

Considered Robot Behaviour in Social Space — A Case for Qualitative Spatial Representation and Reasoning

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Project „Making Space – The Ontology of Social Interaction“
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Terminology

- Different meanings of 'social' in AI
 - Simple agents that bring about complex emergent structures by indirect coordination
 - e.g., ants leave pheromone traces in the environment & by following these traces, ant trails emerge
 - Rule-compliant agents that behave according to sets of rules posed to ensure adequate behaviour
 - Cognitive agents that are able to reason about consequences of their own behaviour towards 'the others' considering the others' specific needs

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Lack of Consideration

- Sometimes, things become apparent, if they go wrong.



Territorialization exemplified



Authority imposes explicit norm on the platform.

Motivation & Research Question

- Robot spatial behavior should consider the spatial needs of others, e.g., not block action possibilities of humans or other robots.
- Research Questions
 - Which kinds of spatial needs do exist?
 - Which role does space actually play for social interaction compared to other concepts like normativity, rational agency, ability, etc.?

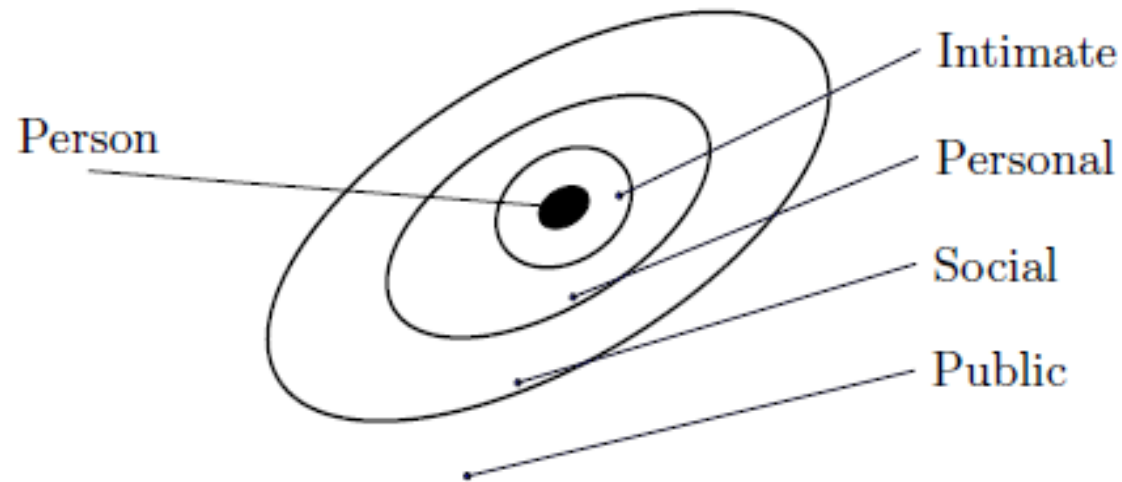
Outline

- Social spaces in the social sciences
- Social spaces in human-robot interaction
- Towards a theory of social space
- Some sample applications to socio-spatial reasoning

Social spaces in the social sciences

Personal Space

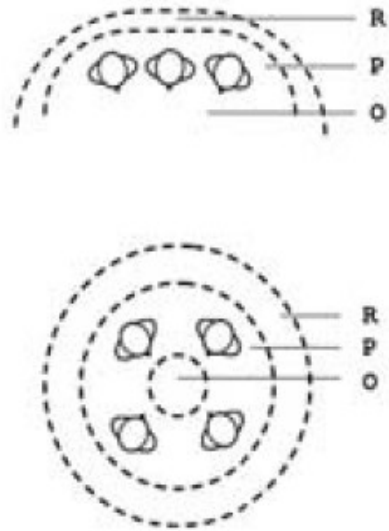
(Hall, 1966)



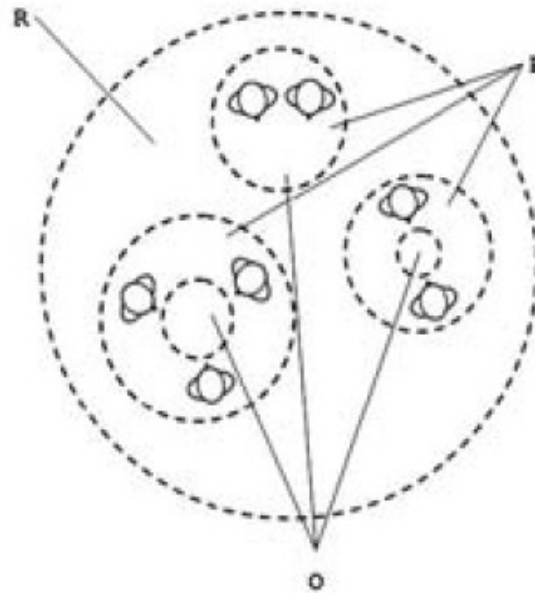
- Intimate distance: 0 – 45cm
- Personal distance: 45 – 120cm
- Social distance: 120 – 360cm
- Public distance: > 360cm

F-Formations and Beyond

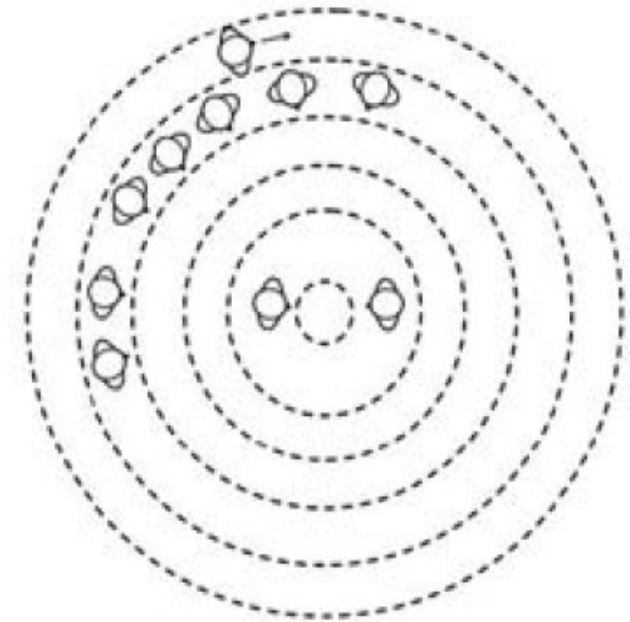
(Kendon 1990, Schefflen & Ashcraft, 1976)



F-Formation



Gathering



Hub

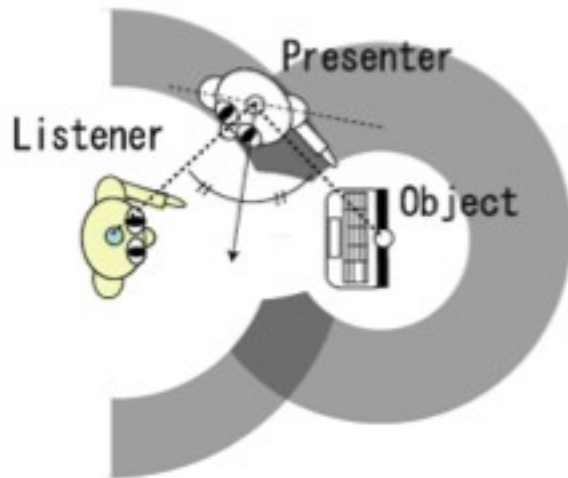
Source: (Pedica & Vilhjalmsson, 2009)

