# Robotika in računalniško zaznavanje (RRZ)

# Spoznavni robotski sistemi

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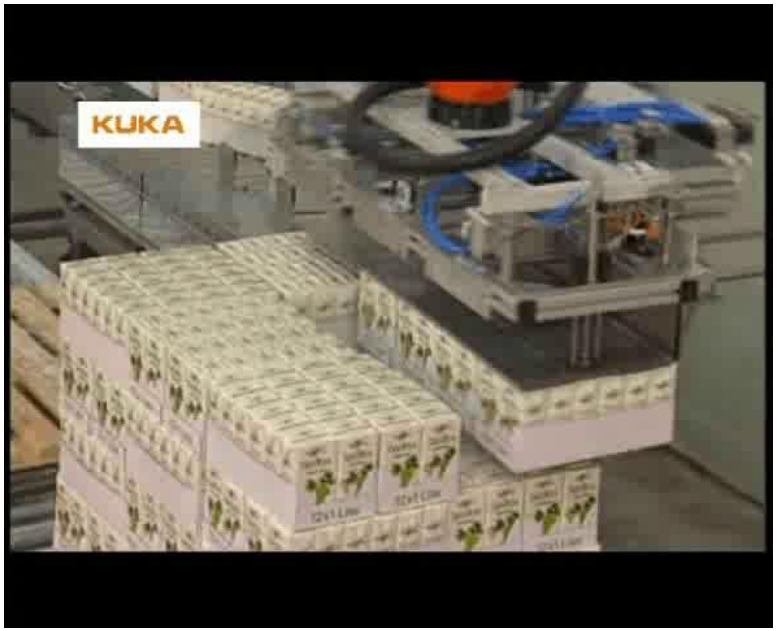
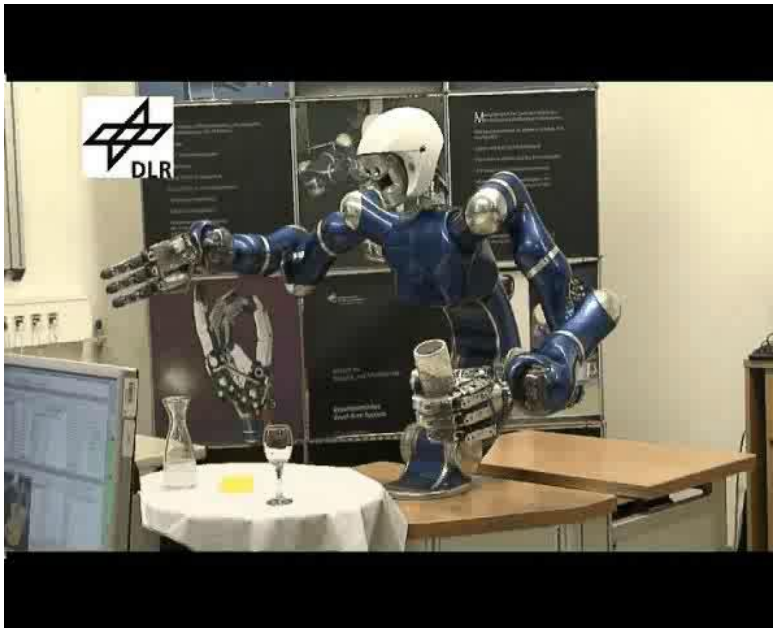
v7.0

# Robotika

- Rutinski industrijski senzorsko robotski sistem




EURON video

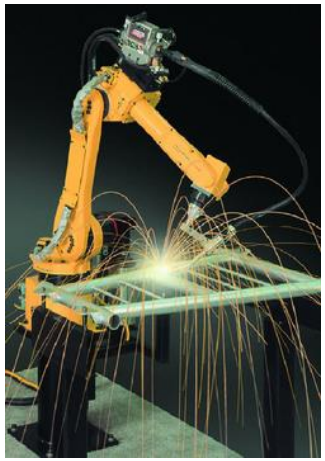



EURON video

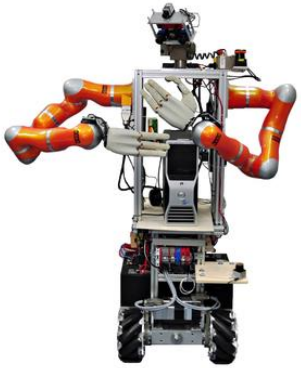
- Inteligentni umetni vizualni spoznavni sistem

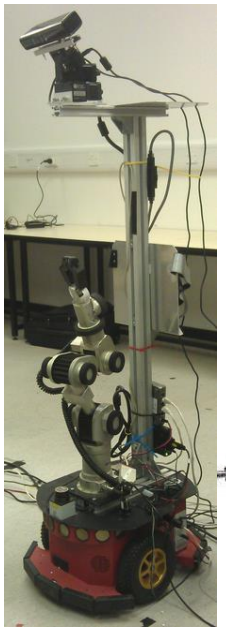
# Spoznavni roboti

spoznavni roboti



industrijski roboti





ZF

človek

zaznavanje | akcija

pozornost | cilji

načrtovanje | sklepanje

komunikacija | učenje

# Spoznavna robotika

- Wikipedia:

  **Cognitive robotics** is concerned with endowing **robots** with mammalian and **human-like cognitive capabilities** to enable the achievement of complex goals in complex environments. Robotic cognitive capabilities include **perception processing, attention allocation, anticipation, planning, reasoning about other agents**, and perhaps reasoning about their **own mental states**. Robotic cognition embodies the **behaviour of intelligent agents** in the **physical world**.

