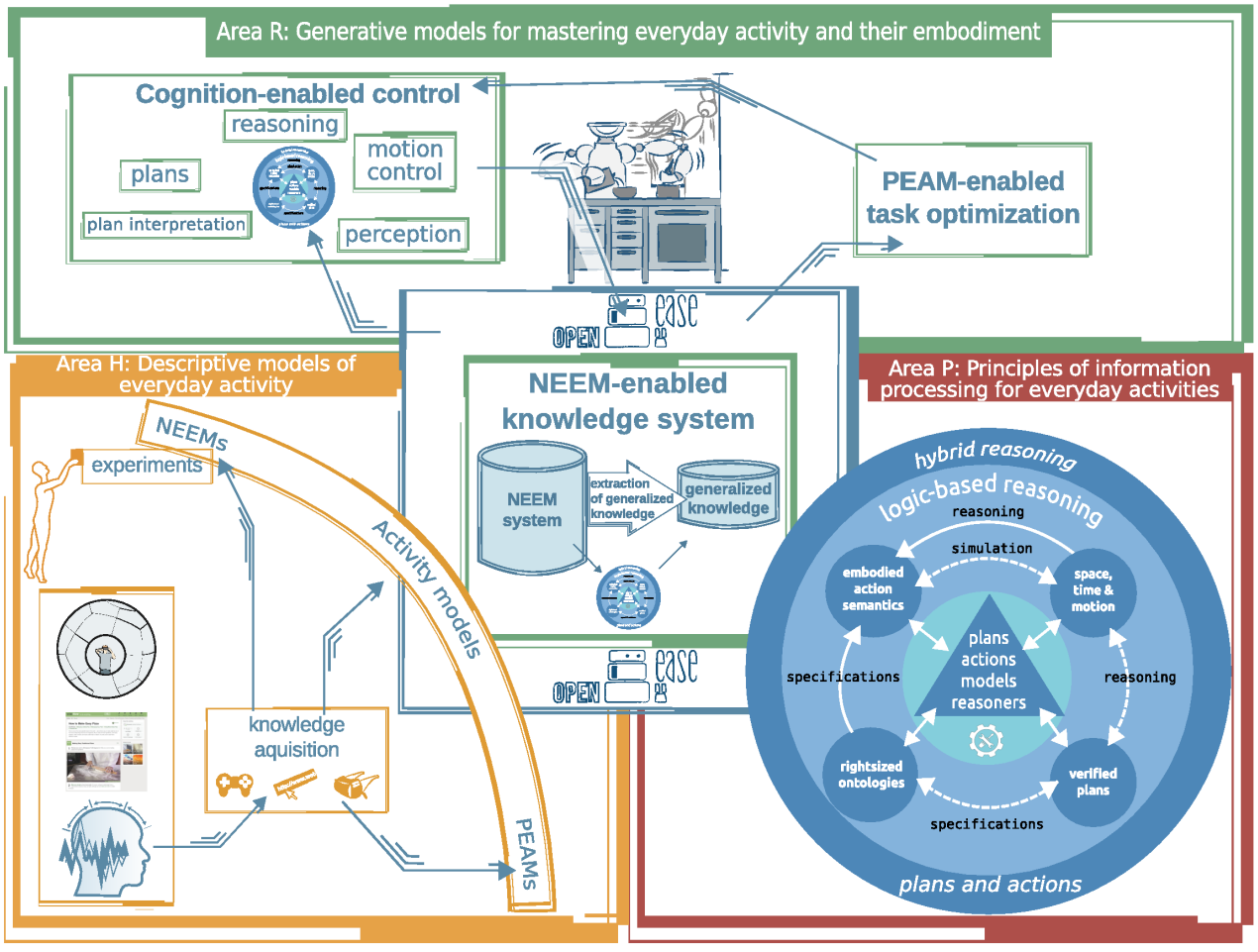
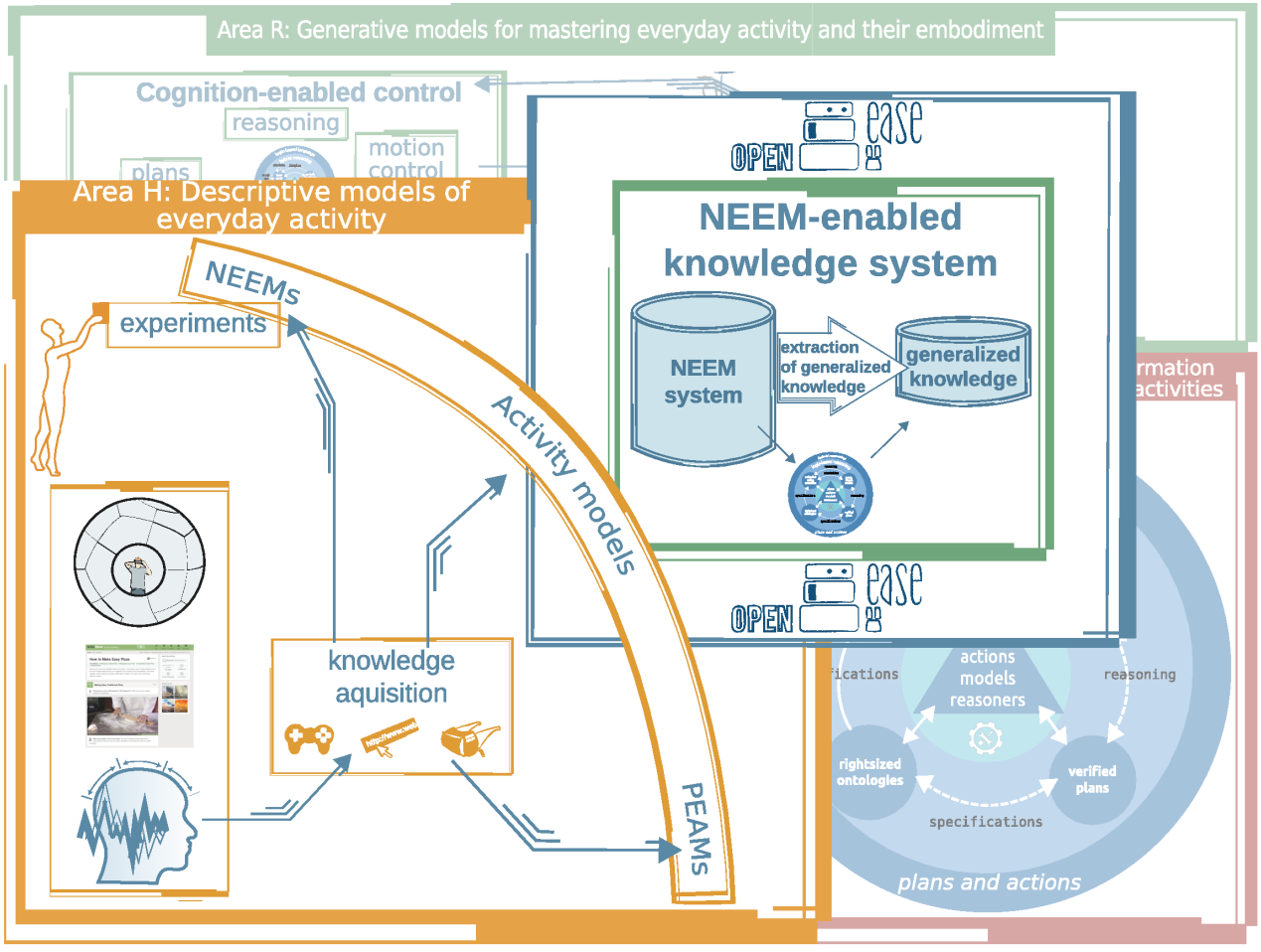


Overview

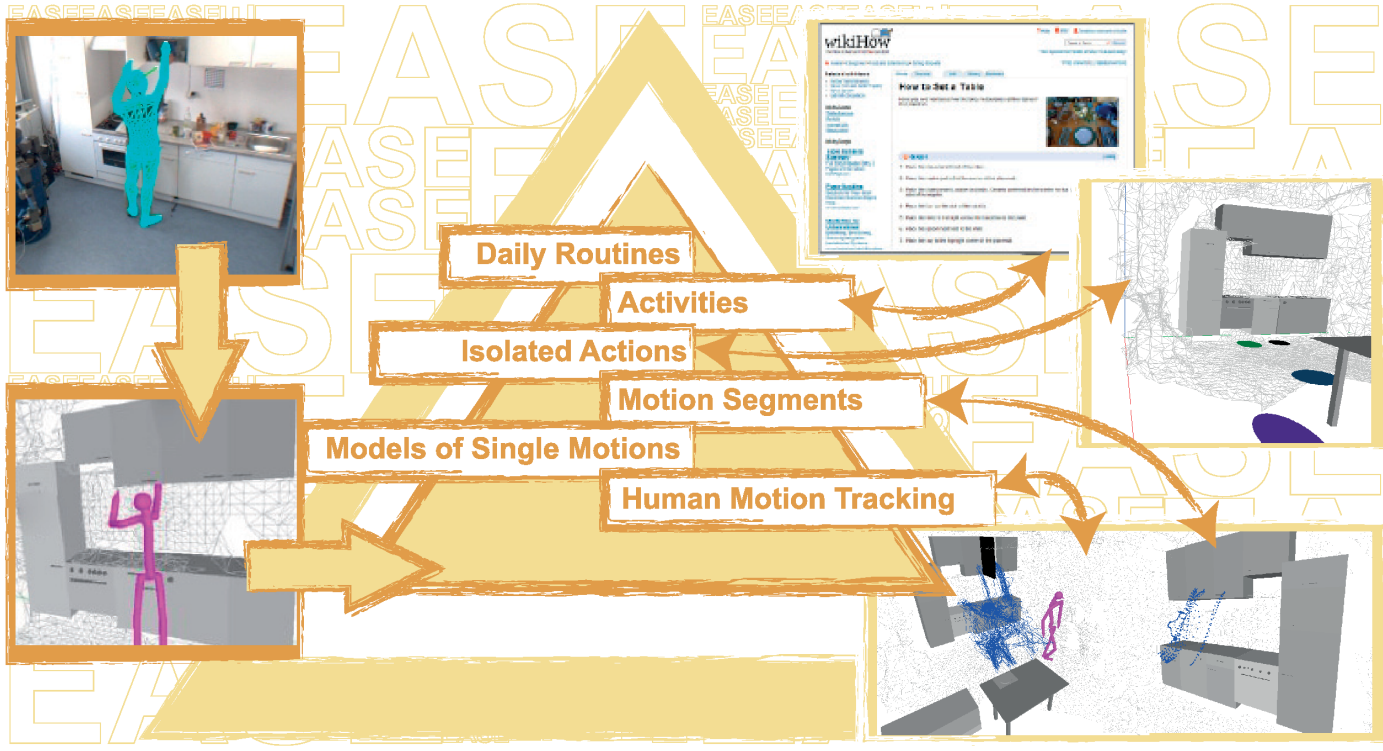

Area R: Generative models for mastering everyday activity and their embodiment
Cognition-enabled control
reasoning
plans
motion control
plan interpretation
perception
PEAM-enabled task optimization
OPEN ease DB
Area H: Descriptive models of everyday activity
NEEMs
experiments
Activity models
knowledge aquisition
PEAMs
NEEM-enabled knowledge system
NEEM system
extraction of generalized knowledge
generalized knowledge
OPEN ease DB
Area P: Principles of information processing for everyday activities
hybrid reasoning
logic-based reasoning
reasoning
simulation
embodied action semantics
space, time & motion
specifications
plans actions models reasoners
reasoning
rightsized ontologies
verified plans
specifications
plans and actions

Research Area H



RA H: Role in EASE

- observe human activity and interpret activity descriptions
- represent collect recorded data as NEEMs
- interpret and abstract NEEMs into layered activity models
- hypothesize promising PEAMs



RA H: Objectives and Measures of Success

- **Goal:** understand how people perform vaguely formulated everyday manipulation tasks
- **Objectives:**
  - **Acquiring and managing multimodal, semantically annotated, high-volume data sets of humans performing vaguely formulated everyday manipulation tasks**
  - **Learning descriptive and causal models of everyday manipulation activities**
- **Measures of success:**
  - queries that can be answered based on the learned generalized descriptive and predictive models
  - PEAMs

Starting points

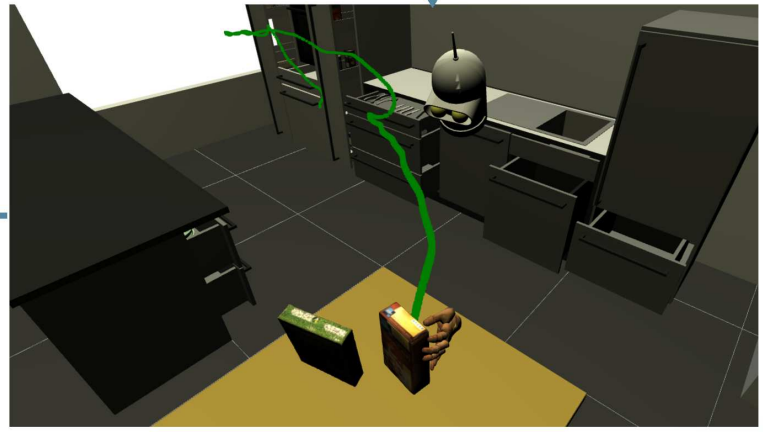
Game events:

Contact :
LeftHand - Cereals
State :
Drawer - Opened
Contact :
Spoon - Bowl
[...]

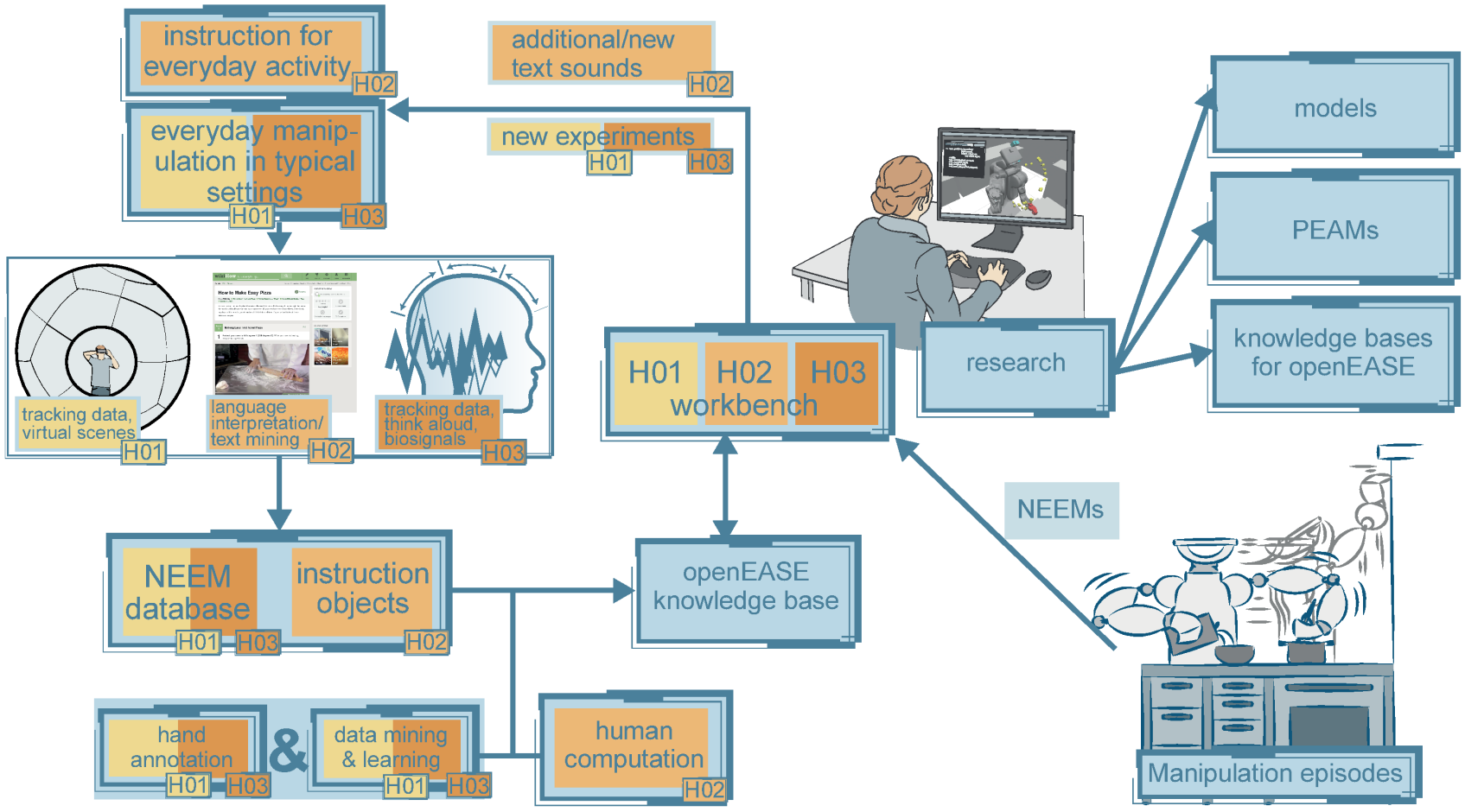

```
"actors" : [
  {
    "timestamp" : 0.7693396806,
    "name" : "LeftHand_oaE8",
    "pos"
      "x" : -3.9839282035827637,
      "y" : 0.5687724947929382,
    } "z" : 1.6235991716384888

    "rot" : {
      "w" : 0.1385824829339981,
      "x" : 0.4796800911426544,
      "y" : 0.0469124391674995,
    } "z" : -0.8651595711708069

    "bones" : [
```