Territory

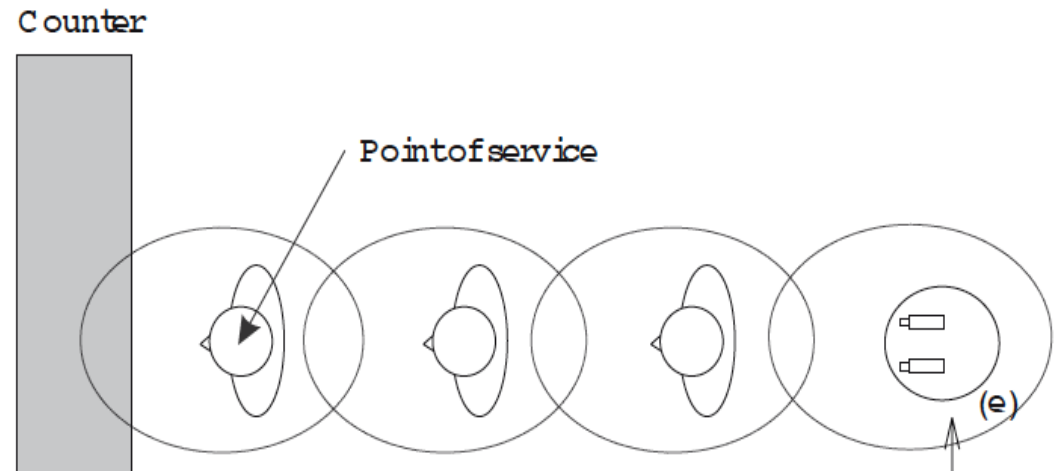
- Has an owner / authority having the power of deciding who has access to the inside and how behaviour of the agents being inside is restricted
- „This fundamental relationship to social power is one of the features that distinguishes territory from other forms of social space“.
(Delaney, 2004)
- Often, territorial markers are used:
(Goffman, 1971)
 - Central markers
 - Boundary markers
 - Ear markers

Social Spaces in HRI

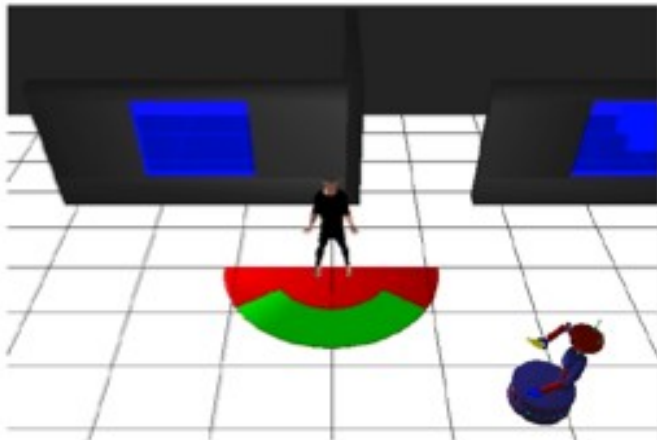
Social Spaces in HRI (Very Briefly)



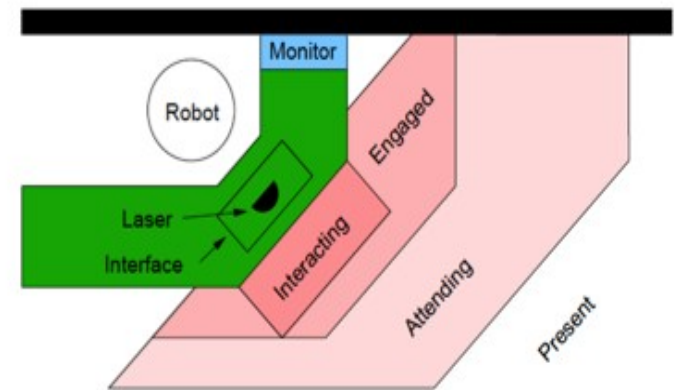
„F-Formation“ (Yamaoka et al., 2008)



„Personal Space“ (Nakauchi & Simmons, 2002)



„Interaction Area/Security Area“ (Sisbot et al., 2010)



„Spatial Region“ (Michalowski et al., 2006)

Results from a broader Literature Review

- „F-Formations“ and „Personal Space“ popular in HRI (and in other areas such as Virtual Agents, Ambient Intelligence, etc.)
- There seems to be no consensus upon which concept fits to which kind of problem
- Seemingly new concepts are invented, which are in fact already described
- Different terminology for the same concepts;
Same Terminology for different concepts

Research Goal

- A theory of social spaces
 - What can be said about social space *as such* apart from the various forms they take?
 - Identifying essential properties to discriminate social space types
 - Conditions for production
 - Normative meaning
 - Spatial structure
 - Analyse interrelations between social space types
 - A framework for KR&R w.r.t. social spaces
 - Fixed vocabulary
 - Compact set of axioms
 - Supports comparability, interoperability, and reasoning services

Towards a Theory of Social Space

(cf., Lindner & Eschenbach, 2011)