- A cognitive robot should exhibit:
  - knowledge
  - beliefs
  - preferences
  - goals
  - informational attitudes
  - motivational attitudes (observing, communicating, revising beliefs, planning)

# Definicije raziskovalcev

- Cognition is the ability to relate perception and action in a meaningful way determined by experience, learning and memory. *Mike Denham*
- A cognitive system possesses the ability of self-reflection (or at least self-awareness). *Horst Bischof*
- Cognition is gaining knowledge through the senses. *Majid Mermehdi*
- Cognition is the ability to ground perceptions in concepts together with the ability to manipulate concepts in order to proceed toward goals. *Christian Bauckhage*
- An artificial cognitive system is a system that is able to perceive its surrounding environment with multiple sensors, merge this information, reason about it, learn from it and interact with the outside world. *Barbara Caputo*
- Cognition is self-aware processing of information. *Cecilio Angulo*
- Cognitive Systems are ones that are able to extract and (most importantly) represent useful aspects of largely redundant, possibly irrelevant sensory information in a form that is most conducive to achieving a particular high level goal. *Sethu Vijayakumar*
- A cognitive system is a system that can change its behaviour based on reasoning, using observed evidence and domain knowledge. *Bob Fisher*
- Cognition is when I know what I am doing, when I can judge how good or bad it is, and explain why I am doing it. *Markus Vincze*
- Cognition is the ability to plan, reason, adapt and act according to high level motivations or goals and using a range of senses, typically including vision, and may be communicate. *Patrick Courtney*
- A cognitive system is an autonomous anti-entropy engine. *David Vernon*

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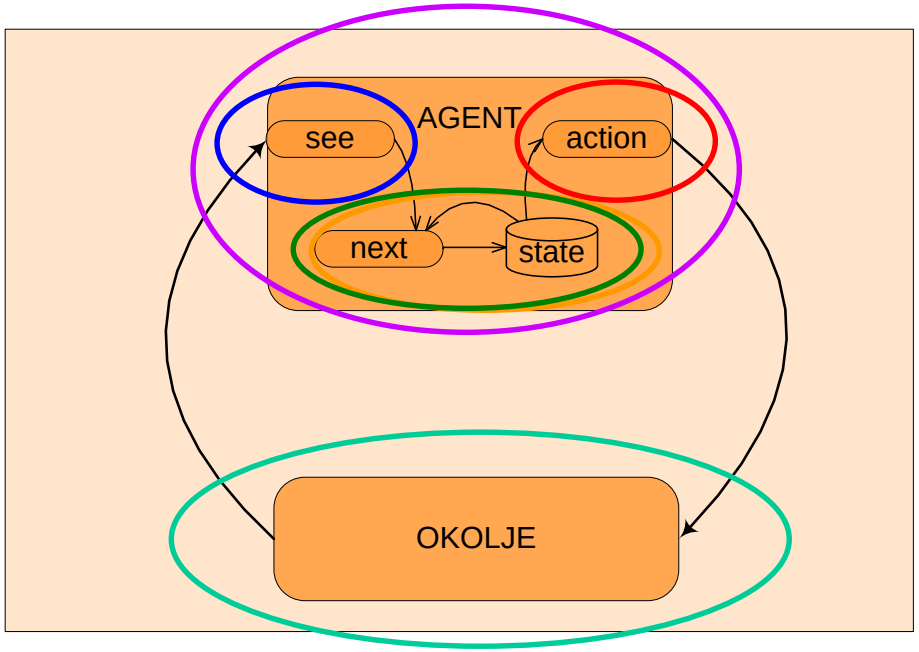
# Glavni poudarki

- Zaznavanje (perception)
- Akcija (action)
- Sklepanje, načrtovanje (reasoning, planning)
- Cilji (goals)
- Avtonomija, samozavedanje (autonomy, self-awareness)
- Okolje (environment)



# Primer spoznavnega sistema

- Hišni robot Robi
- Ukažemo mu: “Prinesi mi pivo”.

# Primer

- Sosledje dogodkov:
  - Robot mora biti pozoren in poslušati za naš ukaz. *[pozornost, motivacija]*
  - Mora nas slišati in razumeti naš ukaz. *[zaznavanje, razpoznavanje govora, komunikacija]*
  - Postaviti si mora cilj in težiti k temu, da ga izpolni. *[cilj, proaktivnost]*
  - Mora vedeti kje se pivo nahaja, to se je moral prej naučiti. *[učenje]*
  - Mora narediti načrt kako nam bo prinesel pivo. *[načrtovanje]*
  - Mora poiskati najboljšo pot do hladilnika, na osnovi zemljevida, ki si ga je prej zgradil. *[navigacija, gradnja zemljevidov]*
  - Mora se premikati po načrtovani poti. *[akcija – premikanje]*
  - Po poti mora neprestano opazovati kam se giba. *[zaznavanje, akcija]*
  - Po poti se mora izogibati oviram. *[zaznavanje nevarnosti, ponovno načrtovanje, odzivnost]*