Methodology applied in RA H



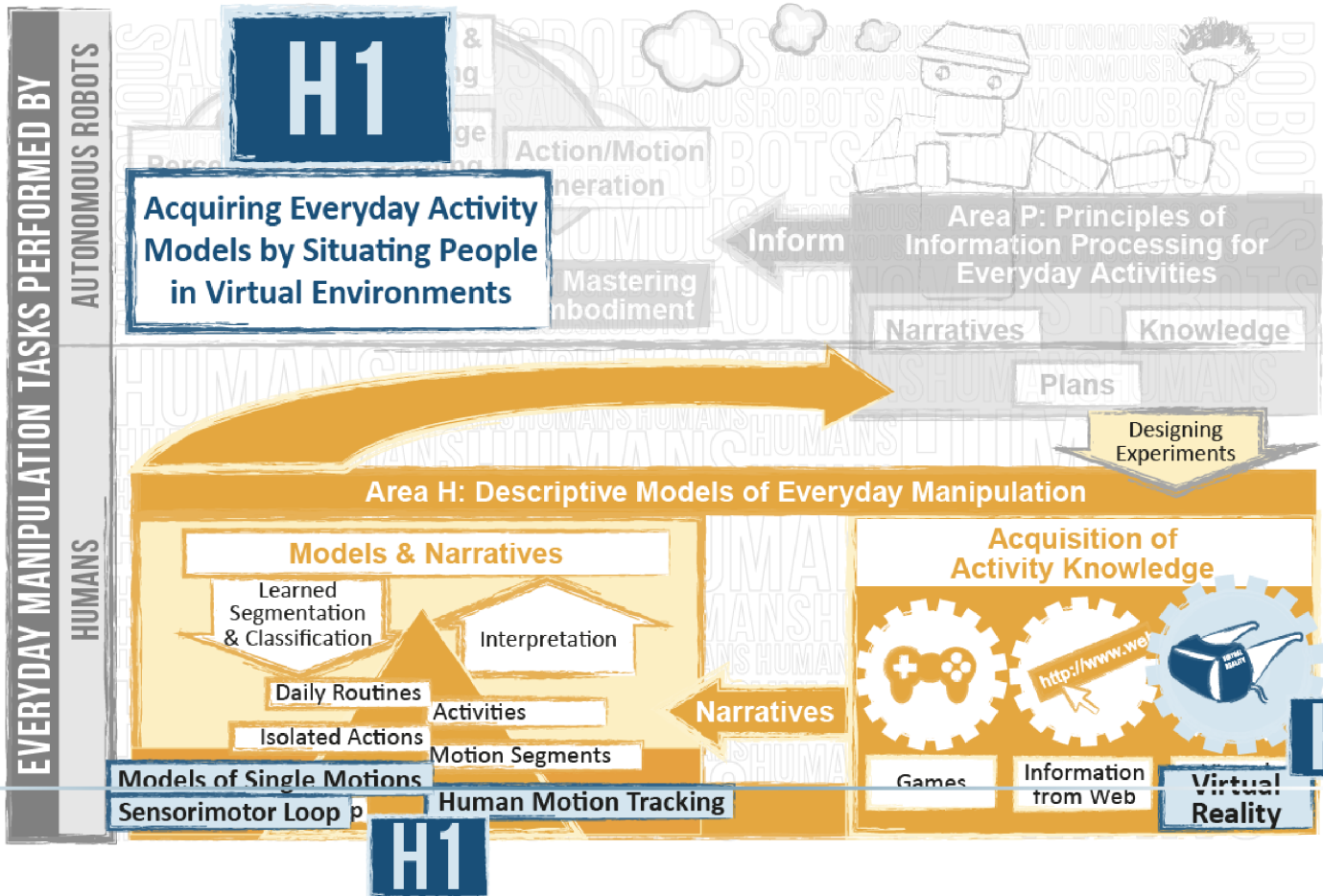
Subproject H01:

Acquiring activity models by situating people in virtual environments


Schill

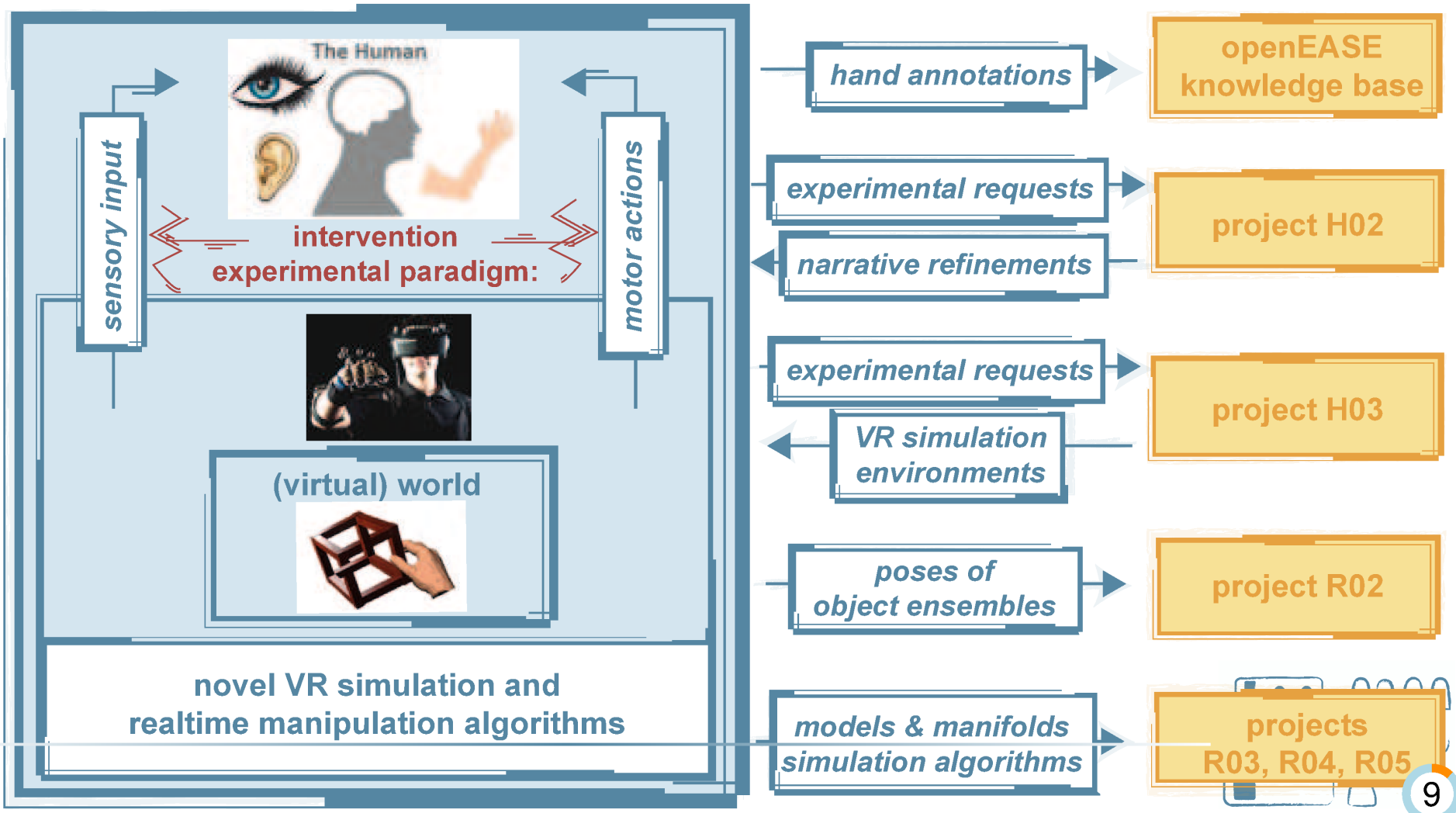

Zachmann


Zetzsche



H01 workbench

H01 workbench for openEASE



H01	Acquiring Activity Models by Situating People in Virtual Environments	Schill Zachmann Herrmann	2 pos

Research Questions

Q1: coordination & planning of senses and motor control in impossible situations
Q2: simulation of virtual hand manipulation with virtual objects in virtual worlds

Goals and Methods

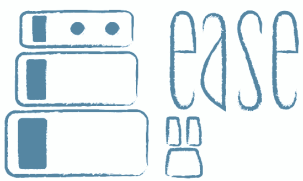
G1: data collection, interpretation, and representation
G2: faithful virtual hand model for natural manipulation

Beyond State of the Art

BSOA1: understanding of adaptivity and strategies for dealing with ambiguous and uncertain information
BSOA2: manifolds and narratives of hand manipulation
BSOA3: VR manipulation including haptic rendering

Integration in EASE

R1: data collection from VR manipulation

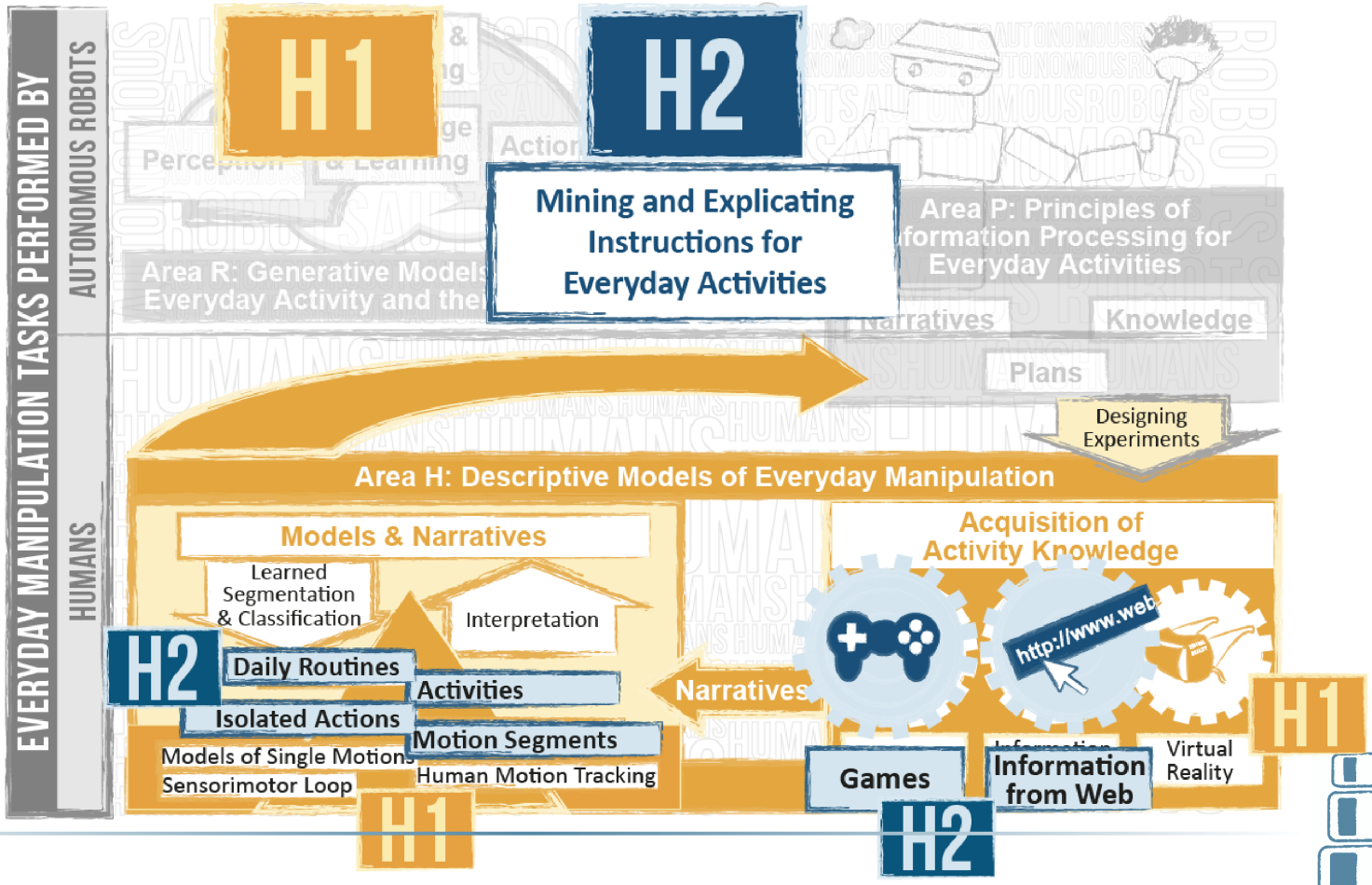


Subproject H02:

Mining and explicating instructions for everyday activities


Malaka


Bateman



H02	Mining and Explicating Instructions for Everyday Activities	Malaka Bateman	2 pos

Research Questions

Q1: how can we extract proto-narratives from text?
Q2: computation environment for harvesting for explicating proto-narratives
Q3: evaluation of harvested knowledge in the robotic agent domain

Goals and Methods

G: finding a fitting ensemble of NLP and human computation approaches to generate explicated representations of everyday activities out of textual instructions

Beyond State of the Art

BSOA1: extent to which relevant information is extracted from instructional texts
BSOA2: handling of ambiguities and alternative explications through human computation

Integration in EASE

R: gathering basic proto-narratival information from nl descriptions and from human computation experiments

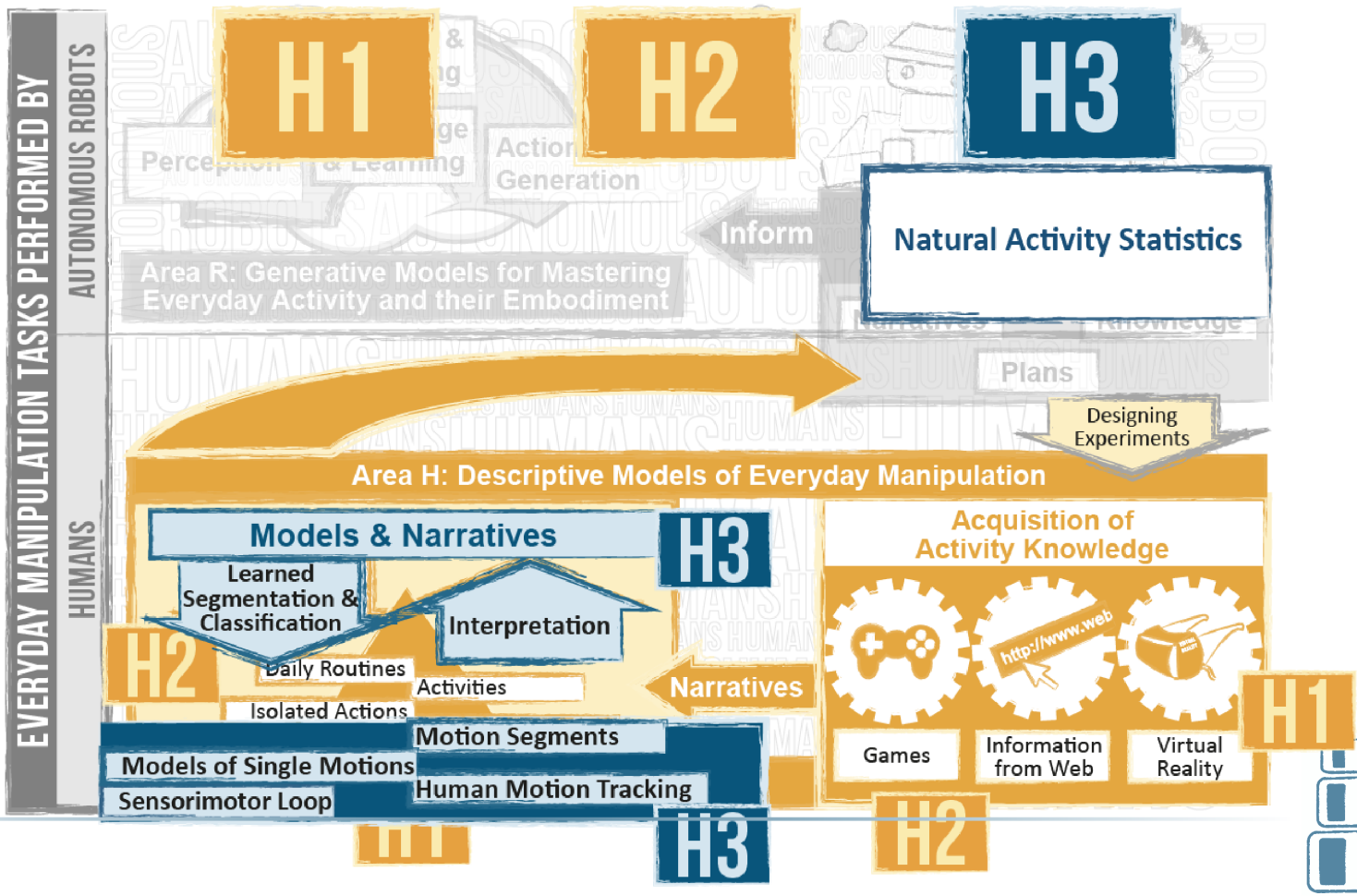
Subproject H03:

Natural activity statistics

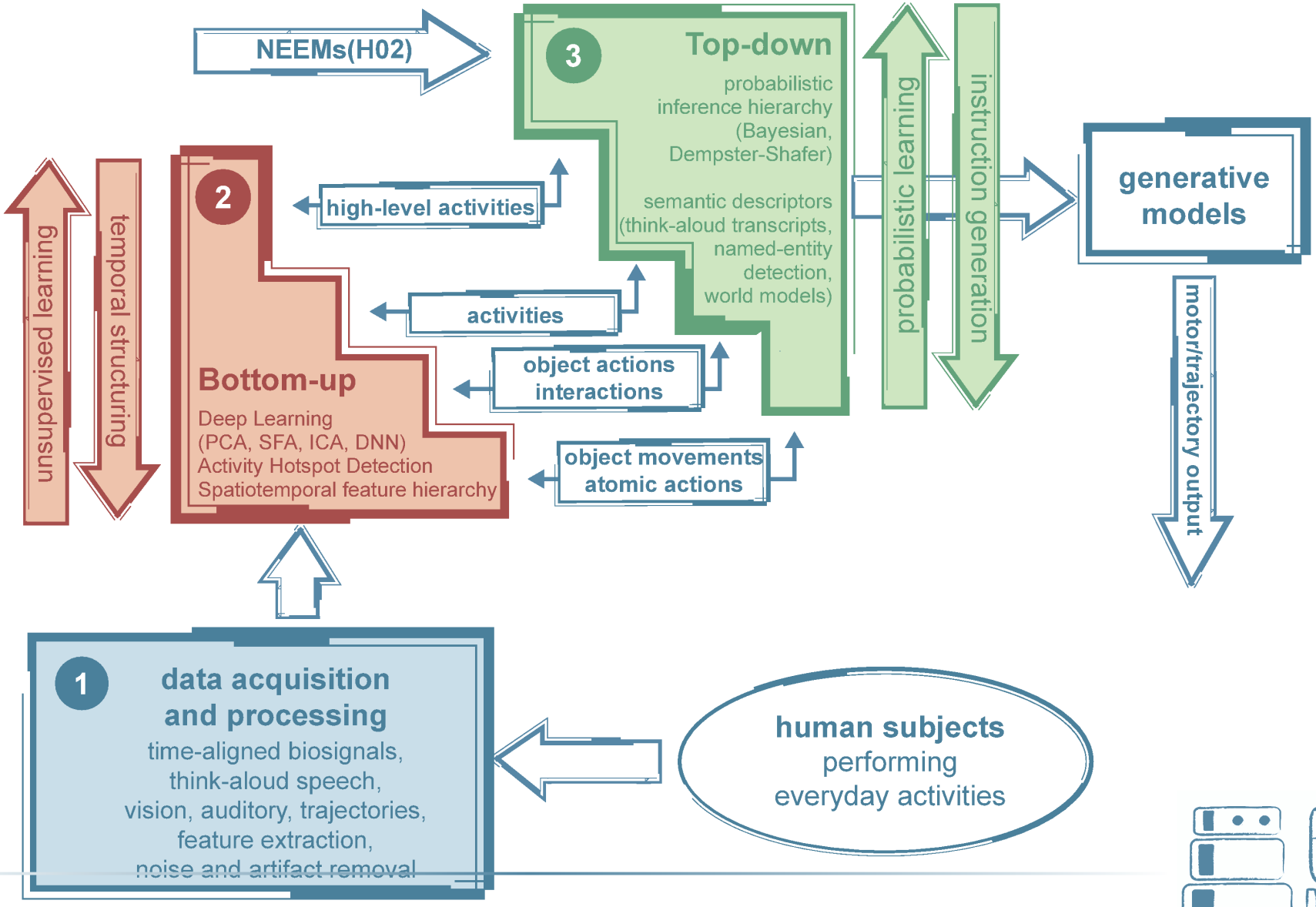

Schill


Schultz


Herrmann



H03 Approach



H03	Natural Activity Statistics	Schill Zetsche	2 pos

Research Questions

Q1: how can we identify the "manifolds" underlying human everyday activities, in particular with respect to the motor components?
Q2: how can we generate probabilistic models from a large collection of sensor recordings?
Q3: how can we apply statistical methods to the high-dimensional spatio-temporal activity patterns to build hierarchical representations?

Goals and Methods

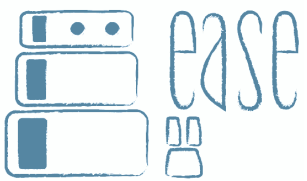
G: integration of low-level (spatio-temporal trajectories) and high-level information (symbolic descriptions, plans) in a manifold learning approach

Beyond State of the Art

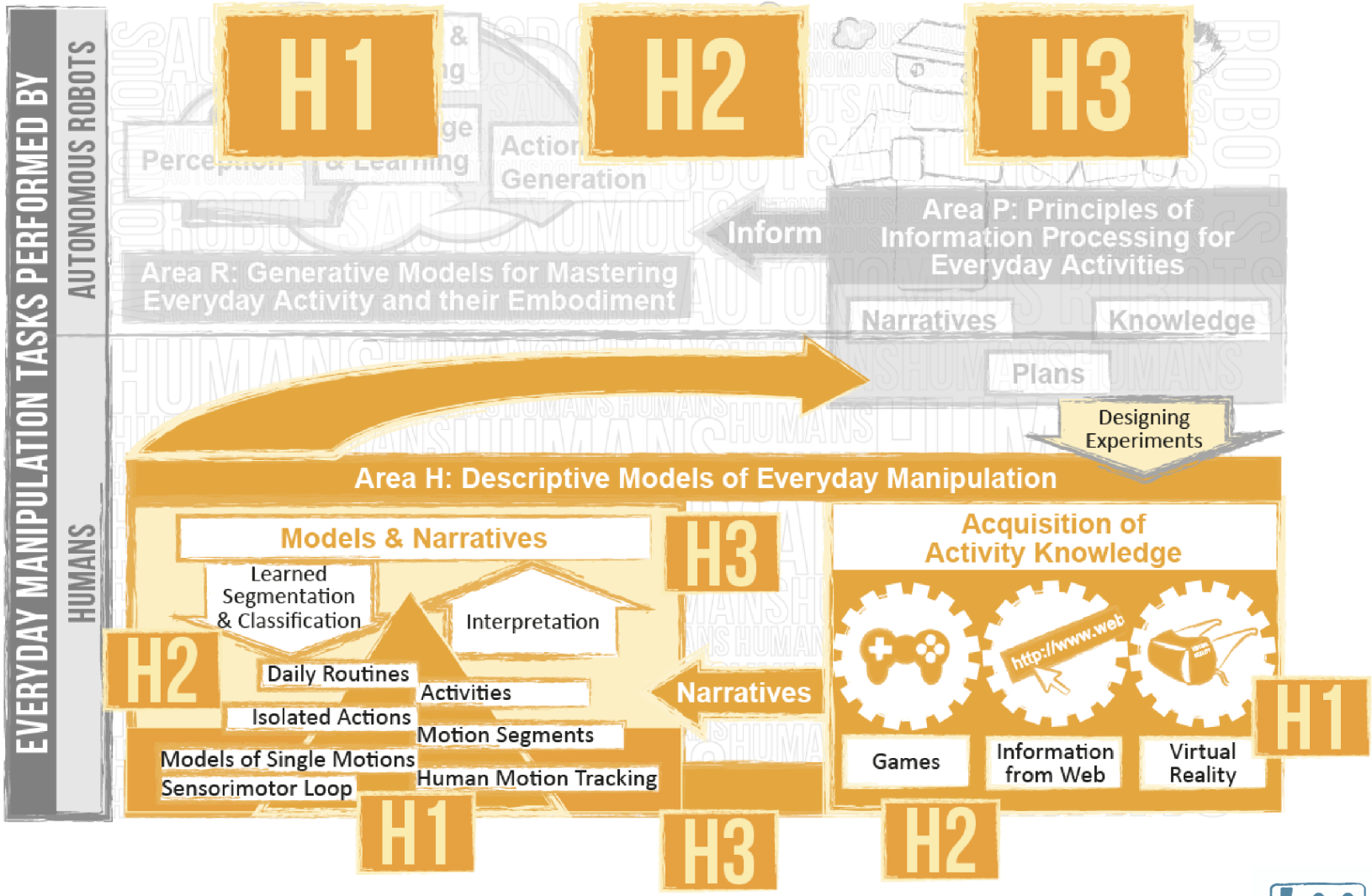
BSOA1: unsupervised learning of the complete hierarchical representation by variants of established learning paradigms (PCA,ICA,SFA)
BSOA2: integrated and coherent description of complex motion sequences by low-dimensional manifolds

Integration in EASE

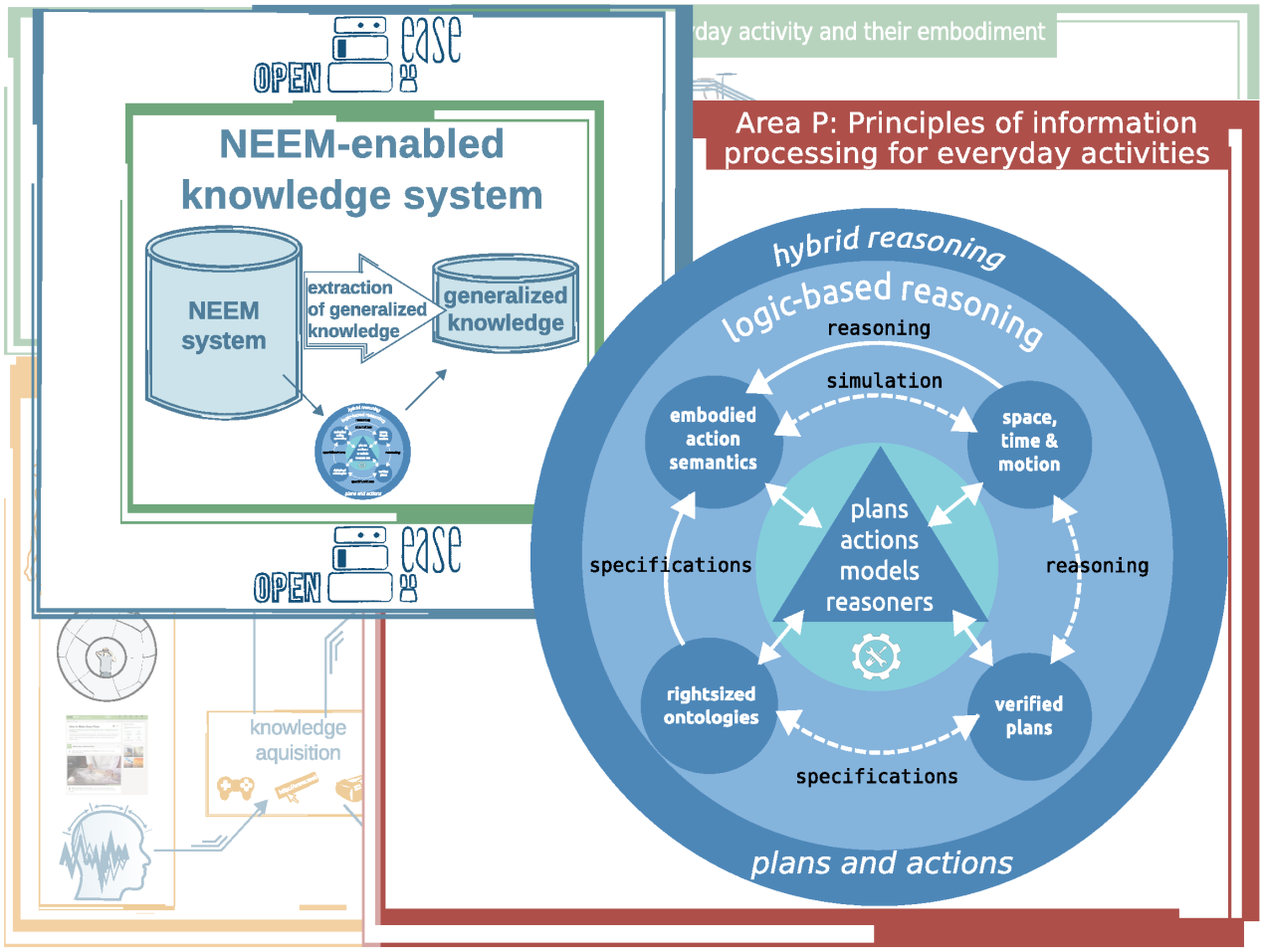
R: H3 is the central project for statistical analysis and data reduction of low-dimensional manifolds



Research Area H

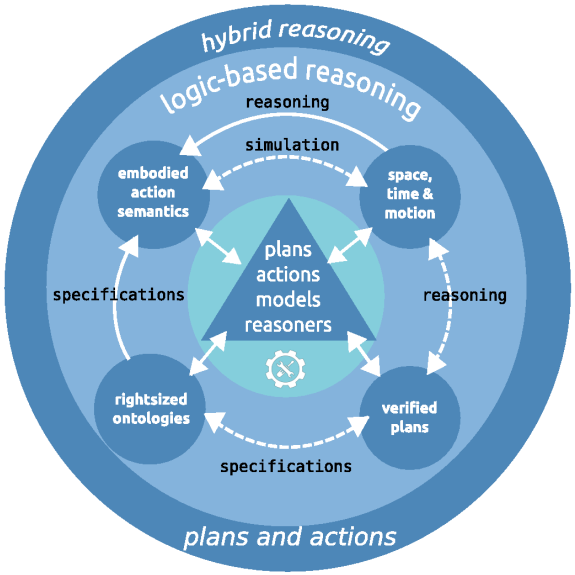


Research Area P



RA P: Role in EASE

- provide foundations for the formalisation of and reasoning about everyday activities
- establish principles for the information representation and processing required
- provide ontologies, reasoners, and semantic specifications mediating NEEMs and PEAMs
- interfacing to hybrid reasoning in research area R



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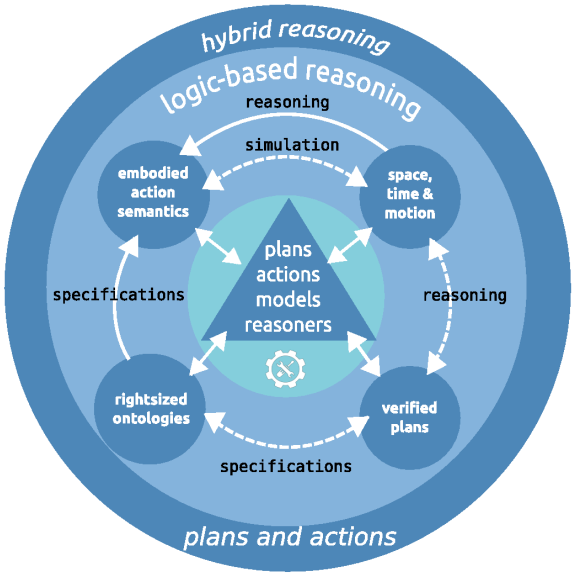

Intuition & Ambition

From several quite distinct perspectives, strikingly similar approaches, requirements and solutions are being pursued: it is now time to leverage off this situation to achieve a **new level of performance**: EASE makes this possible.