Social Space

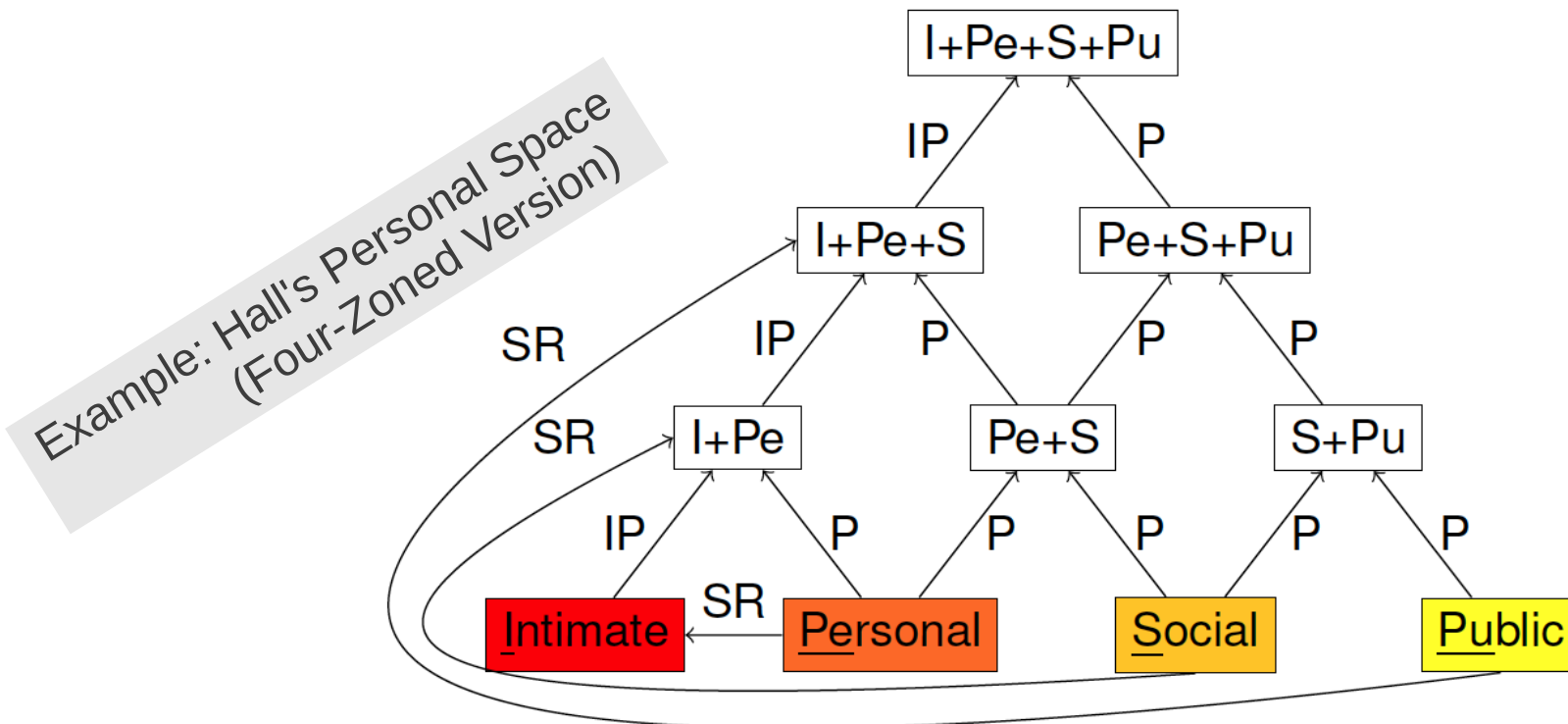
- Social Spaces are produced
 - By arrangements of things at places (cf., Löw 2001)
- Social Spaces consist of social zones
 - Relations between SZ topologically stable
- Social Spaces carry a normative meaning
 - Distributed among its social zones

Social Zones

- Spatial extension of social spaces
- Social zones carry a maximally homogeneous normative meaning
 - The normative meaning does not change within a social zone
 - No two social zones within the same social space carry the same normative meaning

Characterizing Personal Space

- Produced by an agent
- Spatially structured as concentric ellipses with the producer being located in the center



$$SR(r, r') \equiv_{def} EC(r, r') \wedge \forall r'' [EC(r'', r') \supset O(r'', r)] \quad (\text{Surrounds})$$

Meaning of PS Zones

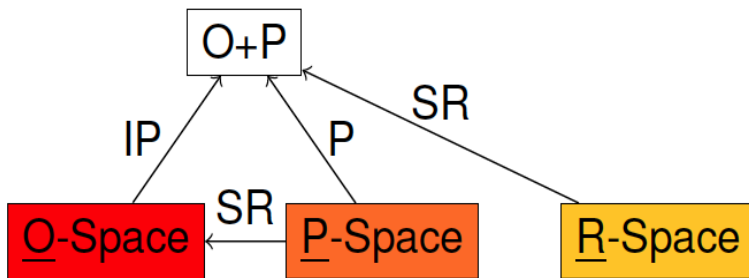
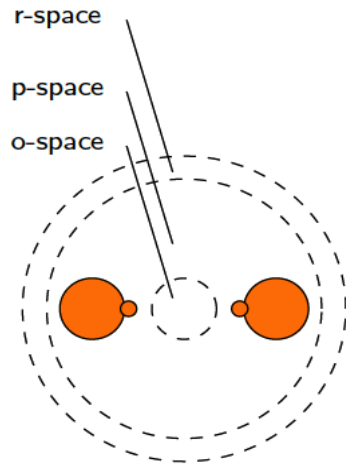
- Normative meaning relates to the degree of perceived intimacy of the producer
- Different social zones represent qualitative changes in the degree of perceived intimacy

Note: The Hallian four-zoned northern-american personal space is not *the* personal space but just one sub-type of the general personal space type.

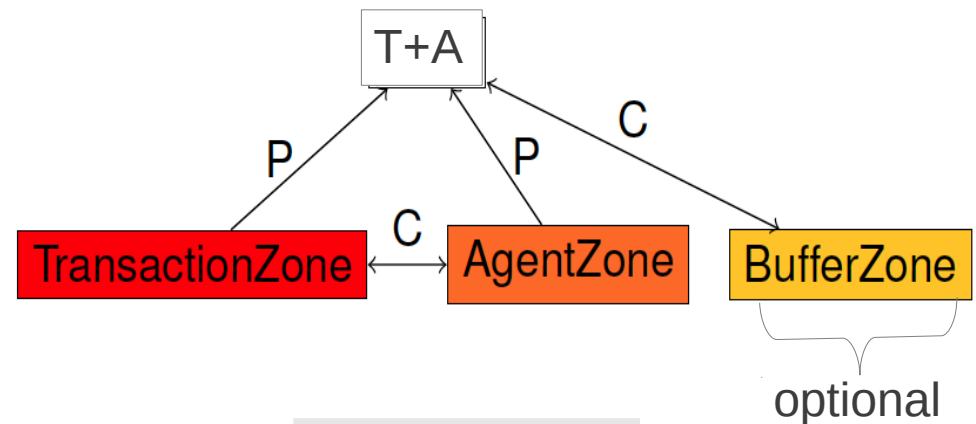
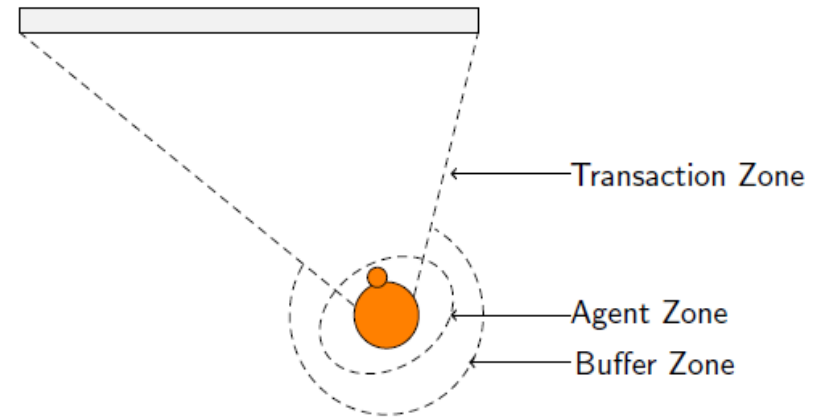
Characterizing Activity Spaces

- Activity Spaces are produced by activities
- Normative meaning of activity space zones relate to the maintenance of the activity
- Different zones play different roles w.r.t. the activity, e.g., location for the participants, further space needed for the transaction

Activity Space Examples



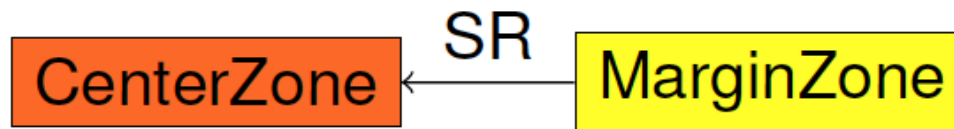
Example: Kendonian F-Formation



Generalization

Territory

- Territories are produced by claims
- Normative meaning relates to the integrity of the claimant, its rights and possession
 - Speciality: Violation of territory is possible even if no agent is co-present



Intermediate Summary

	Personal Space	Activity Space	Territory
Producer	Agent	Activity	Claim
Spatial structure	concentric zones	agent zone, transaction zone (connected)	center zone, margin zone
Meaning	(Distance- dependent) Intimacy perception	Maintenance	Integrity / Power / Possession
Application	HR-Approaching, Avoidance (Path Planning)	Joining & participating in activities, Avoiding disturbance	Obeying rules posed by authority; respecting others' possession

- However: All this does not yet explain why a robot should not block a doorway.