# Primer

- Ko pride do hladilnika, se mora pravilno postaviti pred njega. *[utelešenost, umeščenost v prostor]*
- Mora znati odpreti hladilnik. *[razpoznavanje funkcionalnih lastnosti]*
- V hladilniku mora znati poiskati pivo (njegov izgled se je moral prej naučiti). *[zaznavanje, kategorizacija, učenje]*
- Načrtovati mora kako ga bo zagrabil. *[načrtovanje]*
- Na pravilen način bo zagrabil steklenico. *[akcija, vizualni nadzor, haptični nadzor]*
- Obrnil se bo in po obratni poti odšel nazaj do nas. *[načrtovanje, navigacija, akcija, zaznavanje nevarnosti, zaznavanje, razpoznavanje]*
- Robi: “Izvoli tvoje pivo”. *[komunikacija]*

# Spoznavni sistemi

- Kognitivni asistent
  - Razišče okolico in zgradi zemljevid
  - Se nauči prepoznati in identificirati predmete
  - Razume namen in funkcije predmetov
  - Zna interpretirati verbalno in neverbalno komunikacijo ljudi v okolici
  - Zazna nove situacije in ustrezno reagira
  - Deluje robustno, v realnem domačem okolju
- Vgrajene osnovne funkcionalne sposobnosti, ki jih razvija in nadgrajuje z učenjem


Willow Garage

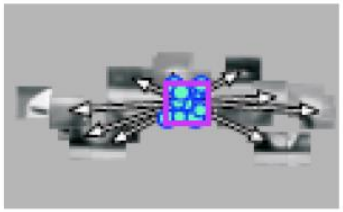
# Primer spoznavnega sistema

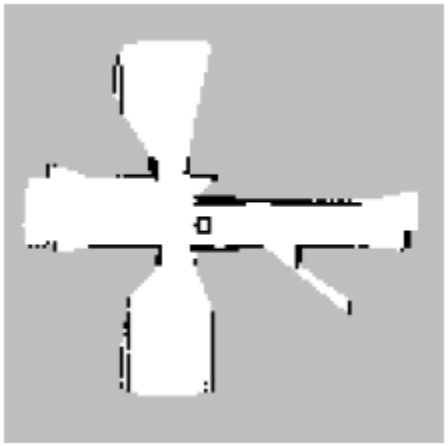
- Avtonomni avtomobili
- Vožnja po mestu
- Sposobnosti
  - Zaznavanje (slika, 3D, trk)
  - Načrtovanje
  - Sklepanje
  - Učenje
  - Navigacija
  - Izogibanje oviram
  - Akcija
  - Fleksibilnost
  - Robustnost
  - Učinkovitost
  - …

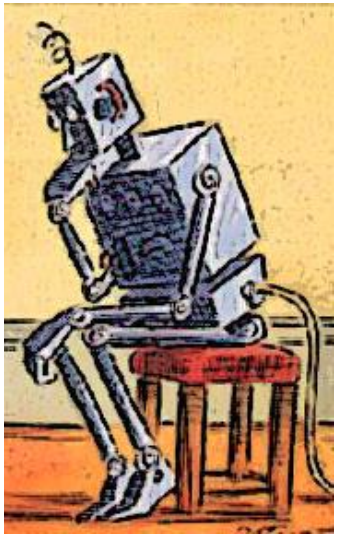

Google self-driving car

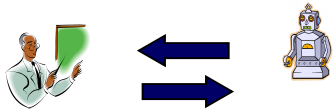
# Zahteve za spoznavne sisteme

- Zaznavanje
- Predstavitve
- Razpoznavanje
- Učenje
- Sklepanje
- Načrtovanje
- Komunikacija
- Akcija
- Arhitektura