RA P: Objectives and Measures of Success

- **Goal:** design, realize, and evaluate a new generation of logic-based knowledge representation and processing infrastructure enabling the mastery of everyday manipulation actions
- Objectives:
  - **Defining models, knowledge structures, and reasoners necessary for formalising everyday activities (for NEEMs)**
  - **Flexibly capturing levels of qualitative abstraction for mediating between everyday behavior and formal specification using a spectrum of formal languages**
  - **Optimising reasoning by exploiting PEAMs**
  - **Formalizing plans for mastering everyday activities and investigating the properties of those plans and their preservation under plan revisions**

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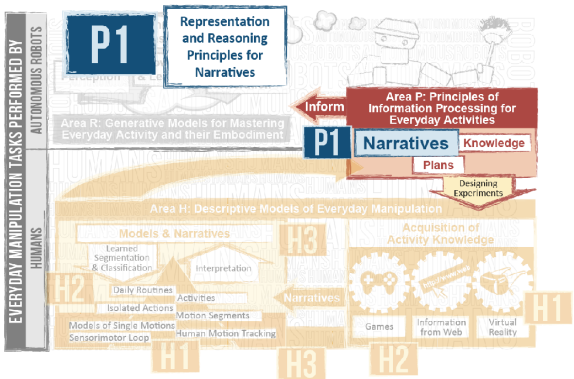
  - **Formalizing plans for mastering everyday activities and investigating the properties of those plans and their preservation under plan revisions**
- Measures of success:
  - growing repertoire of formalised queries relying directly on enhanced inferential capabilities
  - demonstrated principles of knowledge representation, derived and validated for all knowledge areas required

Starting Points: Three $\mathcal{P}$erspectives

- P-projects individually and with respect to the international state of the art
- P-projects in relation to one another and in relation to the EASE CRC as a whole
- The added value of performing the P-projects within the context of EASE: what is the difference?

Subproject P01:

Embodied semantics for the language of action and change



Premise and SoA:


Bateman


Malaka

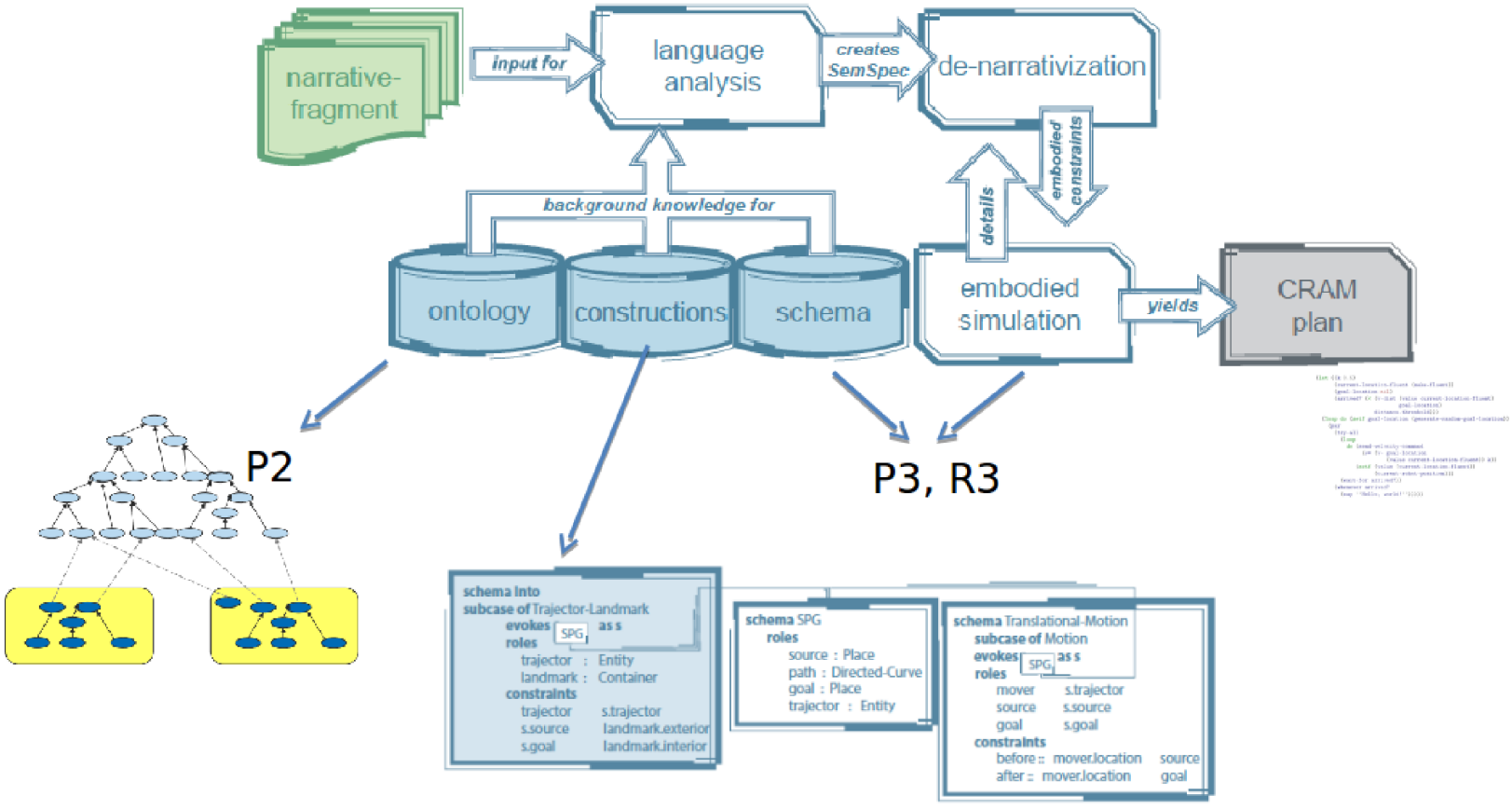
- Language understanding demands abstract, qualitative, embodied simulation
- but this cannot be 'complete' simulation!
- existing approaches limited in scale, in embodied realization, and formalisation

Challenges:

- achieving combination of simulation and qualitative formal semantics for 'embodied semantics'

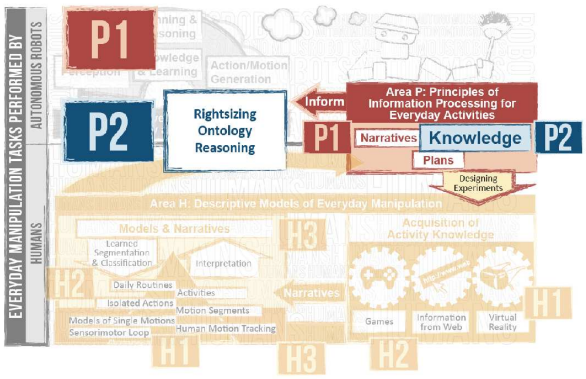
Subproject P01:

Embodied semantics for the language of action and change



Subproject P02:

Rightsizing ontologies



Premise and SoA:

- intelligent everyday behavior requires substantial knowledge (Cyc, etc.)
- existing technology for ontology reasoning unable to cater for the demands of reasoning in performing everyday activities adequately

Challenges:

- to bridge gap between expressive languages for KR and lightweight languages for efficient reasoning

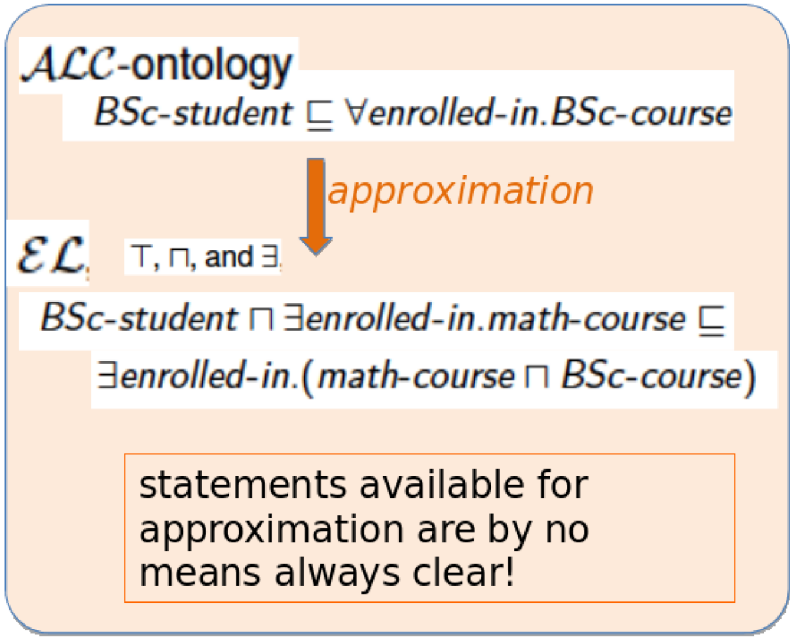
Subproject P02:

Rightsizing ontologies

Approach and Methods:

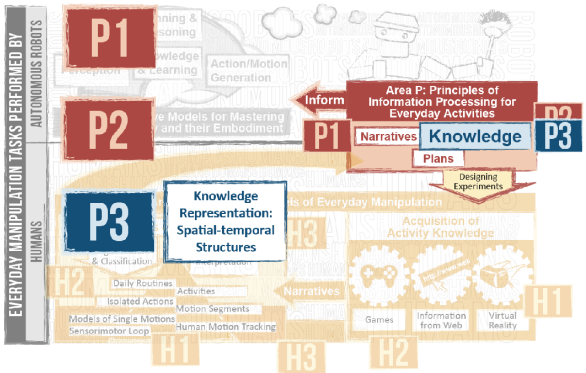
- develop a rigorous and comprehensive theory of ontology approximation in DLs
- guided by the demands of agents executing everyday activities
- new results in knowledge compilation
- answering questions of conditions, completeness, implications, trade-offs, heterogeneity


Batema



Subproject P03:

Spatial reasoning in everyday activity



Premise and SoA:

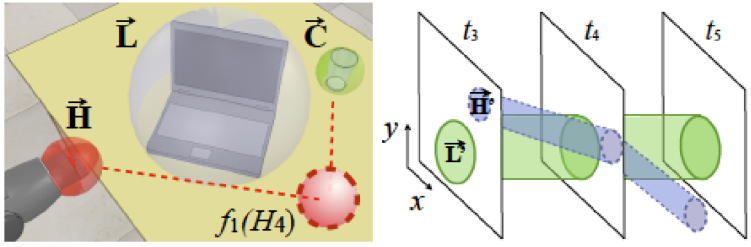
- Human-level performance requires cognitively-motivated spatiotemporal formalisations and use of the environment

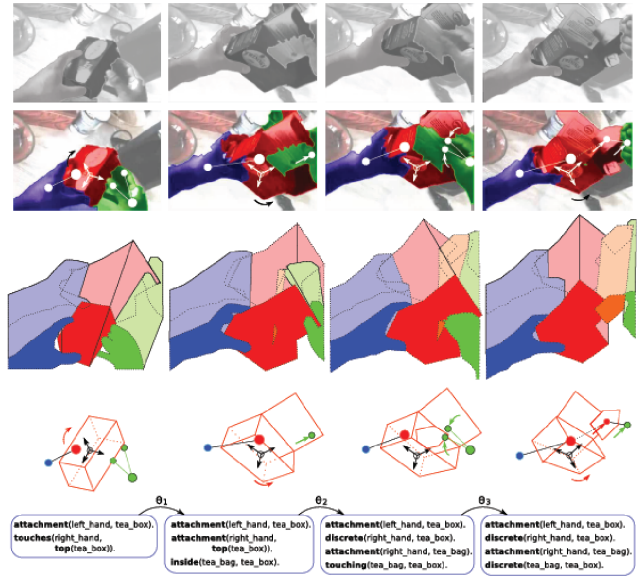
Challenges:

- achieving methods, algorithms and tools for computational representation and reasoning about qualitative space and motion
- direct action-based problem solving using computational models of strong spatial cognition

Subproject P03:

Spatial reasoning in everyday activity



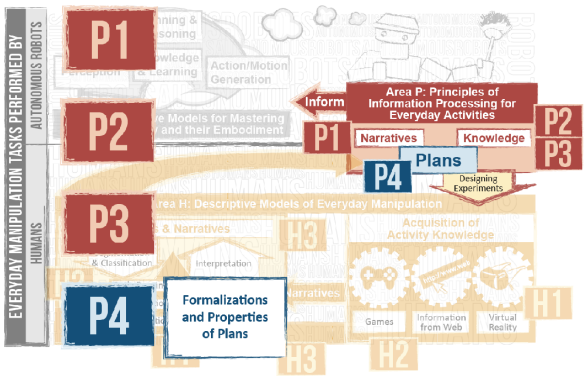


Methods:

- Space and motion relations and patterns are **first-class objects** supporting direct integration with KR methods via qualitative reasoning approaches
- Human spatial knowledge formalized to exploit direct manipulation, capturing externalised, distribution cognition

Subproject P04:

Formalizations and properties of plans



Premise and SoA:

- substantial properties of plans can be formally specified and verified for behavior prior to execution
- existing approaches restricted by scale and flexibility of scenarios

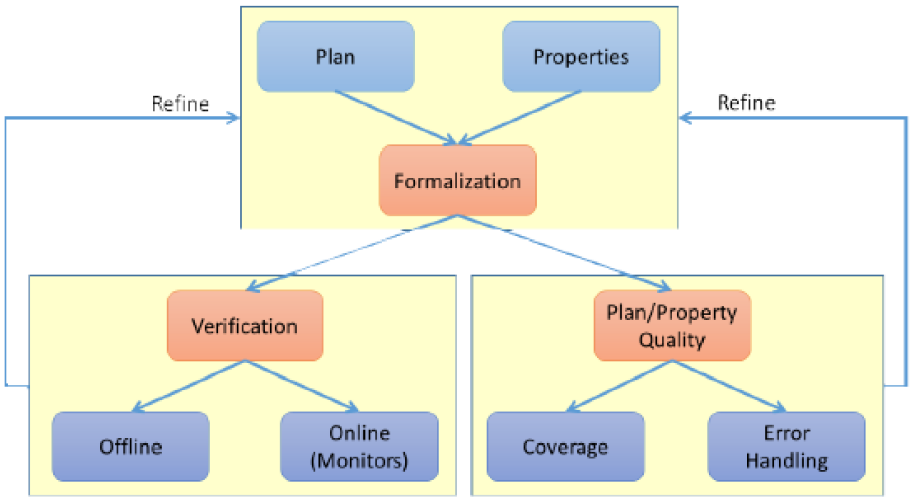
Drechsler

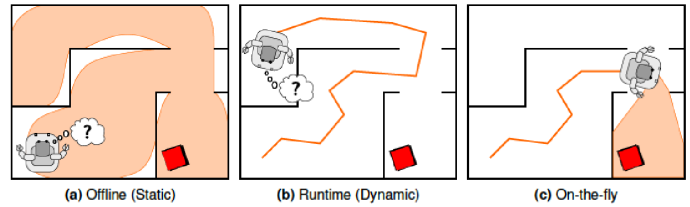
Challenges:

- formalize and draw inferences about the guaranteed behavior of a plan
- create efficient reasoning tools for verifying formal properties of robot plans

Subproject P04:

Formalizations and properties of plans





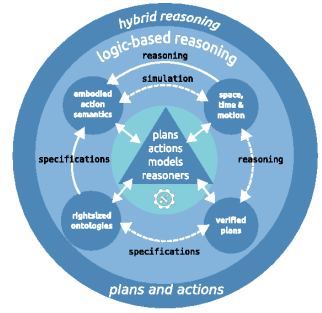

```
(let ((k 0.5)
      (current-location-fluent (make-fluent))
      (goal-location nil)
      (arrived? (< (v-dist (value current-location-fluent)
                           goal-location)
                   distance-threshold)))
  (loop do (setf goal-location (generate-random-goal-location))
    (par
      (try-all
        (loop
          do (send-velocity-command
               (v* (v- goal-location
                       (value current-location-fluent)) k))
             (setf (value current-location-fluent)
                   (current-robot-position)))
        (wait-for arrived?))
      (whenever arrived?
        (say ''Hello, world!'')))))
```

Methods:

- offline/online/on-the-fly verification
- partial order reduction (POR)
- symbolic simulation
- improvements in error-handling and scaling
- annotation of CRAM plans with property specifications

P-projects: interrelationships within P

- The P-projects can be seen collectively as solving a **portfolio of formalisation** challenges essential for gaining control of the central reasoning tasks involved in modeling and performing activities *intelligently*
- The projects constitute a **logic-based** and **closely interacting** network of research activities, thereby maximising synergies and added-value of re-use



P: a complete unified scenario

P01 Instruction: "And better make sure everyone gets something to drink"

- context: at home, setting table for guests
- underspecified action: simulation semantics
- resolution of activities, unmentioned people, objects and actions
- glasses, drink, pouring liquids, movement to table, place settings