Affordances and Affordance Spaces

(Lindner & Eschenbach, unpublished manuscript)

Affordance Spaces

- Affordance Spaces are produced by affordances
 - Affordances are possibilities for action provided by the environment to agents (cf., Gibson, 1977)
- Normative meaning relates to the maintenance of action possibilities relative to agent abilities
 - Violating affordance spaces leads to the deactivation of possibilities to act (for others)
- Different social zones represent the qualitative differences of (spatial) needs/abilities of the potential agents acting upon the affordance

Affordances: Examples

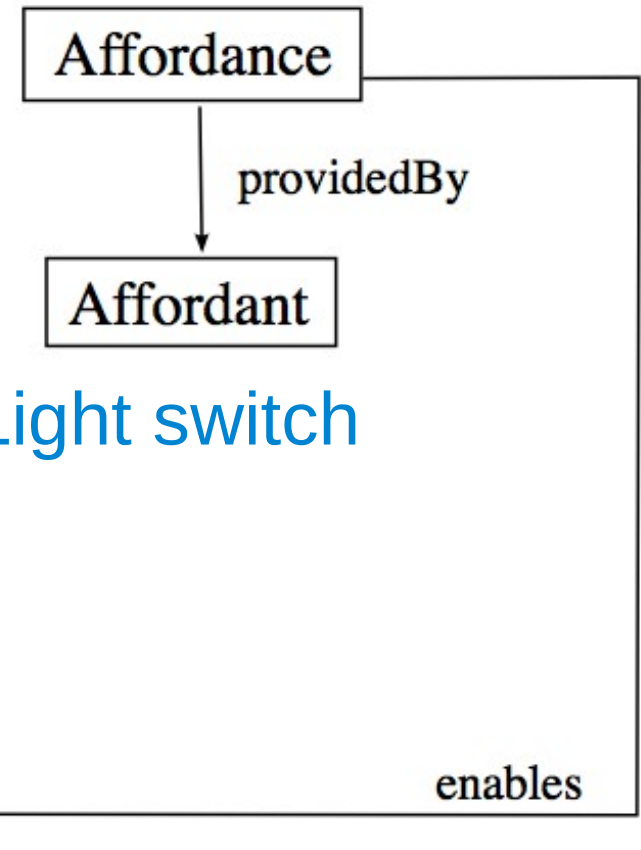
- Light switches afford switching to humans
- Stairs afford climbing to many humans, but form obstacles for most robots
- Doorways afford moving through to humans and robots

Focus on activity types, that have exactly two participants: an Agent and an Affordant.

Affordances

- Exist independently from activities actually taking place
- Provided by affordants
- Enable activity types
- Can be realized more than once by different activities and by different agents

switchability

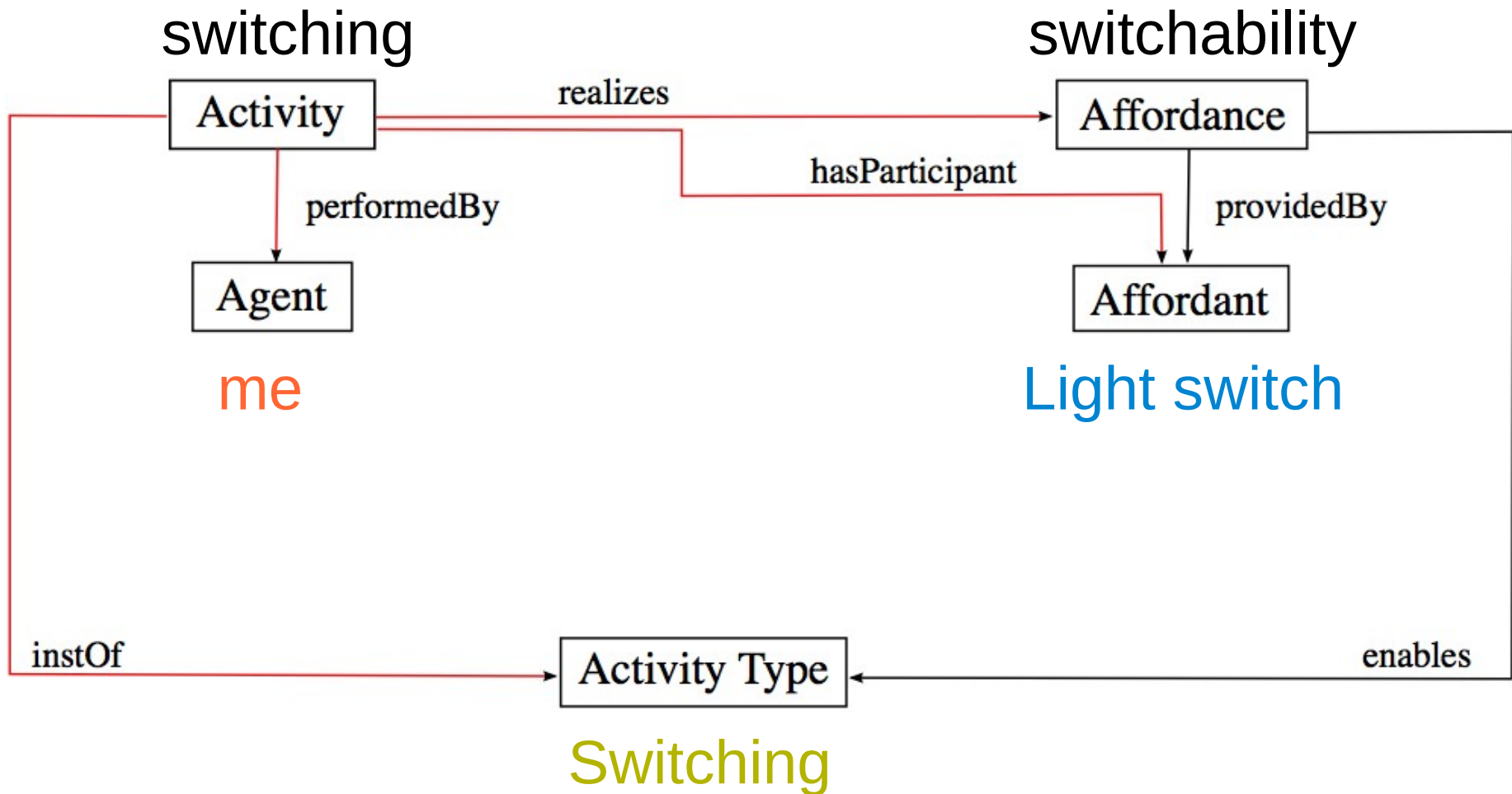


Light switch

Activity Type

Switching

Activities realize Affordances



Activities and Abilities

- If an agent switches a light switch, then relevant motor abilities are intact
 - If an agent climbs stairs, then her leg length matches the step's height
 - If an agent moves through a doorway then her size fits the doorway's opening
- There are agent properties activities use: **Abilities.**