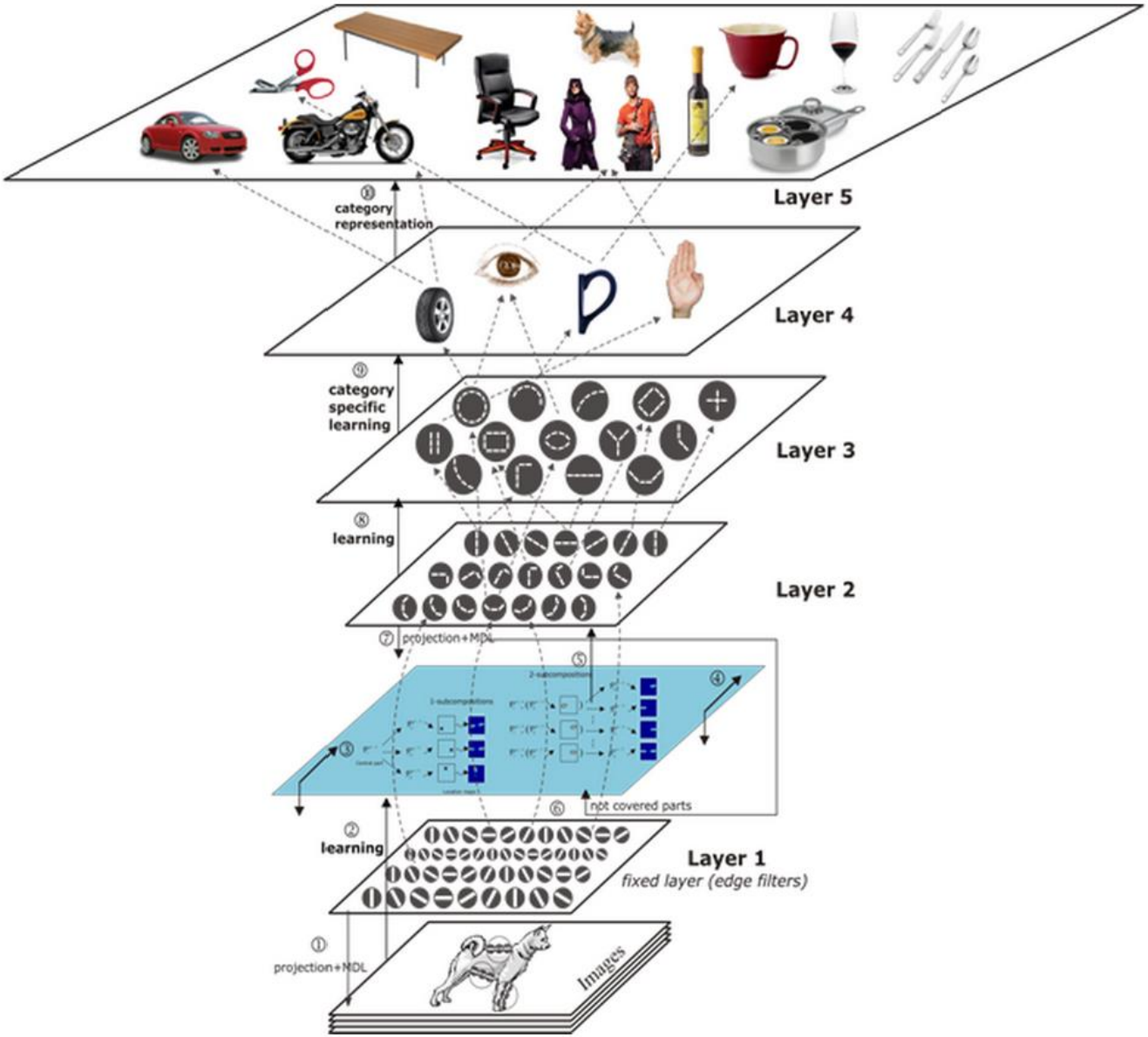


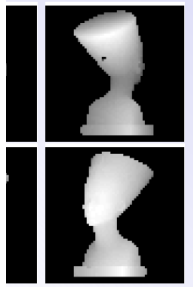
# Zaznavanje

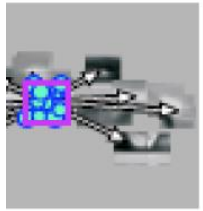
- Zaznavanje:
  - Vizualna informacija (slika, video; barvna, ČB, IR,…)
  - Zvok (govor, glasba, šum, …)
  - Haptična informacija (haptični senzorji, senzorji trka, itn.)
  - Globinska/prostorska informacija (globinske slike, 3D modeli, 3D zemljevidi, …)
  - Veliko različnih modalnosti – zelo večmodalen sistem
- Pozornost
  - Selektivno zaznavanje
  - Obvladovanje kompleksnosti potencialnih vhodnih signalov



# Predstavitev vizualne informacije





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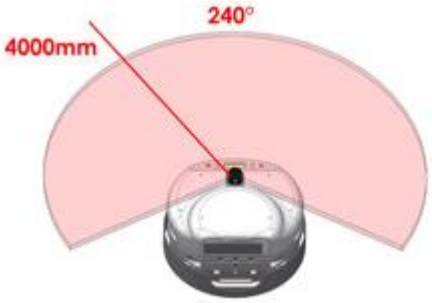
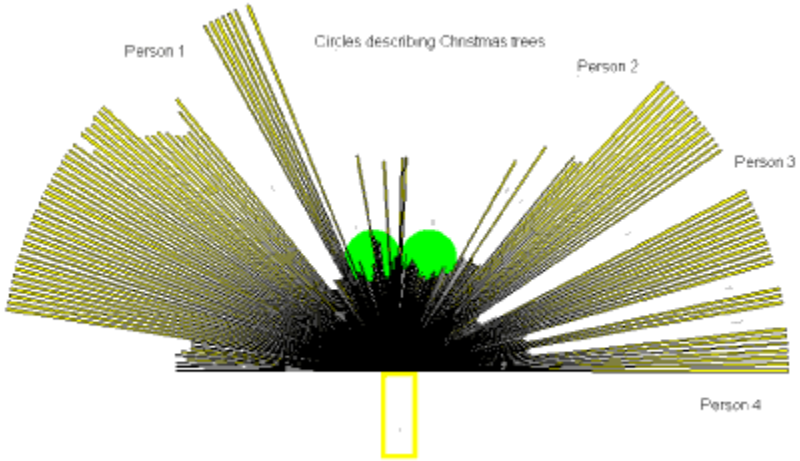
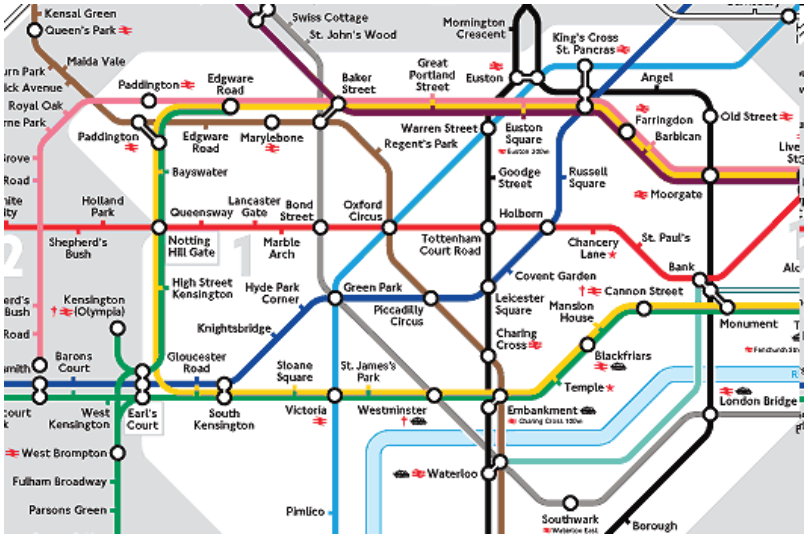
# Predstavitev prostora