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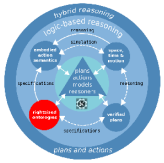

P02 Background knowledge and ontology:

- household, dining room, table, plates, knives, forks
- drinks $\Rightarrow$ activities: containers, glasses
- rightsized for effective reasoning

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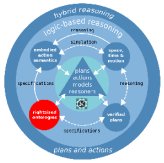

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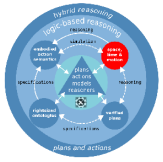

P03 Activities and movement:

- spatiotemporal reasoning and problem solution: getting the drinks to the table, getting the liquid in glasses, the robot to the table
- building on situated activities and bottom-up data
- producing simulations of solutions

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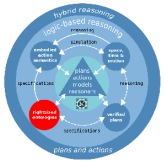

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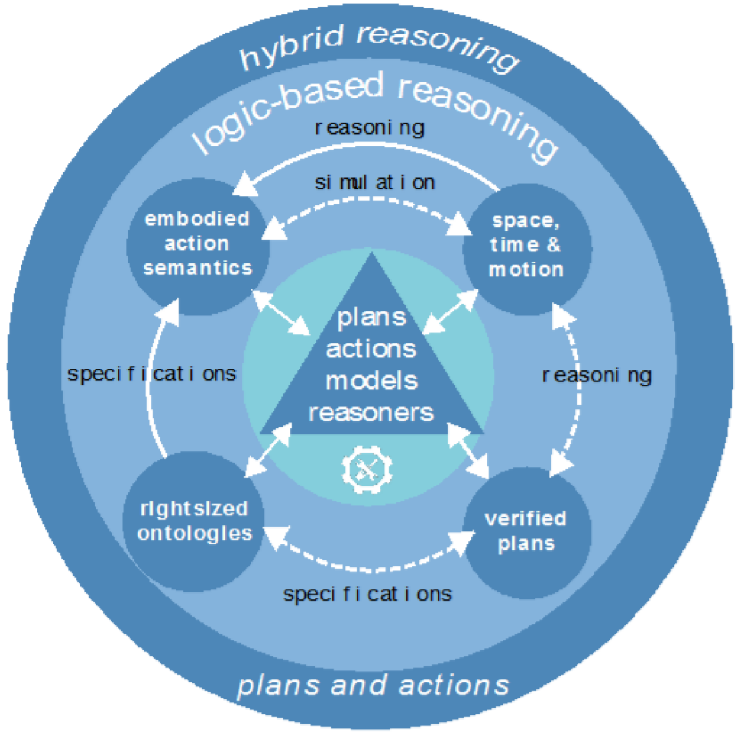
P04 Activities and plans: Verification

- take the glasses and drinks to the table and set them out
- plan verification: is the plan formally correct?
- passing on verified plans to robot
- potential on-the-fly hindrances and correction

P-Projects: interrelationships within EASE: overview



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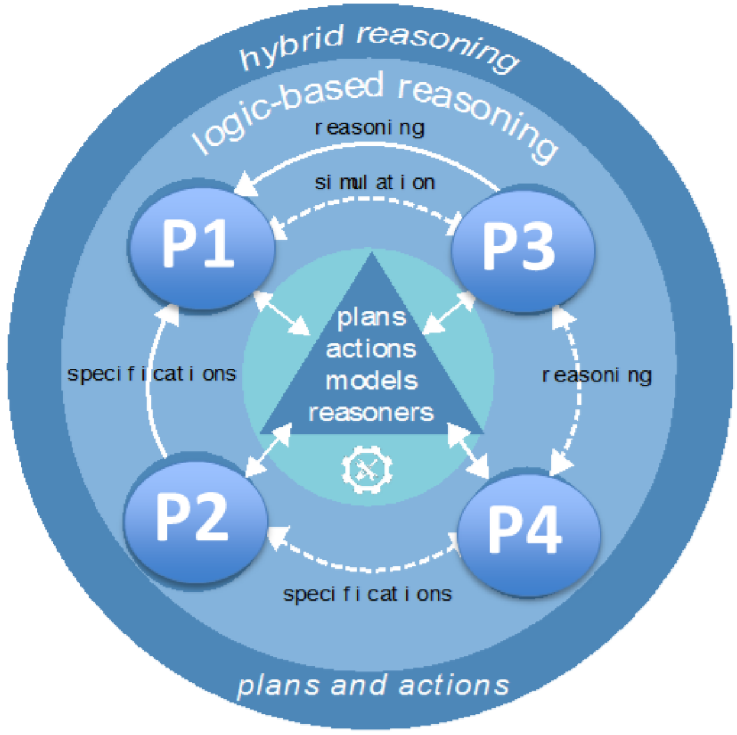

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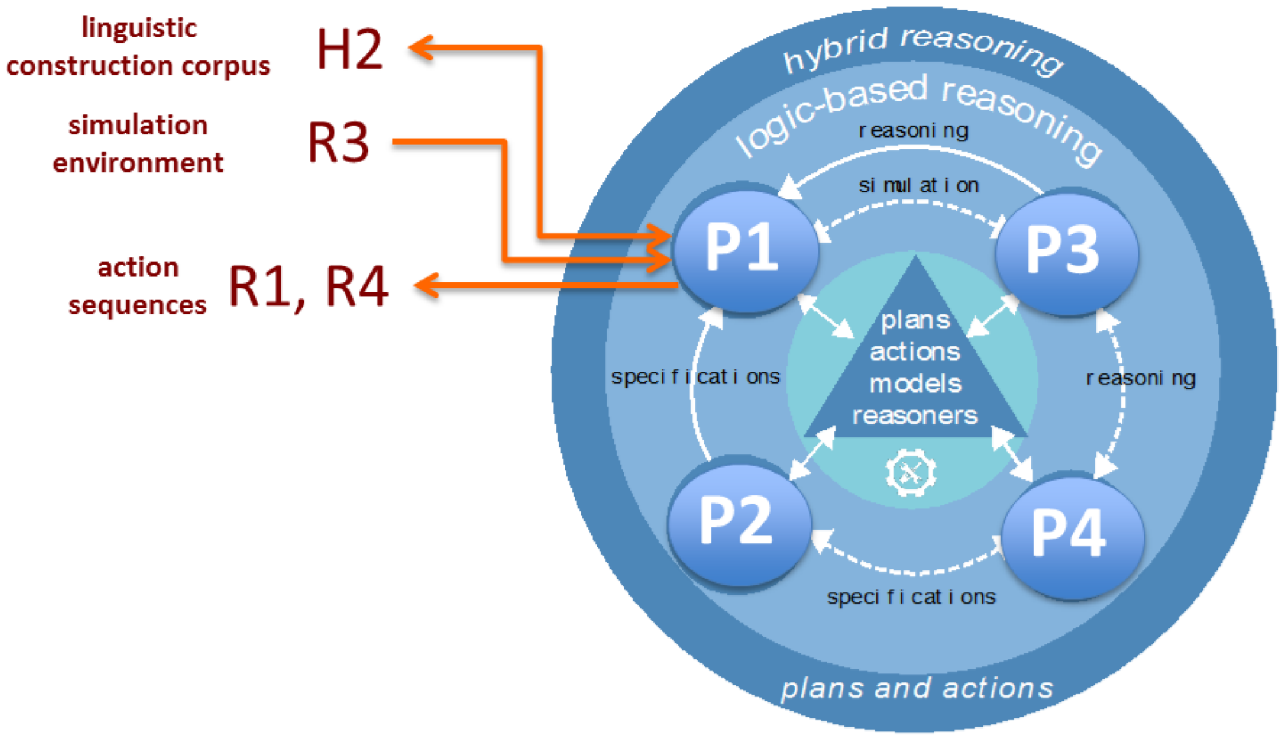
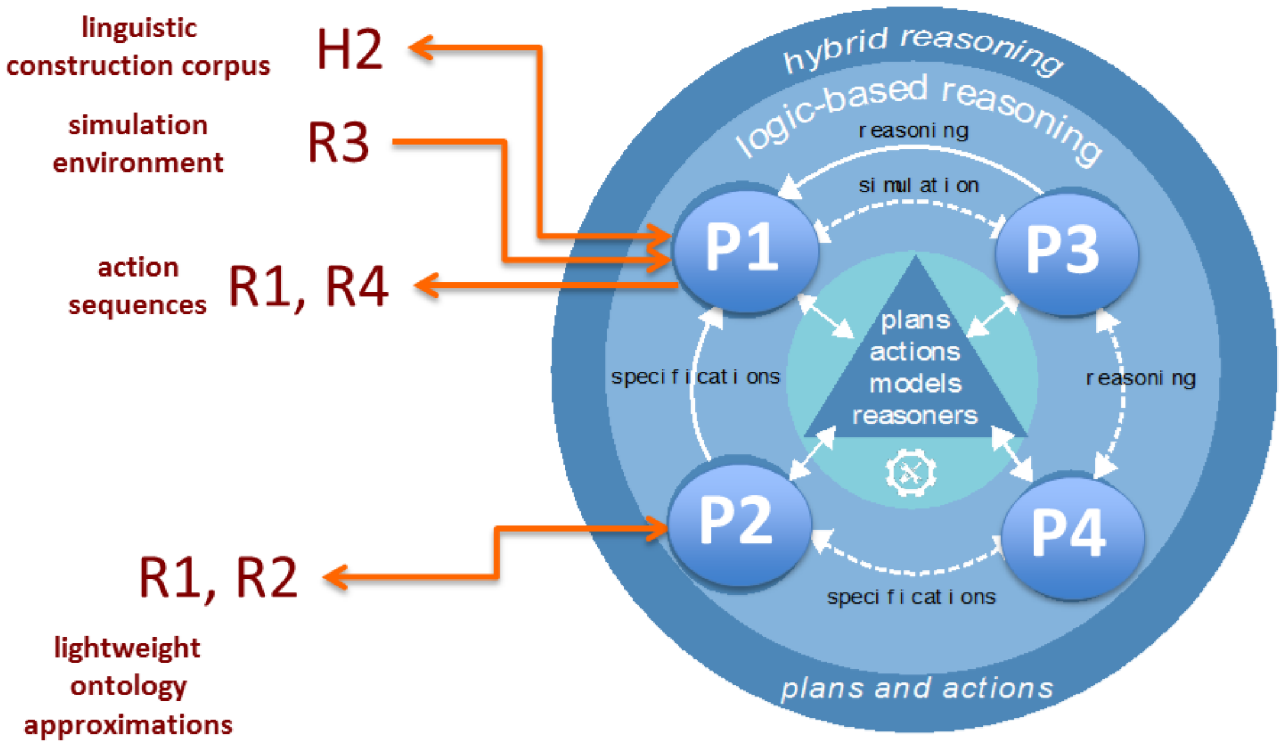
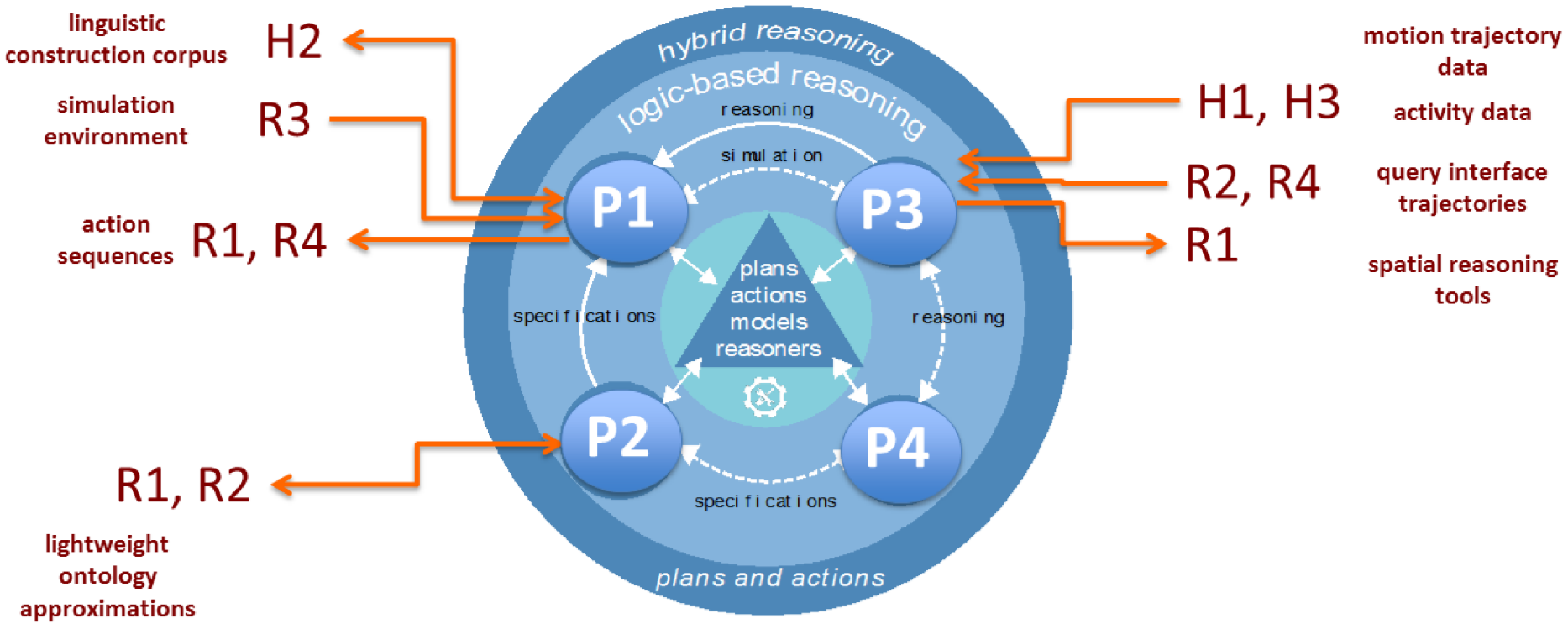


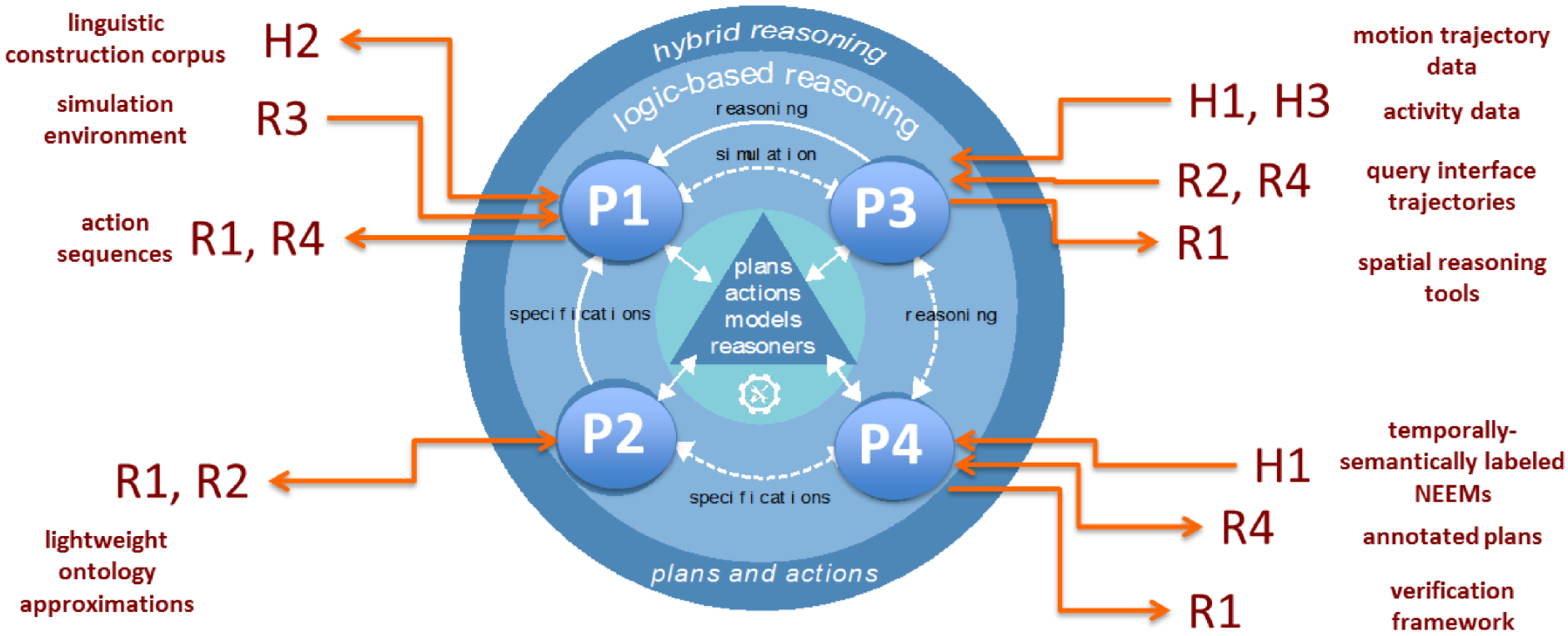
P-Projects: interrelationships within EASE: overview