Affordances and Dispositions

- Switchability is based on the light switch's physical properties
- Climbability is based on stair's properties (e.g., height)
- Passability is based on the doorway's properties (e.g., opening)

→ There are affordants' properties affordances are based on: **Dispositions.**

Abilities and Dispositions w.r.t. Activity Types

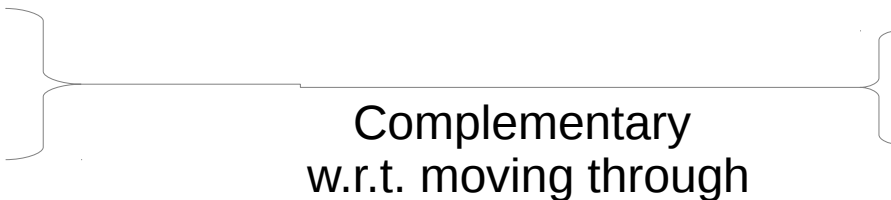
Ability (Human)

1,80m height
50cm width

Disposition (Doorway)

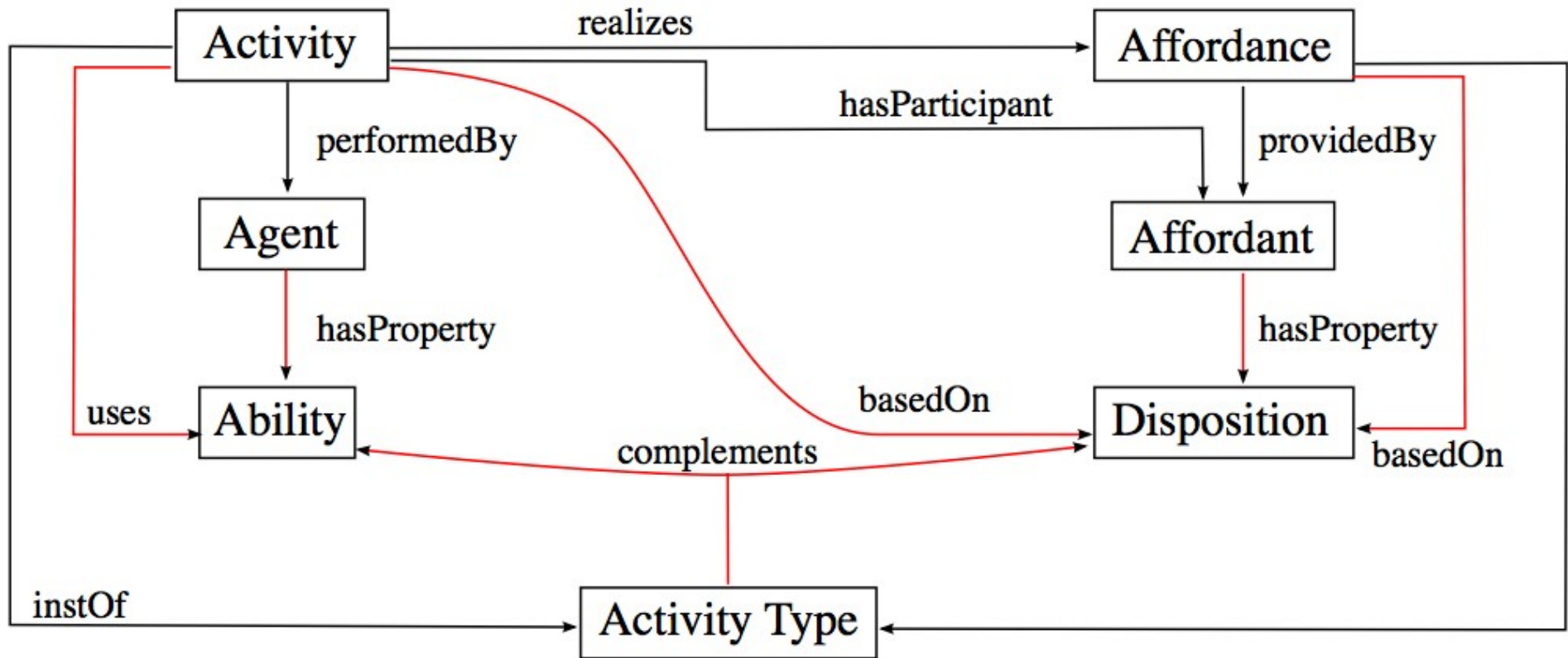
2m height
65cm width

Complementary
w.r.t. moving through