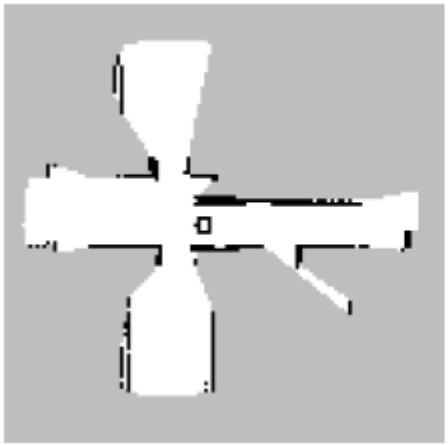
- Metrična informacija

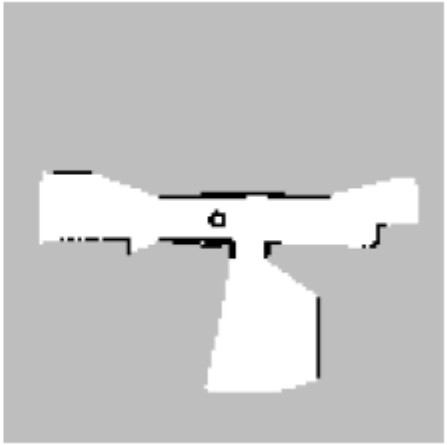


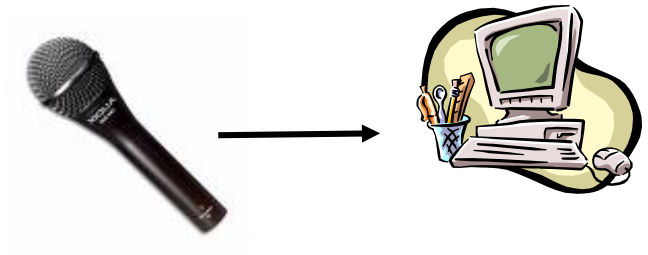

- Topološki zemljevid

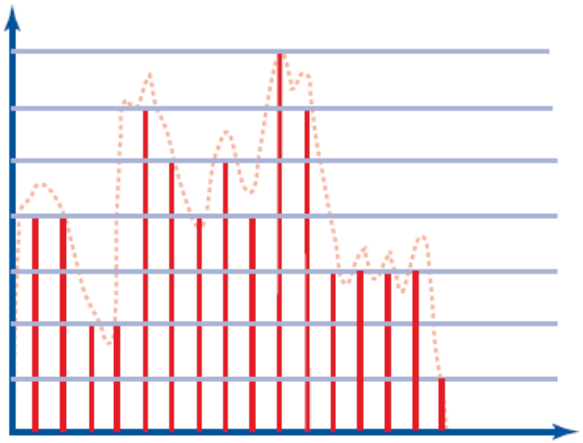


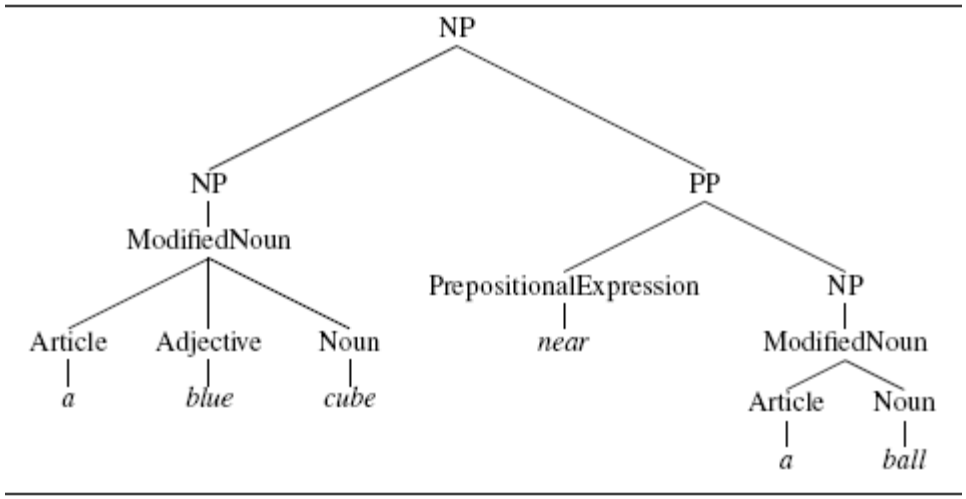


# Predstavitev avdio informacije





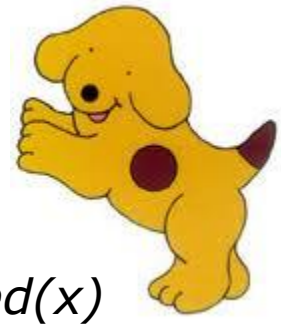
# Predstavitev lingvistične informacije

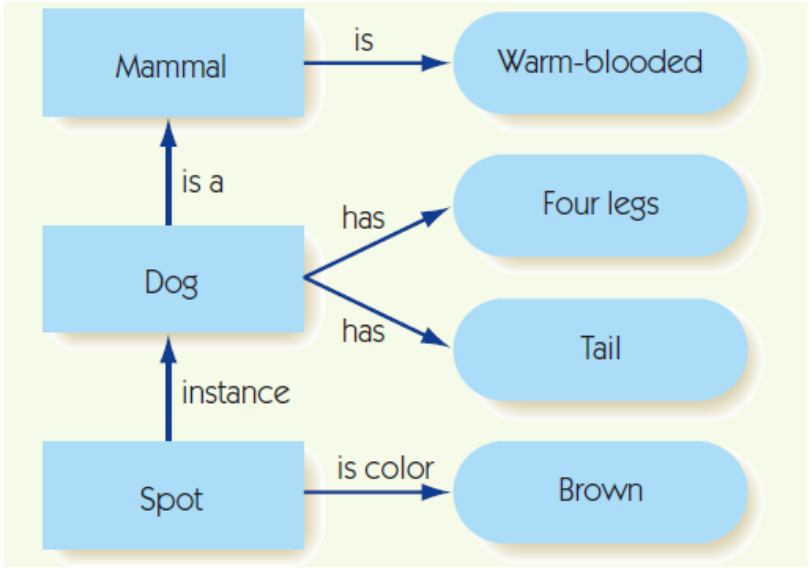



*S* → *Command* | *Statement* | *Question* | *S Conjunction S*
*Command* → *VP*
*Statement* → *NP VP*
*NP* → *Pronoun* | *Modified_Noun* | *NP RelClause* | *NP PP* | *NP Conjunction NP*
*Modified_Noun* → *Noun* | *Article Noun* | *Adjective Noun* | *Article Adjectives Noun*
*Noun* → *Noun_Singular* | *Noun_Plural*
*PP* → *PrepositionalExpression NP*
*RelClause* → *RelPronoun VP*