P-Projects: interrelationships within EASE: overview



P-Projects: interrelationships within EASE: overview



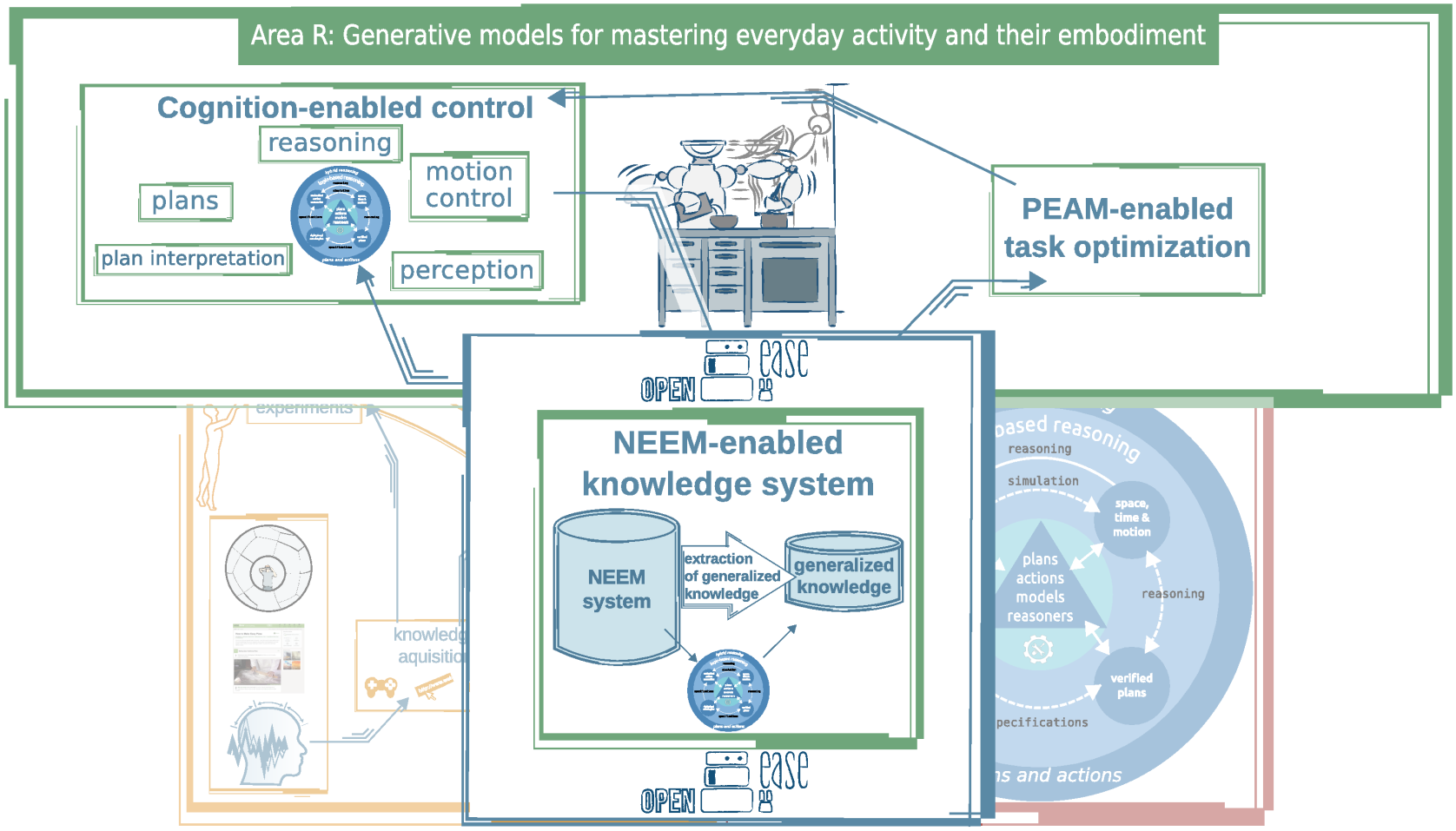
The best of three worlds...

- Direct empirical data (behavioral, perceptual, movement) from situated performance of everyday activities from the H-area
- Realistic grounding in explicit robotic models of activities and embodied perception in the R-area
- Formalisation of knowledge and reasoning at varying levels of qualitative abstraction: refining results from H and producing testable models for R

The 'EASE factor': what participation in EASE adds

- Each of the P-projects explores ground-breaking research tasks **already internationally at the state-of-the-art** or beyond
- Drawing on this foundation, embedding within the EASE scenario and framework provides an unprecedented opportunity for taking those research tasks to the next level: **anchoring both in empirical data and in robotic embodiments**
- This **multiple feedback loop** is precisely what has been missing in more isolated research directions hitherto
- **Long-term perspectives** opened up for sustained results advancing the forefront of international research in each of the areas addressed, to be documented in leading journals and conferences

Research Area R



RA R: Role in EASE

- Boosting information processing for robots by exploiting episodic memory systems
- Acquisition of commonsense and naive physics knowledge as a big data analytics problem
- Radically simplify hard perception tasks through background knowledge and NEEMs
- Construct robust perception systems by combining ensembles of limited algorithms
- Realistically and fast predict symbolic qualitative action effects to parametrize actions
- Autonomously learn simulation models from real-world NEEMs
- Generic robot plans that context-sensitively infer action parameters given desired effects
- Optimize generic robot plans through exploitation of regularities of everyday activity
- Episodic memories for challenging hand manipulation activities
- Rapidly learn from few examples using NEEMs and episode mirroring

RA R: Objectives and Measures of Success

Goal: investigate and construct the EASE control framework including perception, learning, and reasoning mechanisms

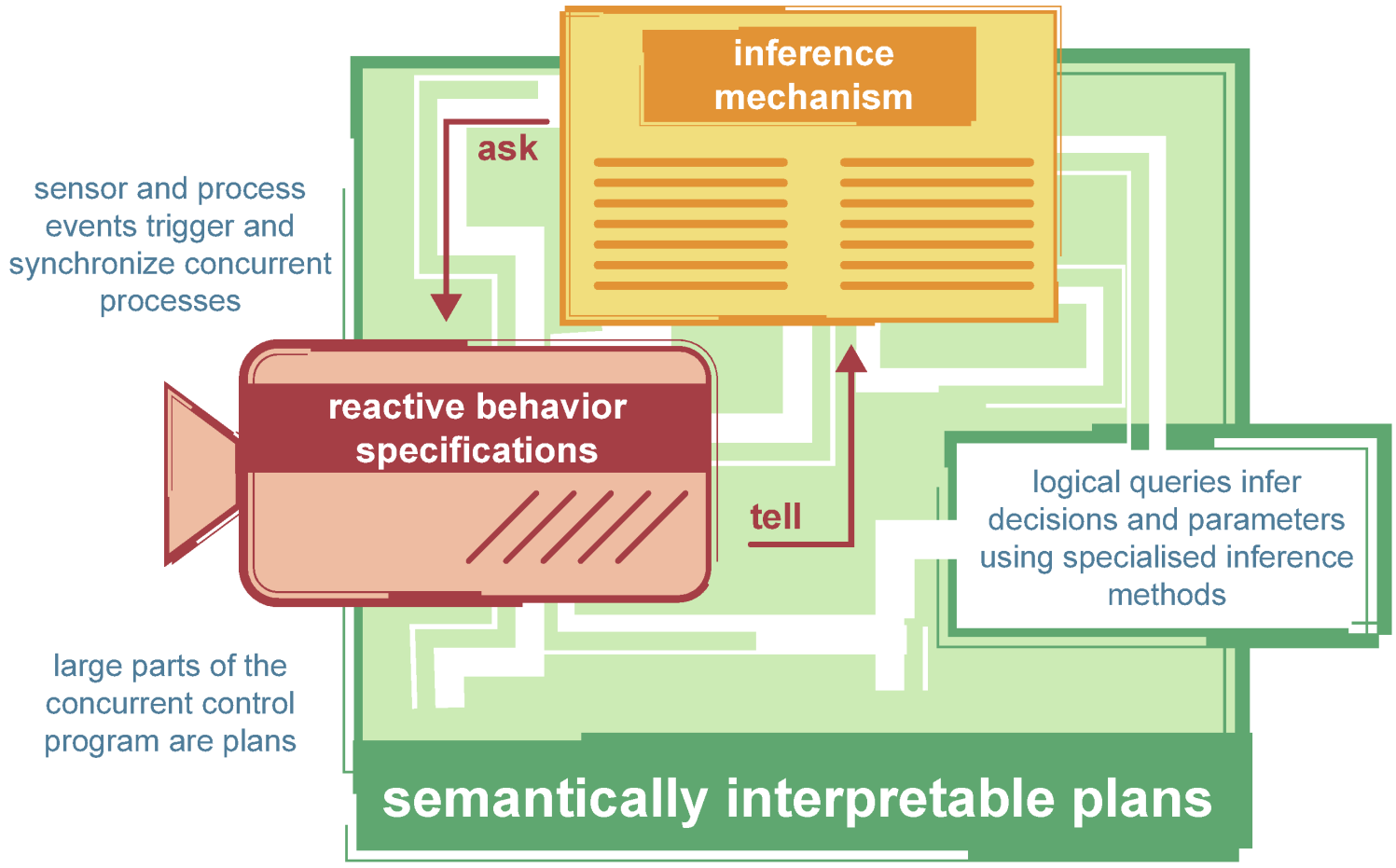
Objectives: realize the

- NEEM-based knowledge system
- perception-based and simulation-based reasoning
- plan-based control framework

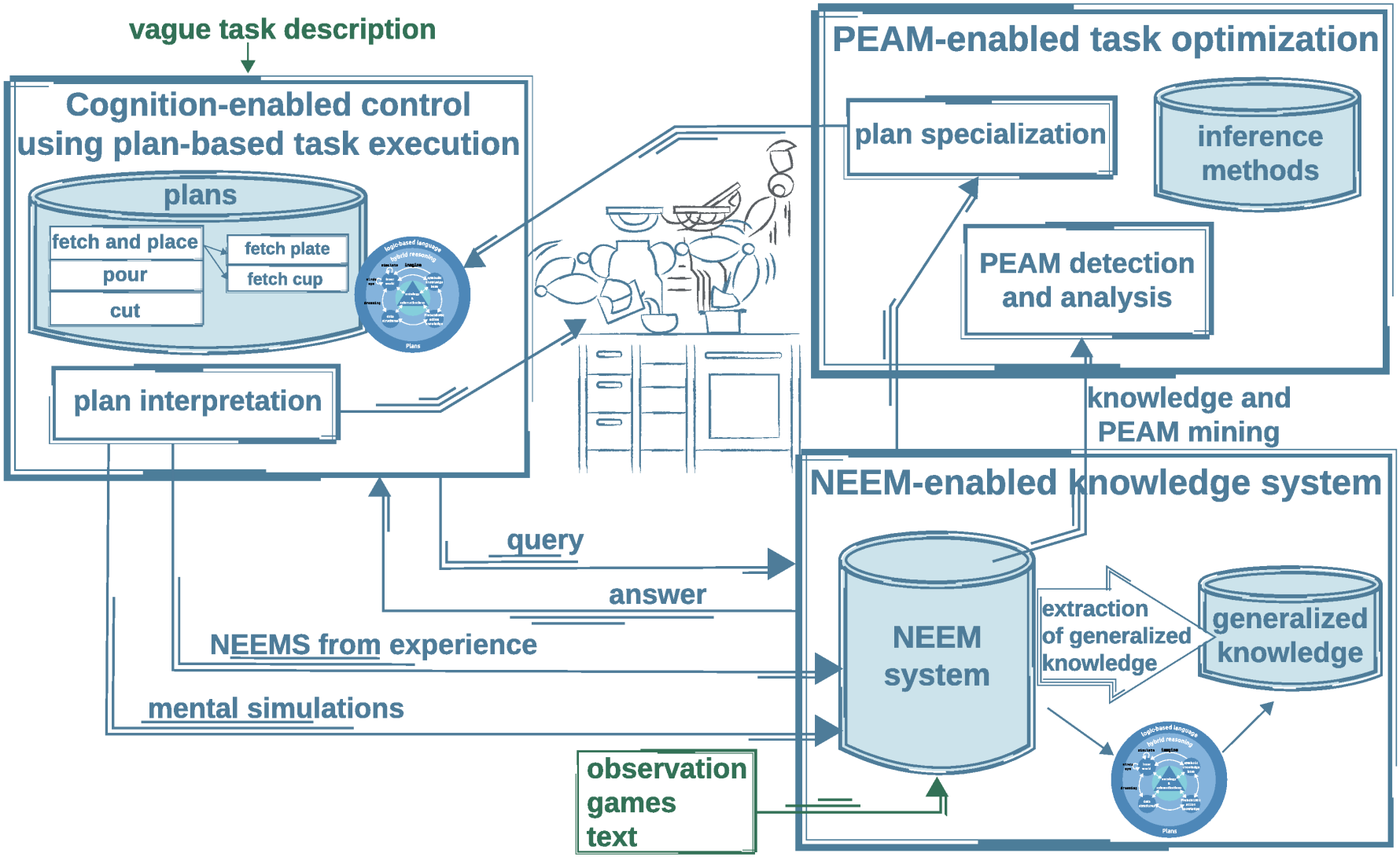
Measures of success:

- benchmark queries to test the cognitive capabilities
- performance increase
- autonomy in adaptation of generic plans