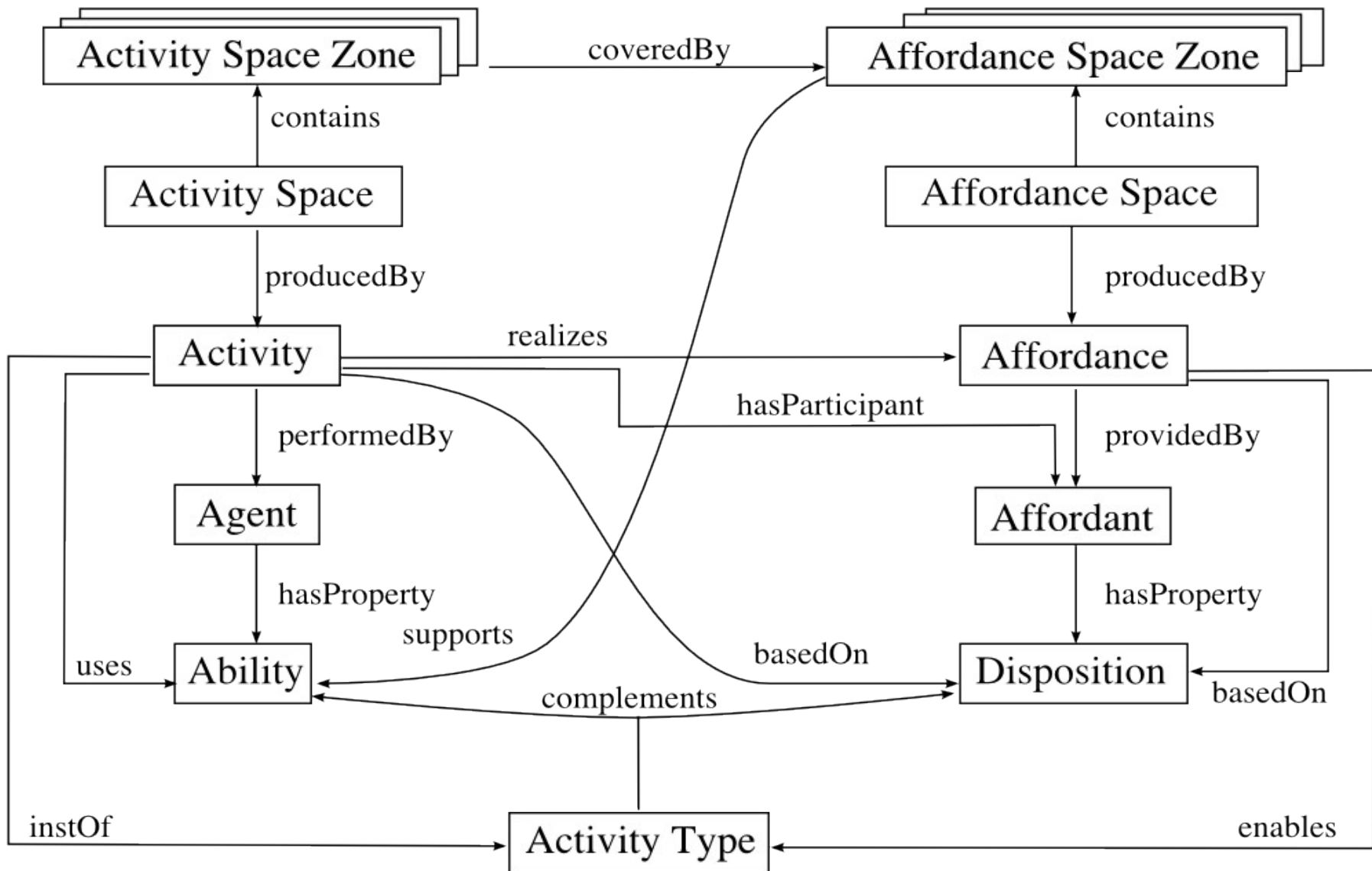


(cf. Turvey, 1989)

ER: Abilities and Dispositions



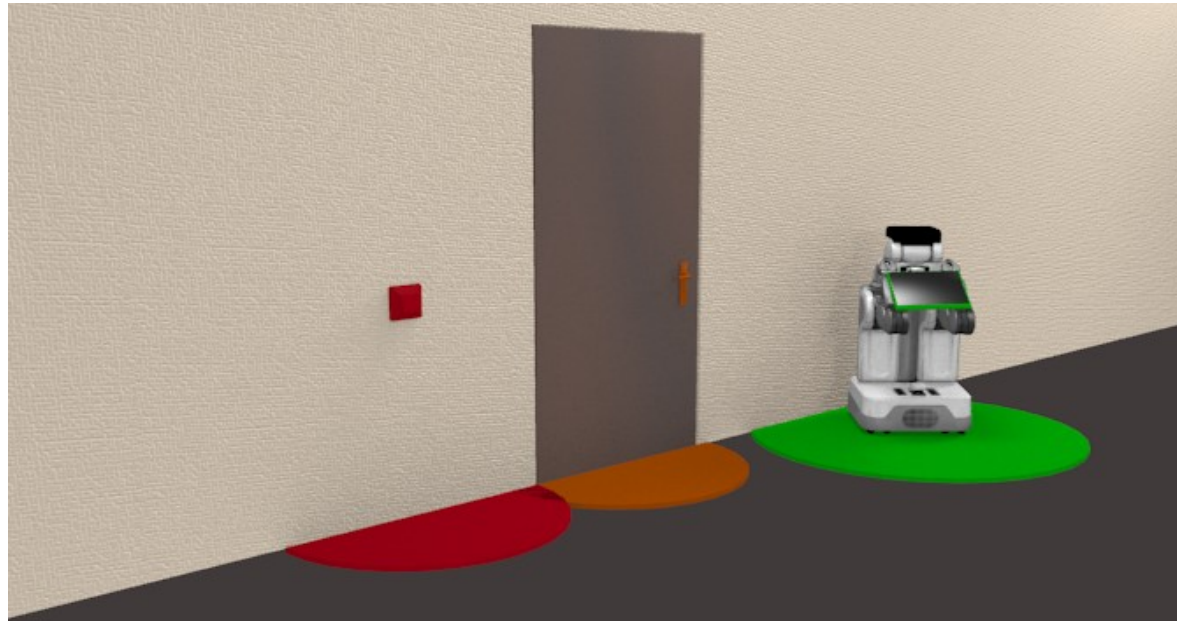
ER: Affordance Spaces



Reasoning w.r.t. Affordance Spaces

Intended Affordances of Constellations

- Which affordances does the spatial constellation provide?



To human with normal abilities: Pressing light-switch, opening the door, interacting with the robot.

Position Planning

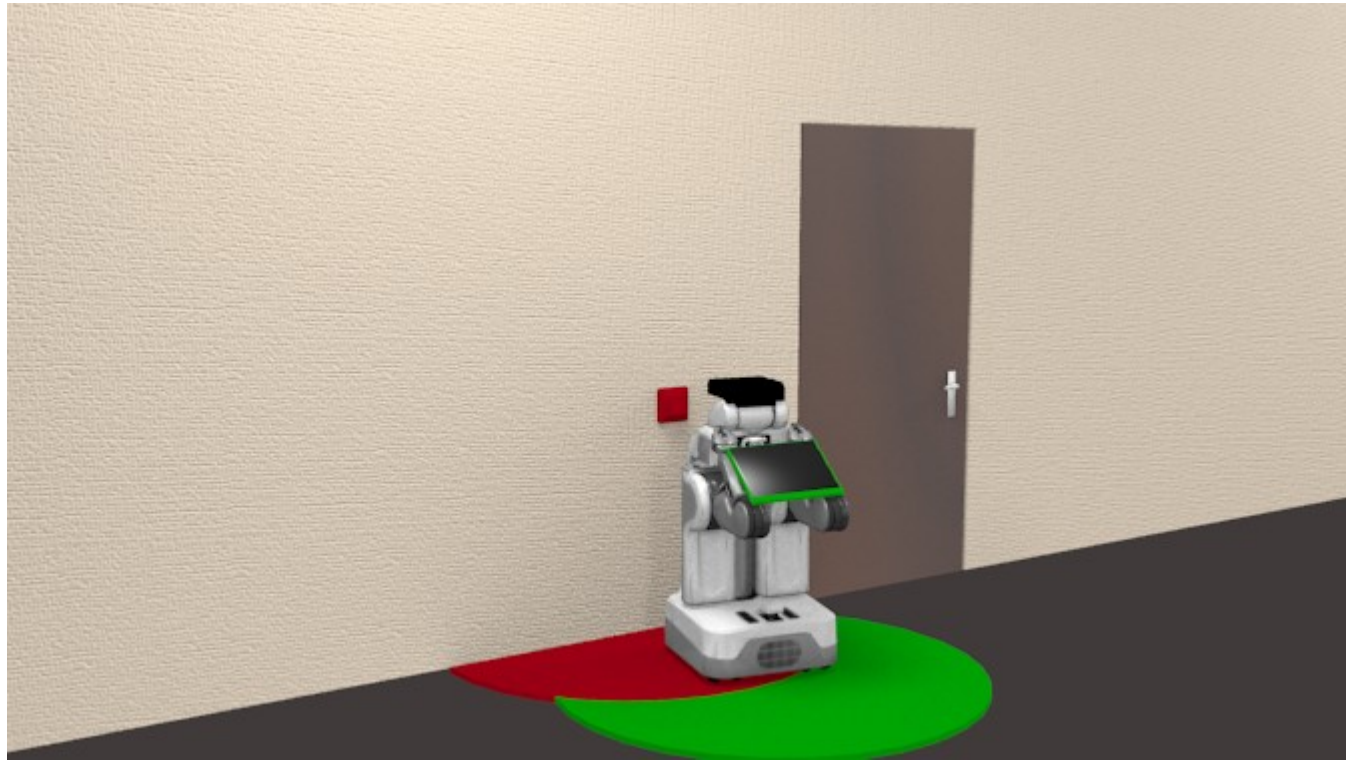
- Where can activity A be performed by agent R?
 - Depends on available affordances and R's abilities.