# Predstavitev znanja

1. Naravni jezik
   - uporaba zahteva razumevanje pomena posameznih besed
   - *Spot is a brown dog and, like any dog, has four legs and a tail.*
2. Formalni jezik
   - jezik formalne logike
   - *"Spot is a brown dog" : dog(Spot) AND brown(Spot)*
   - "Every dog has four legs": *(∀x) dog(x) -> four-legged(x)*
3. Grafična predstavitev
   - znanje predstavljeno z vozlišči povezanimi s povezavami
   - Semantične mreže
4. Idr.
   - ustreznost, učinkovitost, razširljivost, primernost

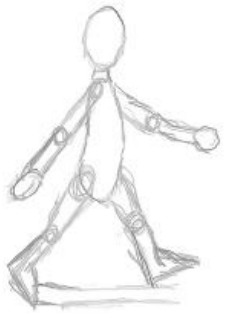




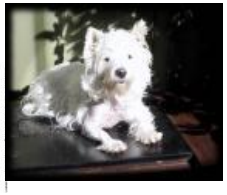
# Razpoznavanje

- Razpoznavanje
  - Objektov
  - Lastnosti
  - Obrazov
  - Prostorov
  - Funkcionalnih lastnosti predmetov
  - Akcij
  - Govora
  - Relacij
  - Namenov,…
- Kategorizacija
- Večmodalno razpoznavanje