Starting points - Embodying plan execution

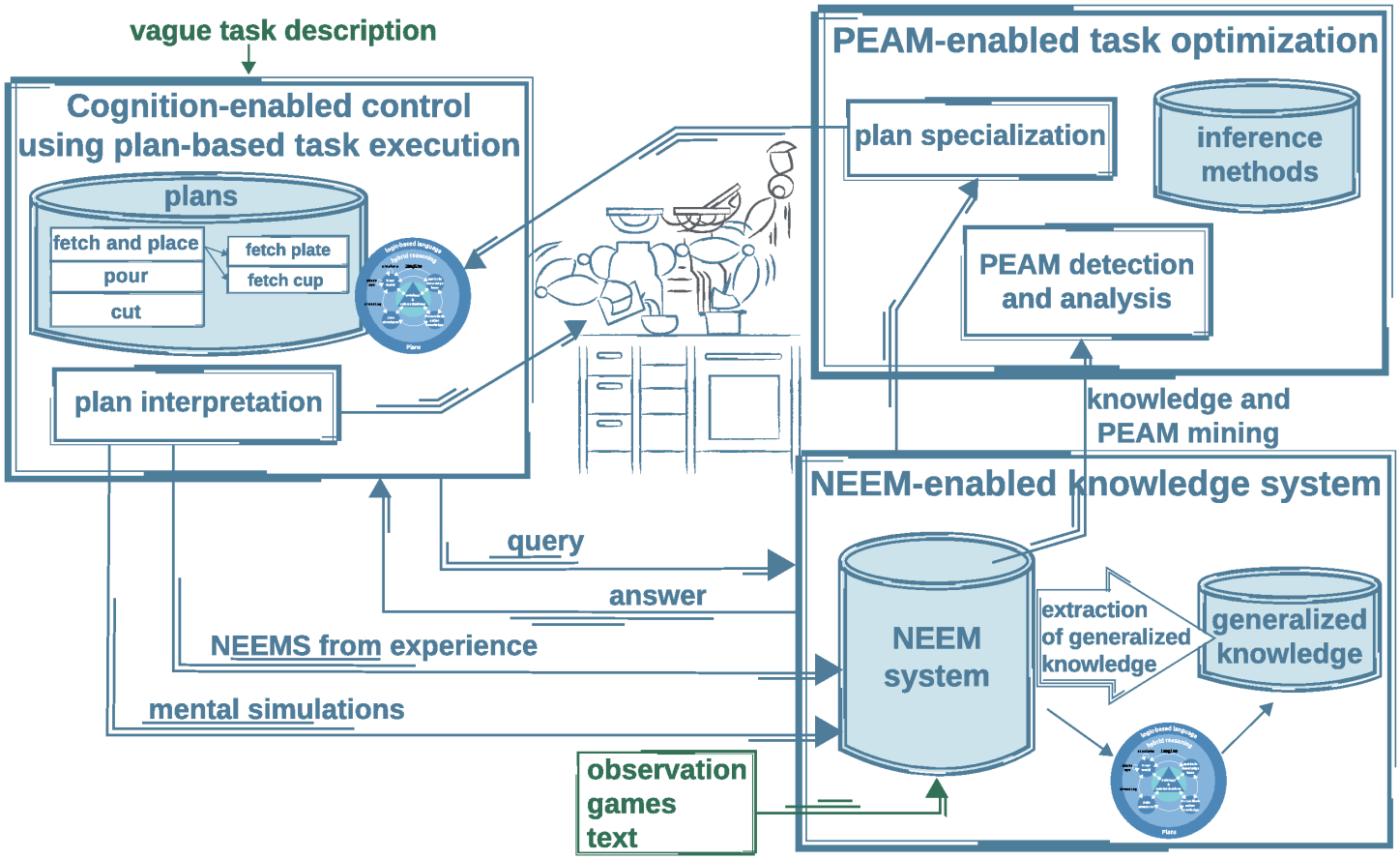


Methodology applied in Area R



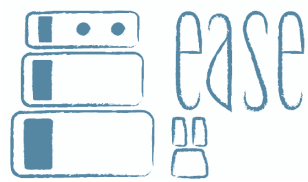
Subproject R01

NEEM-based embodied knowledge system



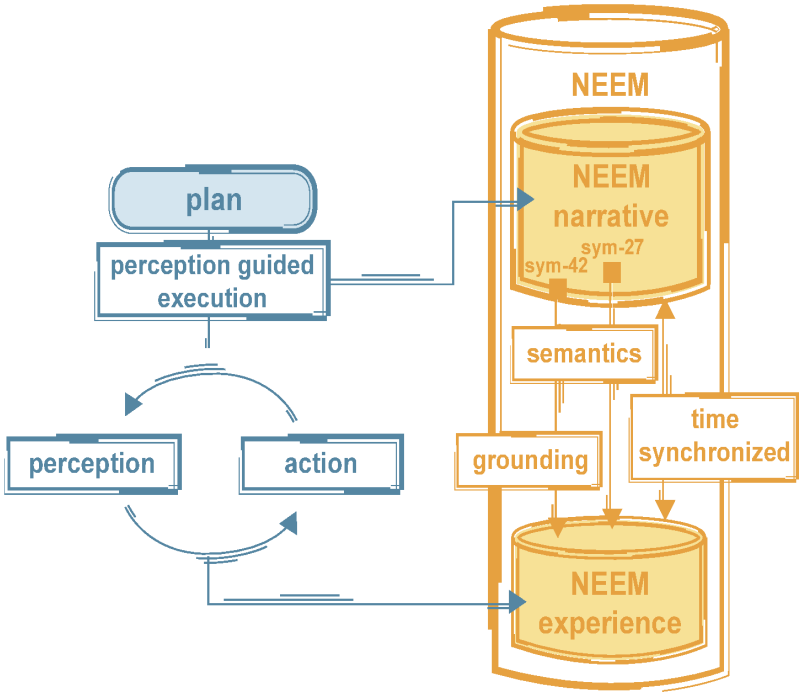
R01 Scientific Goals

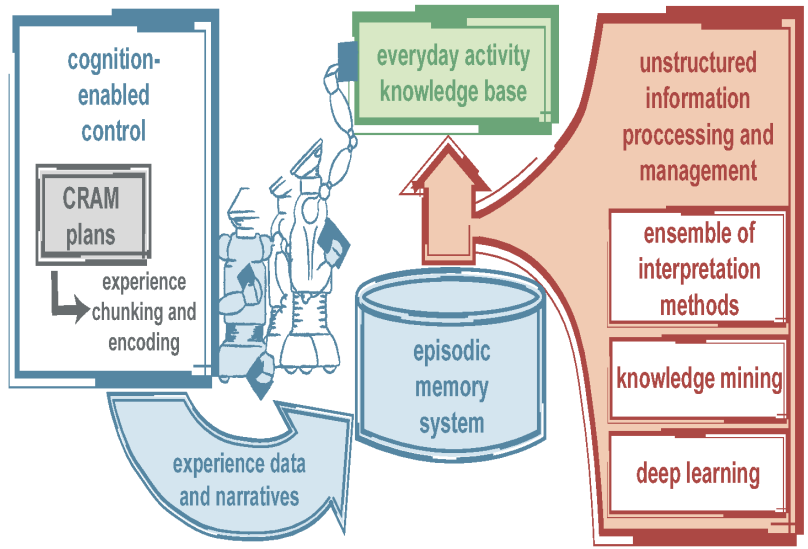
- Development of an embodied knowledge acquisition, representation, and management framework.
  - artificial episodic memories indexed through symbolic narratives
  - declarative knowledge subsystems for everyday activity knowledge
  - experience analytics subsystem to extract commonsense and naive physics knowledge
- Investigation of a physically embodied query answering service for knowledge completion.



R01 Approach

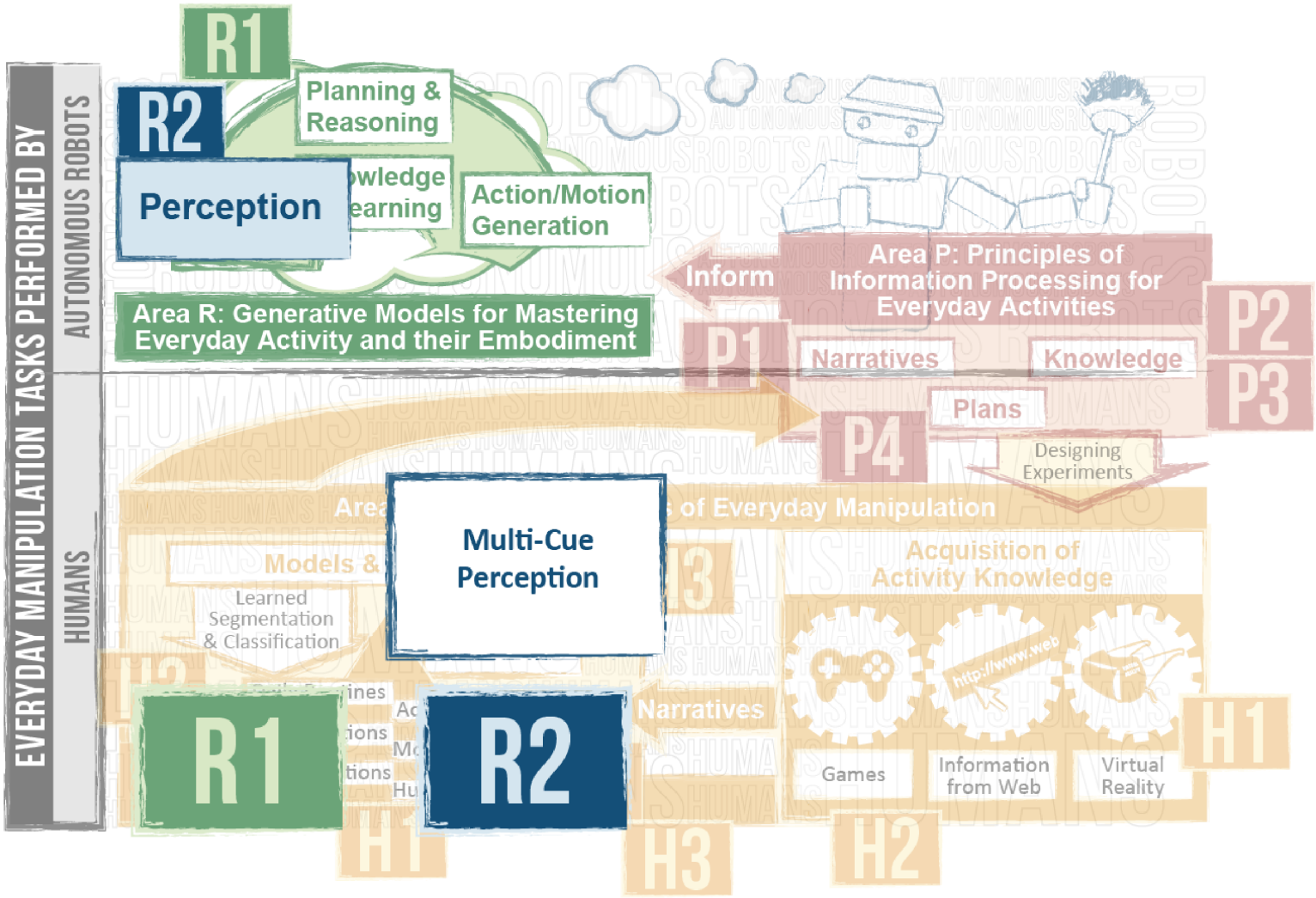
Collecting NEEMs and Learning generalized knowledge from NEEMs





Subproject R02

Multi-cue perception based on background knowledge



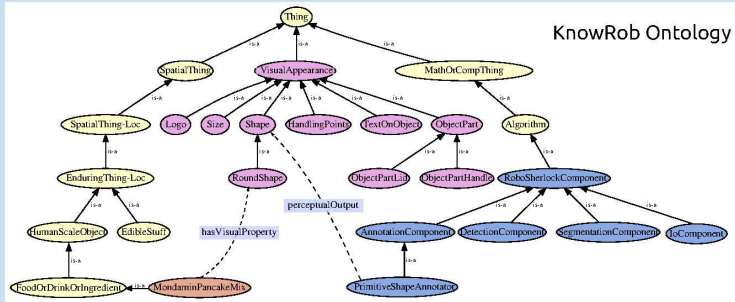
R02 Scientific Goals

- 3D-object localization in, e.g. cupboards and dishwasher
- Extreme occlusion
- Utilize background knowledge and memory to foster recognition
- "PEAM of objects inside containers"

R02 Approach

- Comprehensive Bayesian model of relevant cues and phenomena – geometric depth, edges, color, **reflections**
- Inference Algorithm for this combination
- Integration with RoboSherlock (UIMA) framework

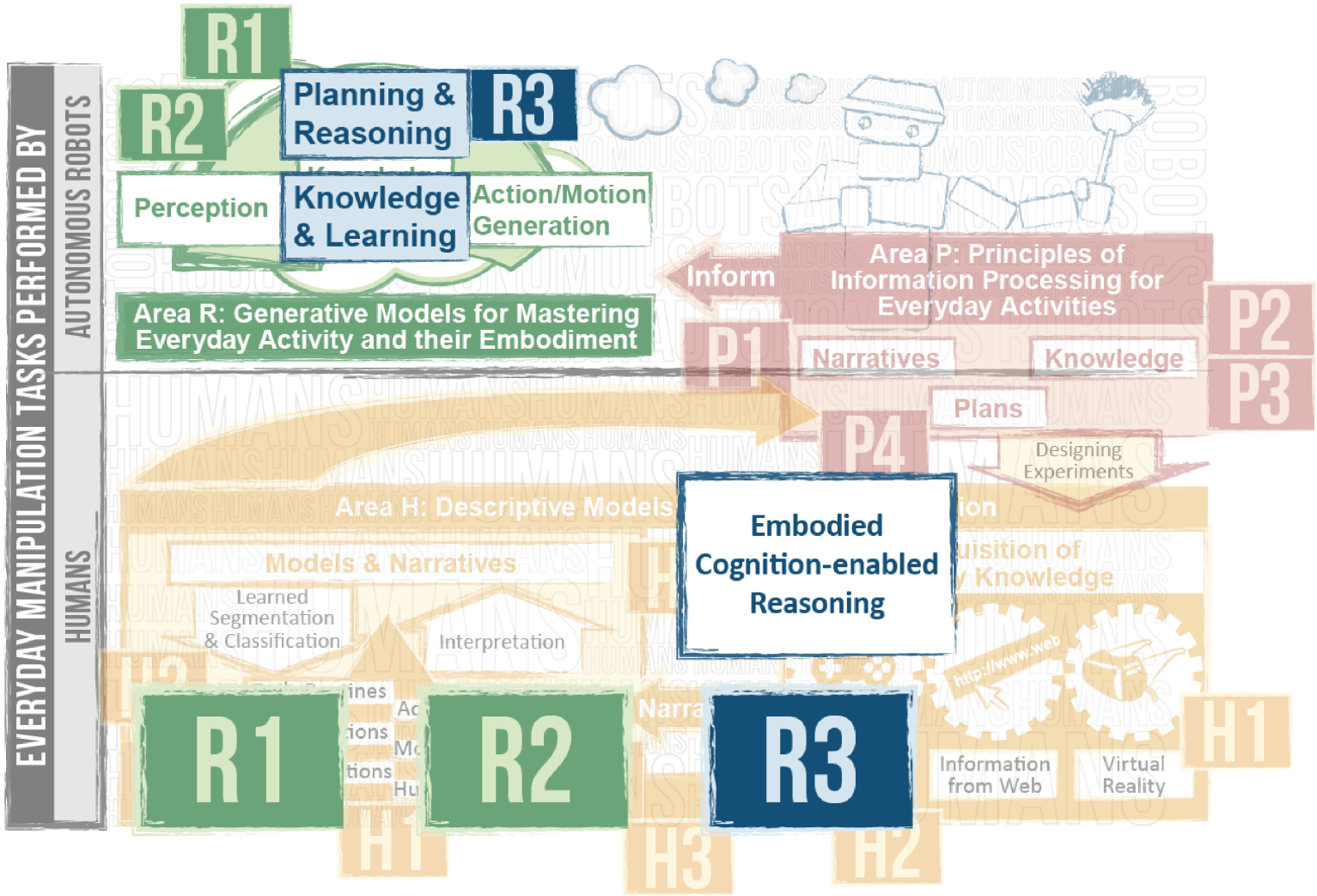
```
(detect(an object
        (name handle)
        (location kitchen_sink)))
```



```
(detect(an object
  (location on (object PancakeMaker))
  (shape flat)
  (color yellow)
  (name Pancake)))
```

Subproject R03

Embodied simulation-enabled reasoning

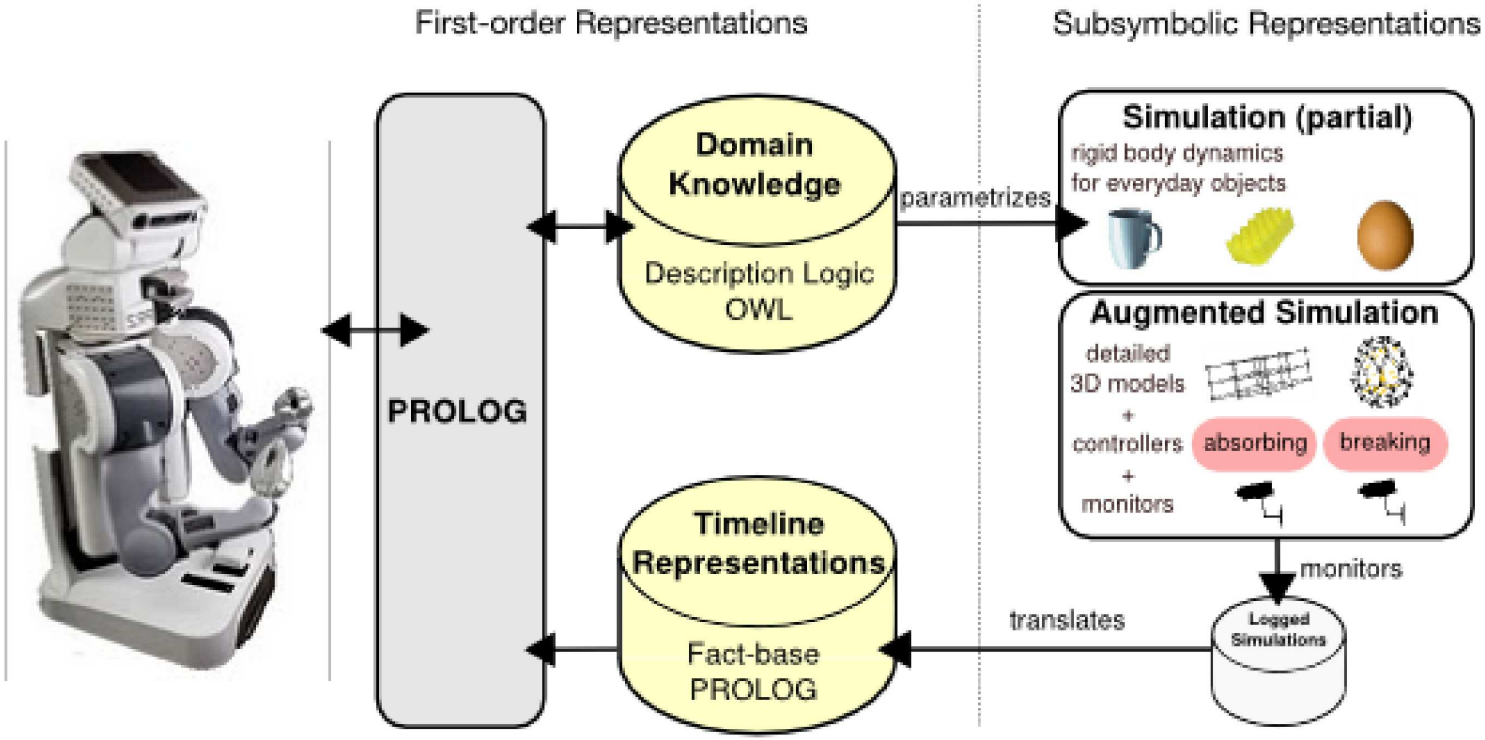


R03 Scientific Goals

- Simulation-enabled reasoning engine for robots
- Integration of simulation-enabled reasoning into the perception-action loops of the robots
- Simulations for naive physics and commonsense reasoning
- Learning simulation models from NEEMs