To switch on the light, the robot has to move to the affordance space zone that supports light switching to it.

Blocking Affordances

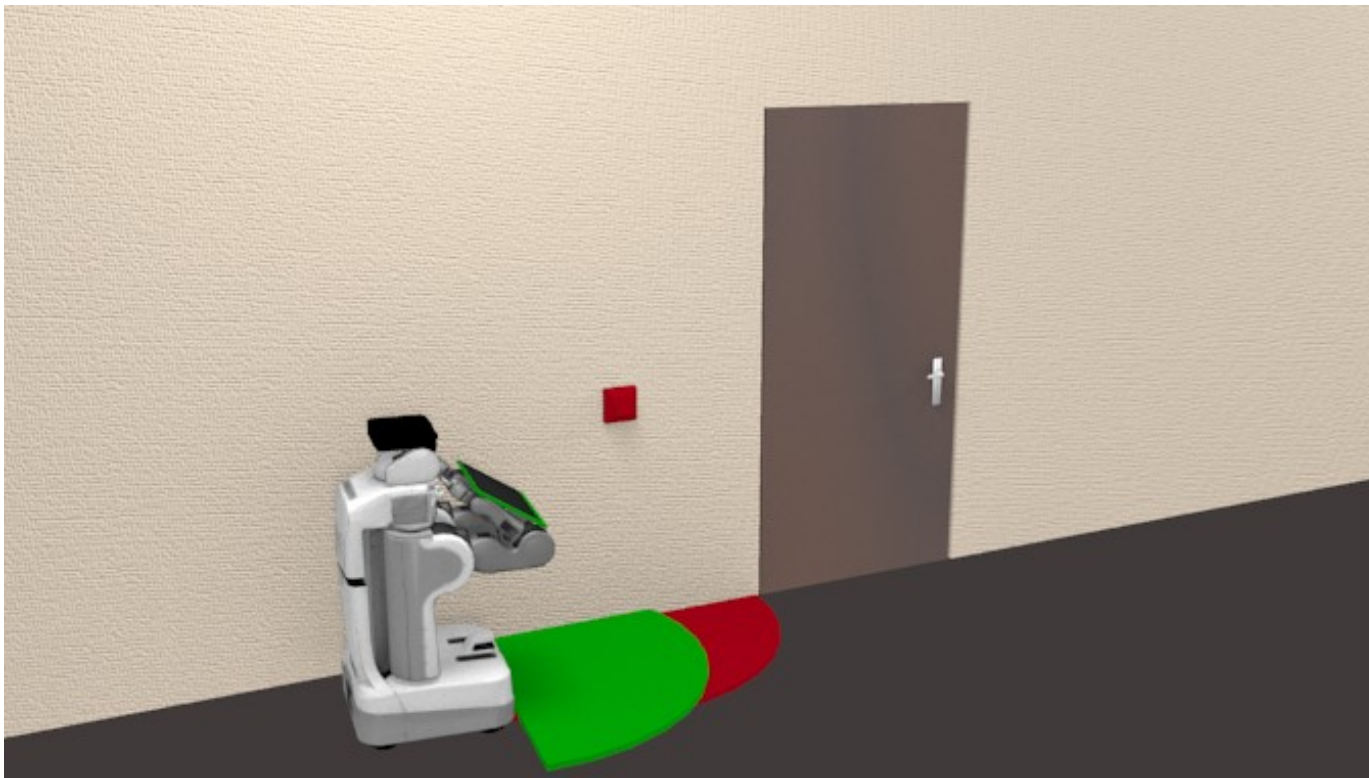
- Which affordances are blocked in the constellation?



- Being located in an affordance space zone while not intending to act upon the affordance yields conflict.

Blocking Affordances

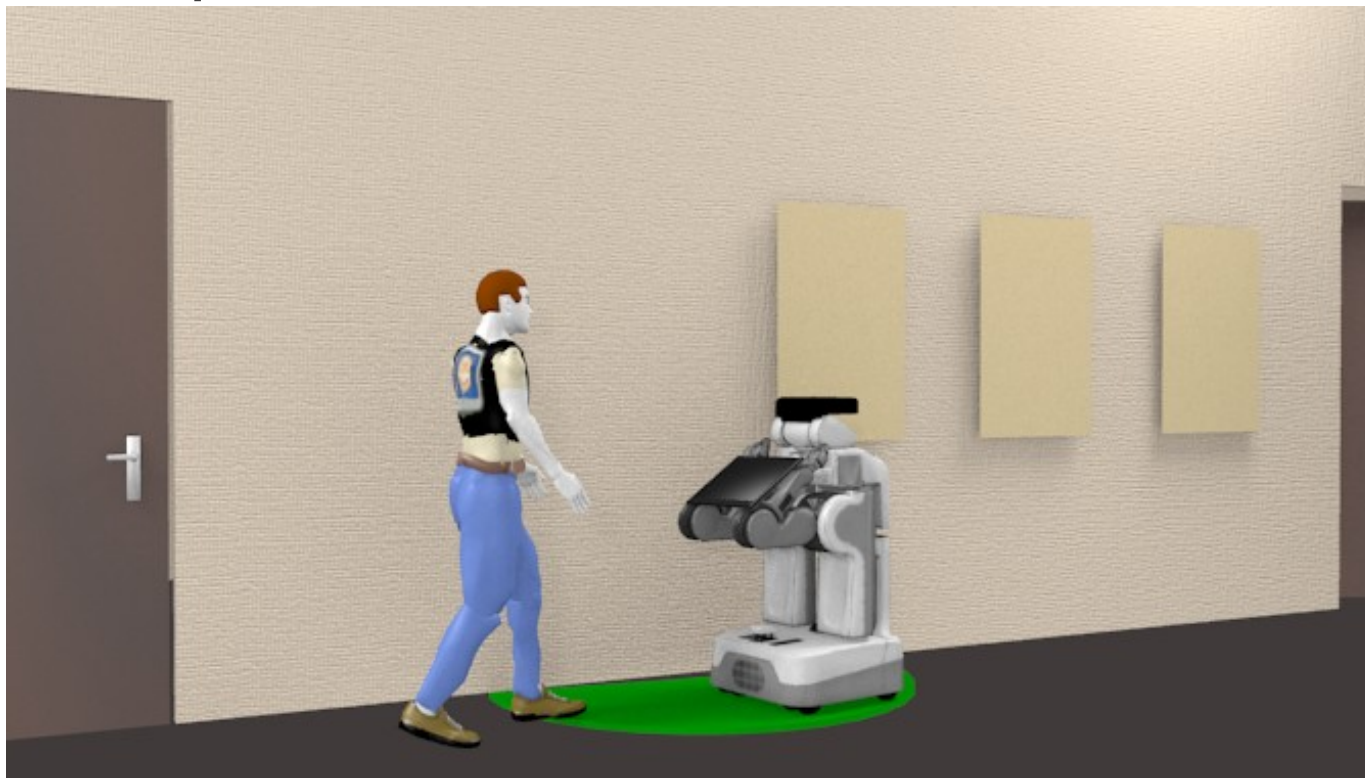
- Which affordances are vulnerable in a given constellation?