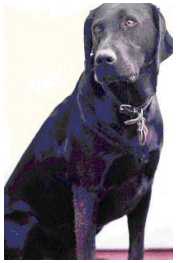


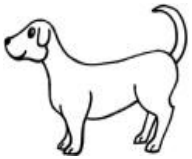







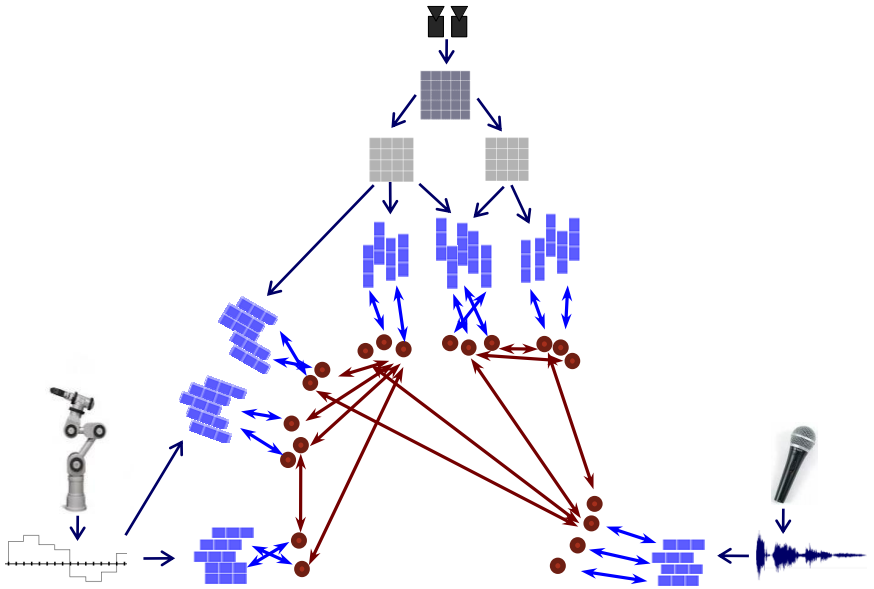


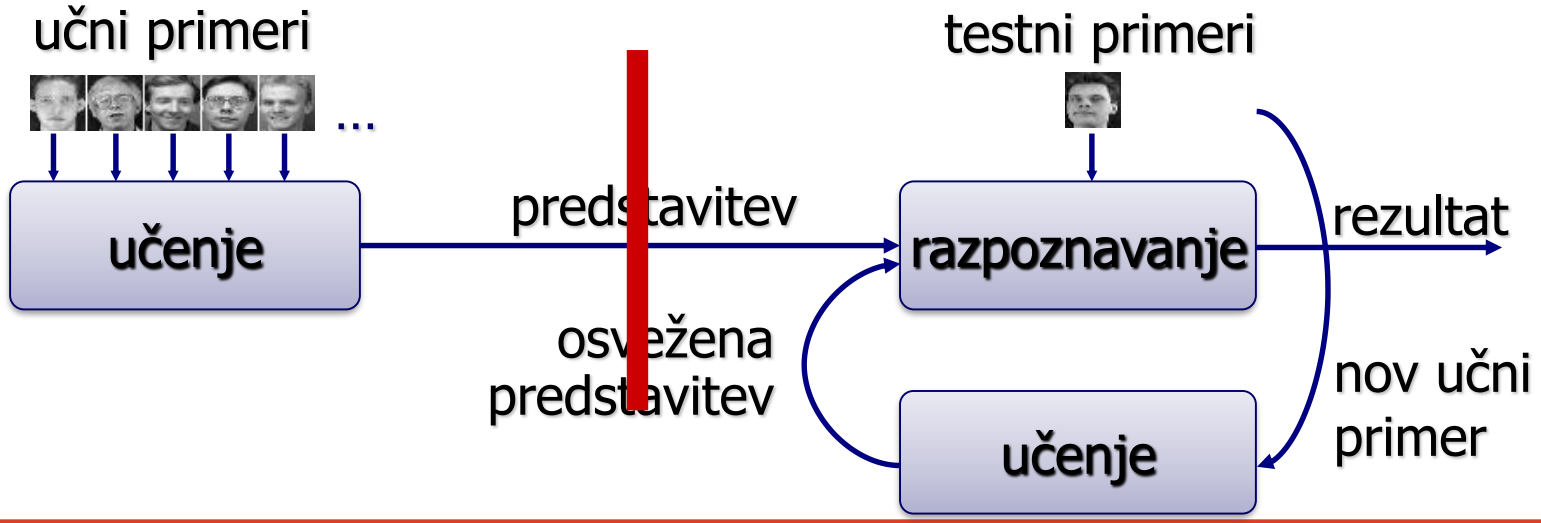




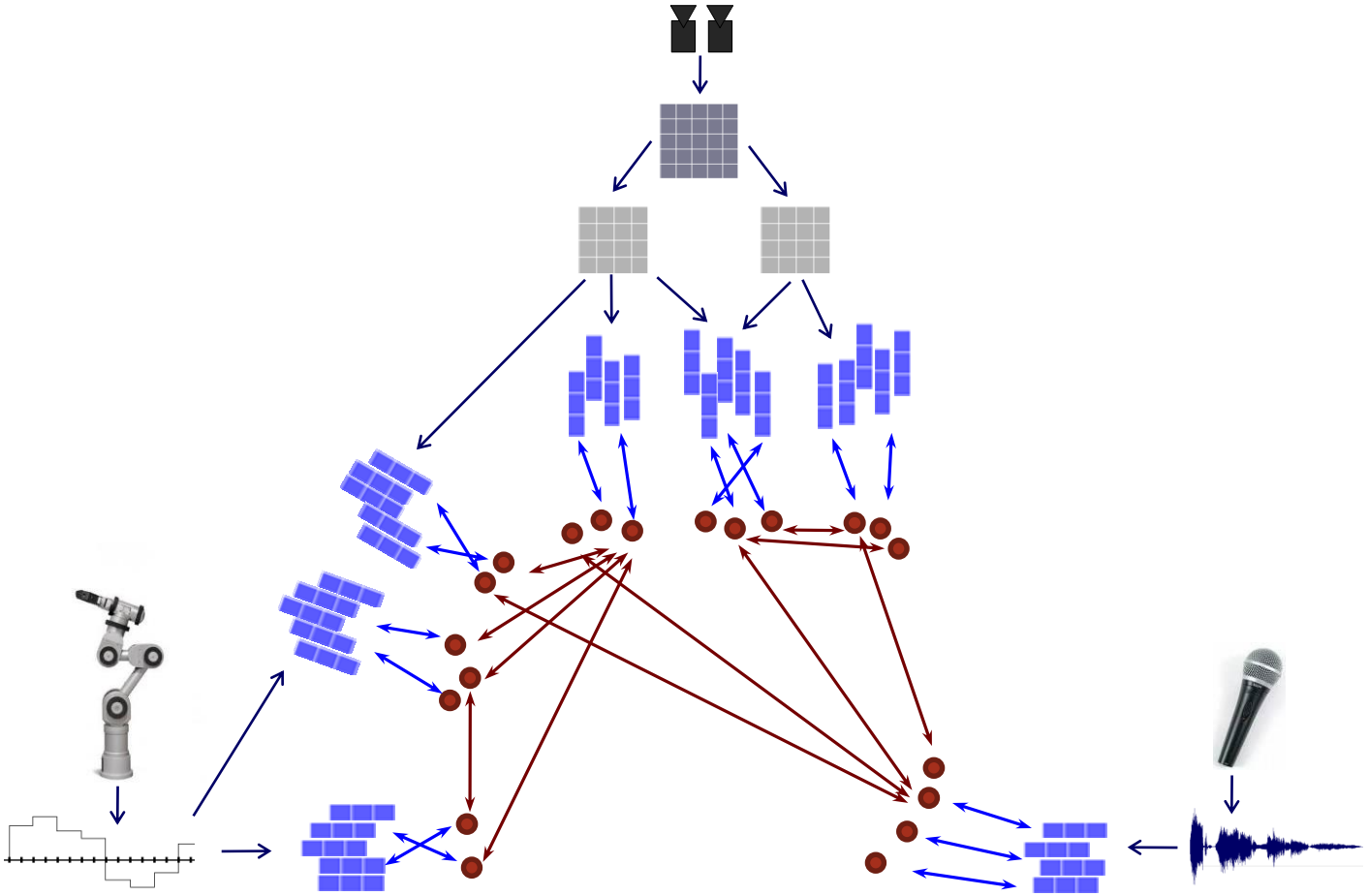