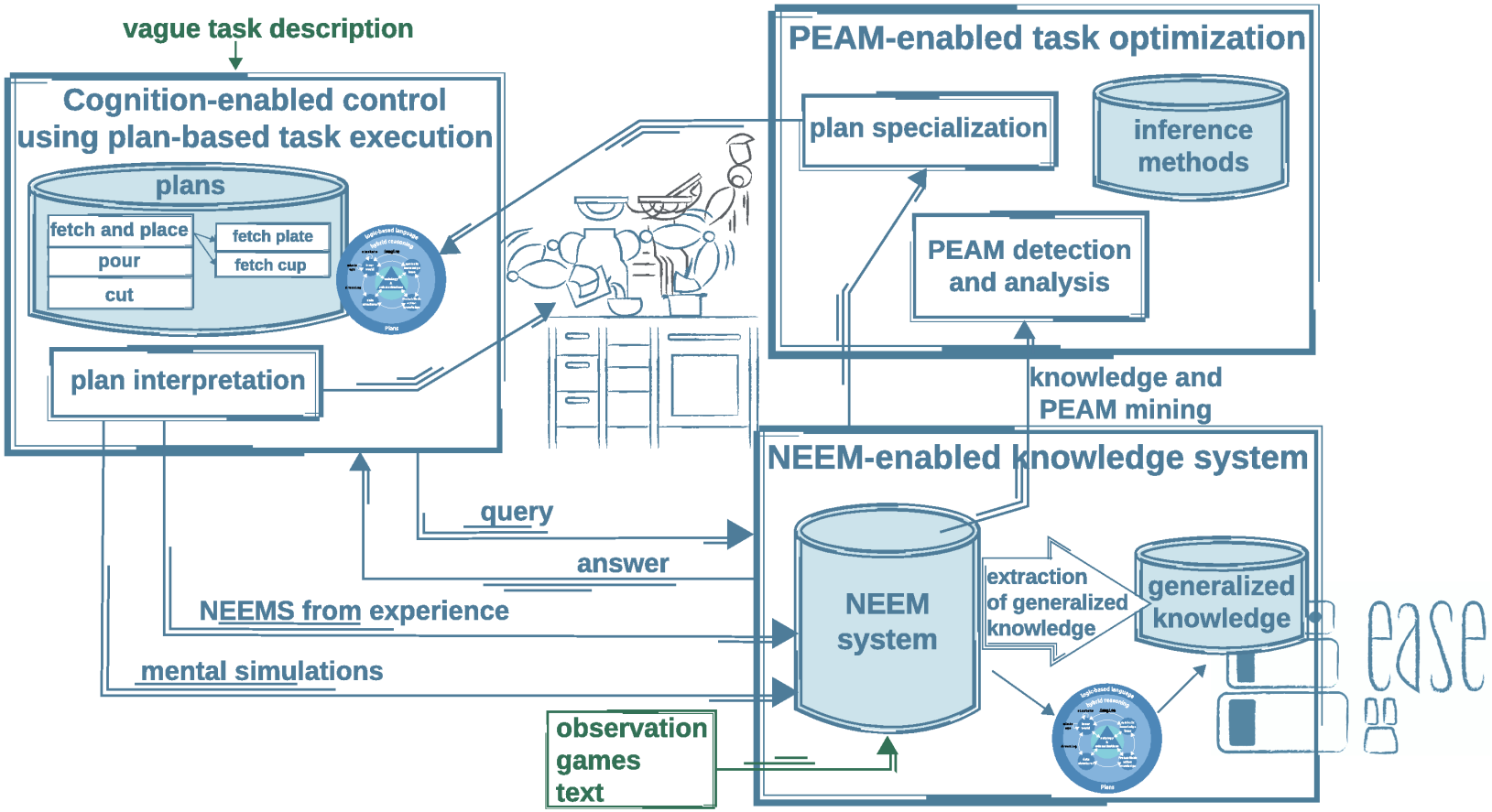
R03 Approach

Develop a qualitative reasoning method that reasons about actions and their effects based on the mental simulation-based predictions.



Subproject R04

Specializing and optimizing generic robot plans



R04 Scientific Goals

- Use PEAMs to improve task performance of generic robot plans for particular task contexts
- Consider plans as executable and modifiable behavior specification subject to reasoning
  - Plans as subjects of learning: Analyse plans and NEEMs to detect flaws and opportunities
  - Plans as high-performance inference engines: Learn query-specific knowledge bases
  - Plans as interpreters of vague action descriptions: Specify actions using desired effects

R04 Approach

A generalized action plan for pouring

def-plan pour (⟨**theme**⟩ : (some stuff)
⟨**source**⟩ : (an object
(type container)
(contains ⟨**theme**⟩)))
⟨**dest**⟩ : (a location))

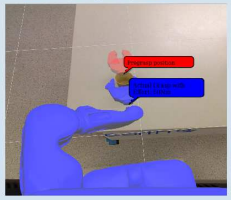
begin

1. reach(⟨**source**⟩)
2. lift(⟨**source**⟩) (a location (above ⟨**dest**⟩))
3. tilt(⟨**source**⟩)
   until (amount (some stuff (at ⟨**dest**⟩))
   ≥ (amount ⟨**theme**⟩)

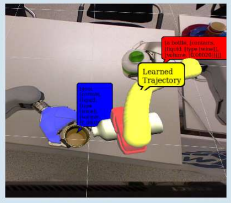
end

Groundings

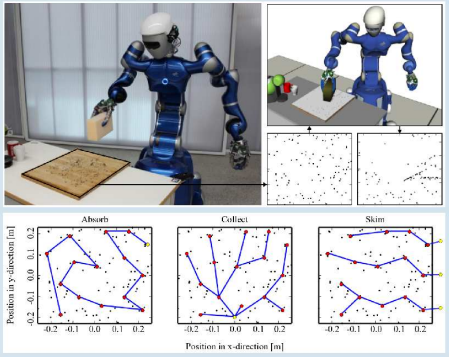
reach:



tilt:

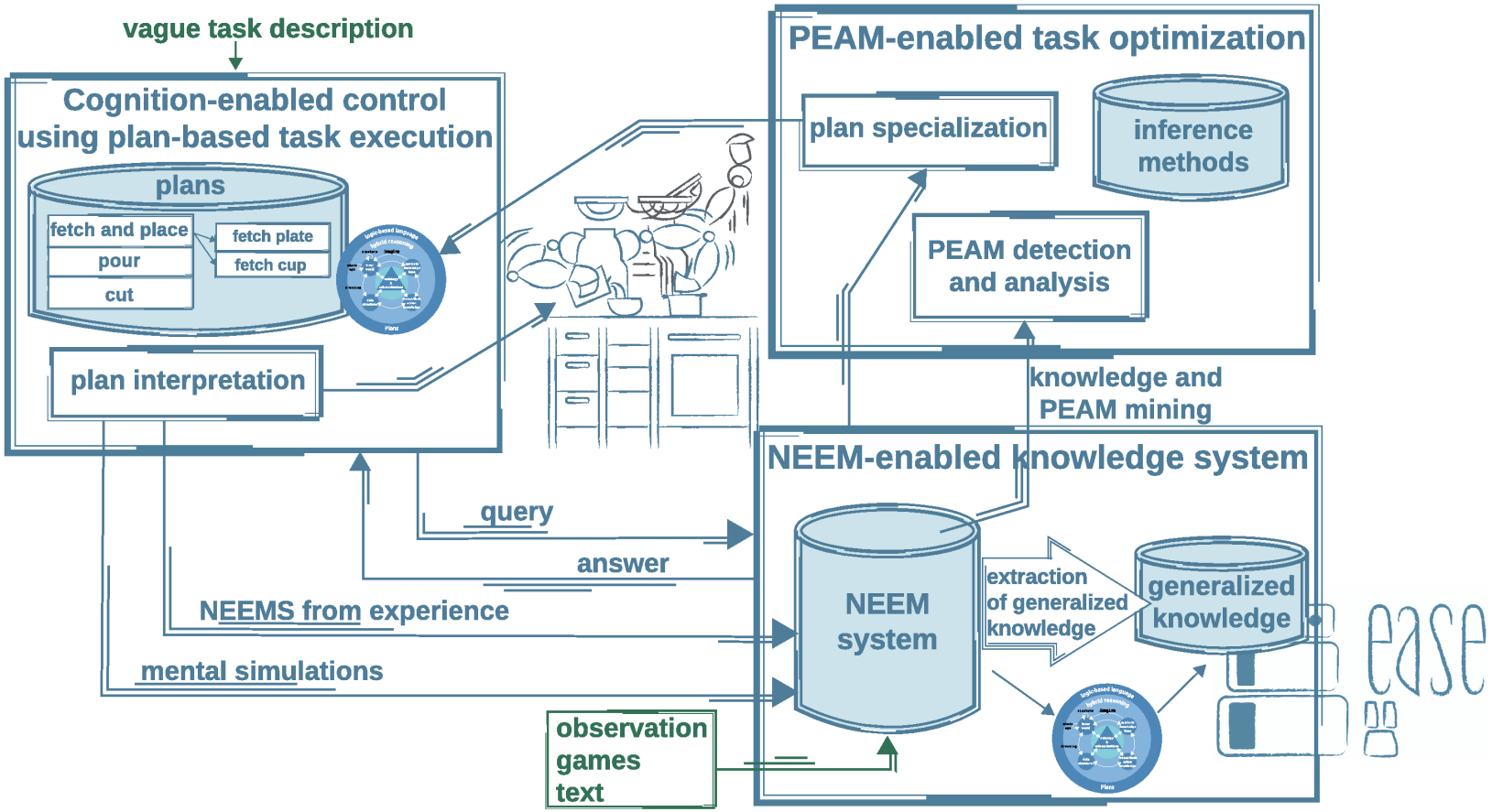


wipe:



Subproject R05

Episodic memory for everyday manual activities



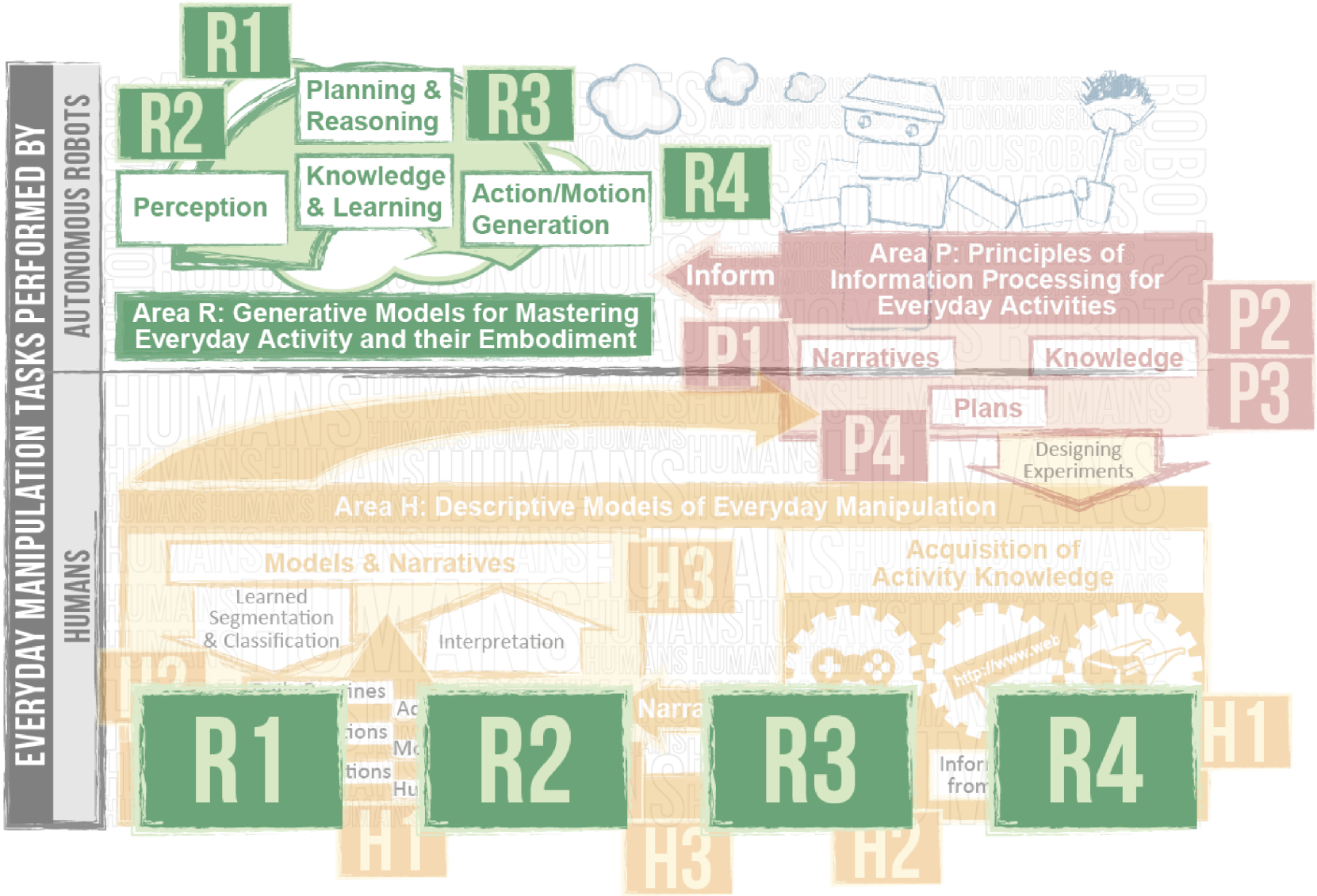
R05 Scientific Goals

- NEEM-based information processing and control models for manual manipulation actions
- link semantic and procedural knowledge representations via NEEMs in order to scale to large numbers of action patterns
- use of NEEMs and episode mirroring to accelerate learning novel hand manipulation skills from very few example episodes

R05 Approach

- Exploration informed by NEEMs
- NEEMs as link between semantic and procedural memories
- Exploitation of grasp synergies (PEAM)

Research Area R



Infrastructure Projects

Z Project Management
F Technical Coordination (Lab/Experiments)
MGK Integrated Research Training Group
INF Information/Data Management

- coordinate the scientific work (Z)
- provide the necessary administrative infrastructure for EASE (Z)
- public relations, dissemination, and exploitation (Z)
- technical management of lab, robots, experimental equipment (F)
- integrated research training group (MGK)
- information and data management (INF)
- support general aims, e.g. scientific excellence, gender equality, international networking (all)

subproject Z

Project Management

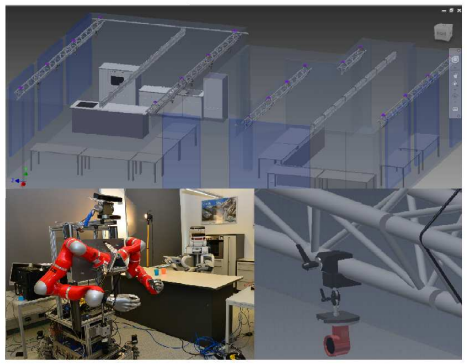
- coordinate the scientific work
- provide the necessary administrative infrastructure for EASE
- public relations, dissemination, and exploitation

Recent dissemination activities

Subproject F

EASE central lab, robots, experimental equipment

- build three new robotic platforms and update current ones
- technical support for experiments
- software integration
- hold tutorials for the use of EASE software components



Subproject MGK

Integrated Research Training Group

- Acquiring scientific excellence in research areas related to EASE
- Acquiring soft skills, e.g. scientific writing, project management, oral presentation and teaching techniques, language skills, dissemination strategies for scientific results, etc.
- Opportunities for cooperative research with scientists from other disciplines
- International experience and networking with experts
- Reduction of graduation time to a maximum of 3-4 years

Subproject INF

Information and Data Management

- Store, manage, and maintain DBs and KBs
- Make them accessible outside of EASE
- Make results reproducible and encourage the community sharing research data
- Provide data in downloadable form and web service