- Affordance *af1* is vulnerable, if there is affordance *af2*, such that *af1* would be blocked, if *af2* is realized.

Intention Recognition

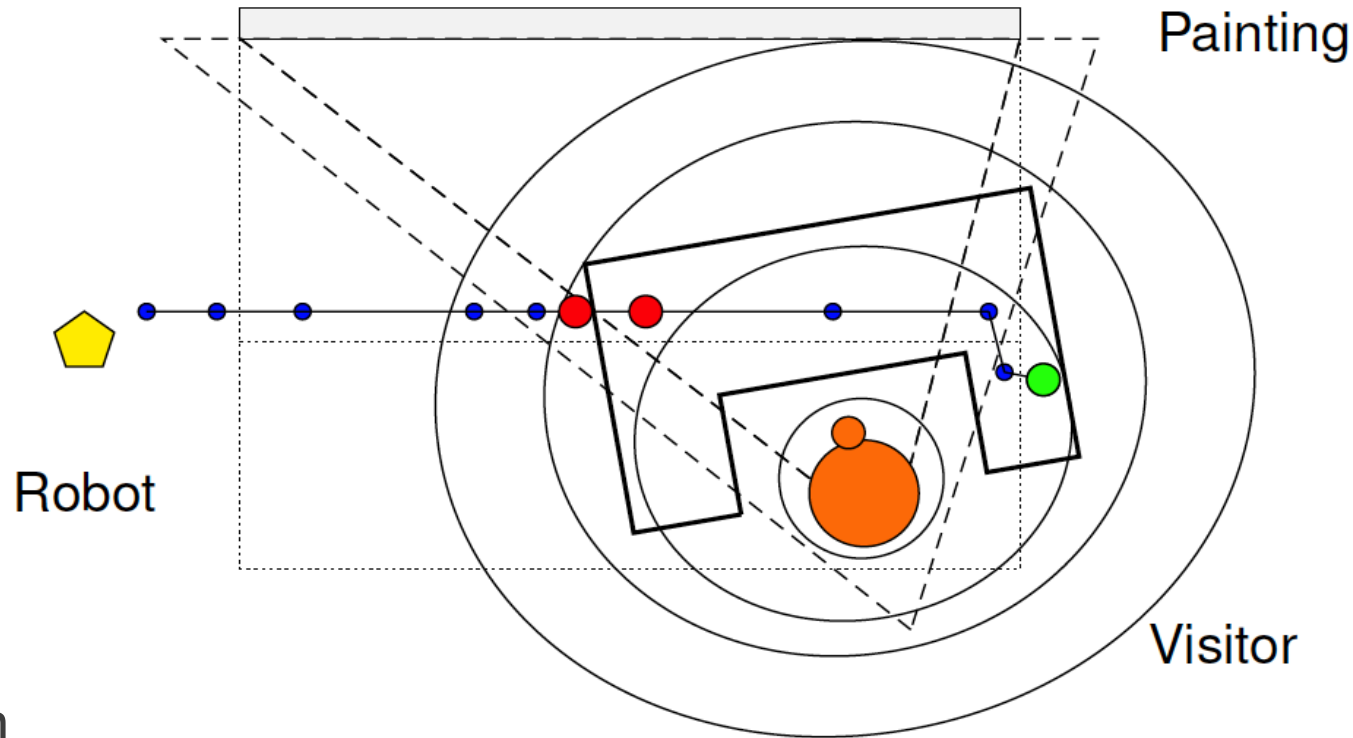
- If an agent performs an activity realizing an affordance, the agent is located in the zone of the corresponding affordance space.



- Thus, by abduction, if an agent R with ability B is located in the zone of an affordance space supporting activity A to agents with ability B, it can be inferred that R might intend A.

A Simple Demonstrator – Putting Social Spaces together in a Simple Path Planning Task

Museum Tour-Guide Robot



Approach

- Deontic constraints on entering social zones
- Topological planner (in logics-based programming language GOLOG)
- Optimization problem: Minimizing violations
 - Path Planning
 - Acquire permissions
 - Signals

Simplistic Planner in Golog

```
proc (simpleSociallyAwarePathPlanner (r),
  if (CurrentRegion (r),
    acquirePermissionAndPerformAction (park, r),
    /* else */
    pi (r', ?(CurrentRegion (r'))
      : pi (r'', ?(EC(r', r'') & SH(r'')))
      : acquirePermissionAndPerformAction (enter, r'')
      : simpleSociallyAwarePathPlanner (r)
    ) ) ) )

proc (acquirePermissionAndPerformAction (actionType, r),
  if (overlappingSocialRegionImpermissible (actionType, r),
    pi (r', ?(SocialSpaceRegion (r') & O(r, r')
      & impermissible (actionType, r')))
    : selectAndPerformSignal (actionType, r')
    : acquirePermissionAndPerformAction (actionType, r)
  ),
  /* else */
  perform (actionType, r)
) )
```

Summary & Outlook

Summary

- An analysis of social space
 - Claiming terminological and conceptual distinction between four social space types: personal space, activity space, affordance space, and territory
- Three dimensions for classification
 - Production, spatial structure, normative meaning
- Gaps identified
 - Affordance spaces not described before
- (In-)adequate behaviour expressable in terms of spatial constellations
- Application to robot path planning & self-positioning
 - Many other applications described in literature
 - Many more yet to be explored

Current Questions

- What is the ontological status of social space?
- What is a social zone?
 - A place in the sense of Basic Place Theory? (cf., Donnelly, 2004)
 - A spatial entity that is located in space? (cf., Bittner, Donnelly, Smith, 2009)
 - A role played by a region? (cf., Lindner & Eschenbach, 2011)

Outlook

- Integration of spatial and deontic logics
 - How can the „normative meaning“ of social zones be represented and efficiently reasoned about?
- Change/Identity of social spaces
 - Life-Cycle
 - Anchoring/Tracking
 - Dynamic activities
- The social meaning of time
 - Sometimes, the location of an activity is not the problem but rather the time span it is located in (e.g., calling someone while her favourite movie is on TV or talking to the lecturer right before a lecture)

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Thanks for Your Attention!