# Učenje

- Gradnja predstavitev
- Kontinuirano učenje
- Različni načini učenja
- Učenje v več modalnostih
- Pozabljanje, popravljanje
- Robustno
- Prirojeno:priučeno



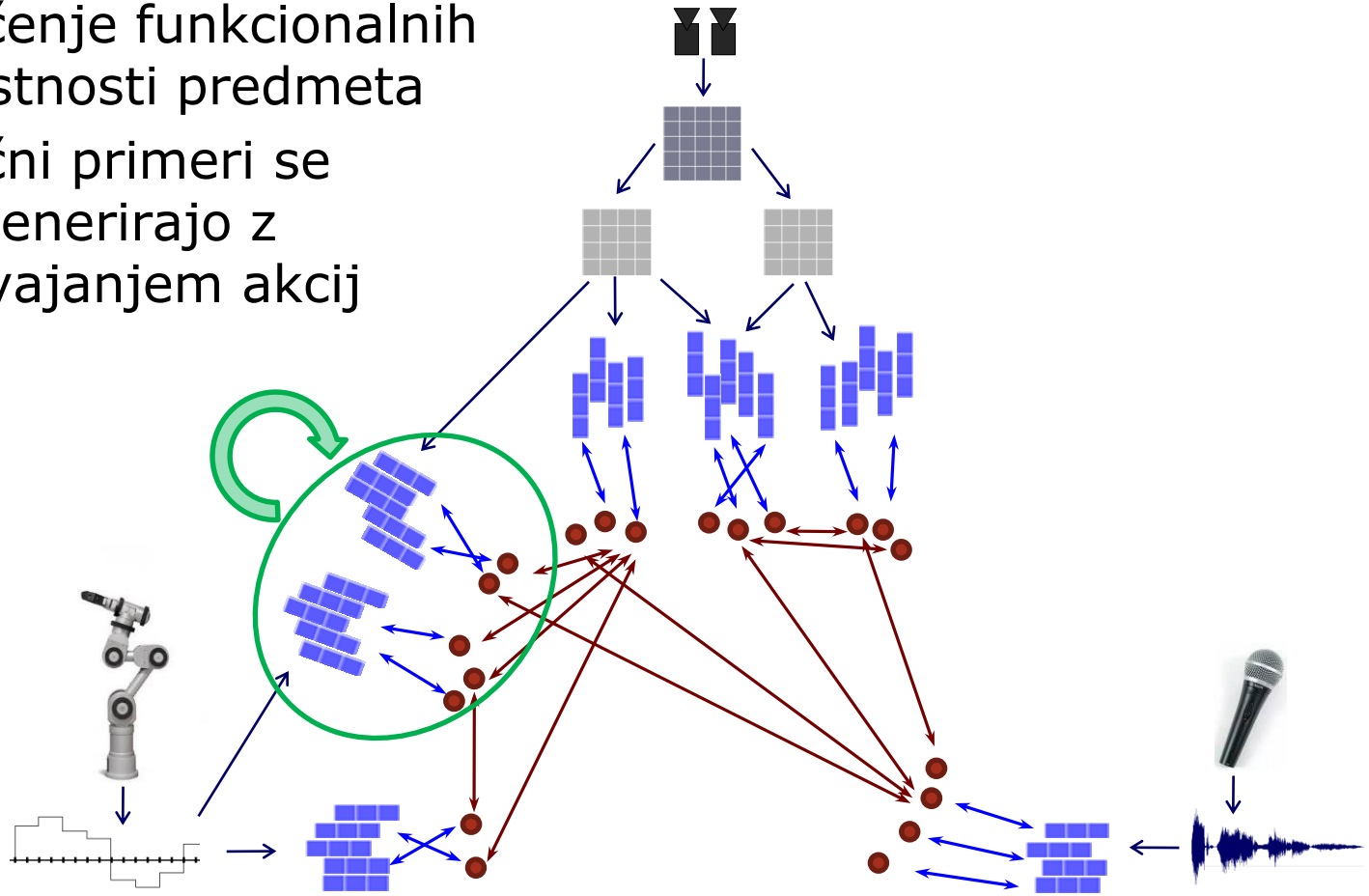


# Večmodalno učenje



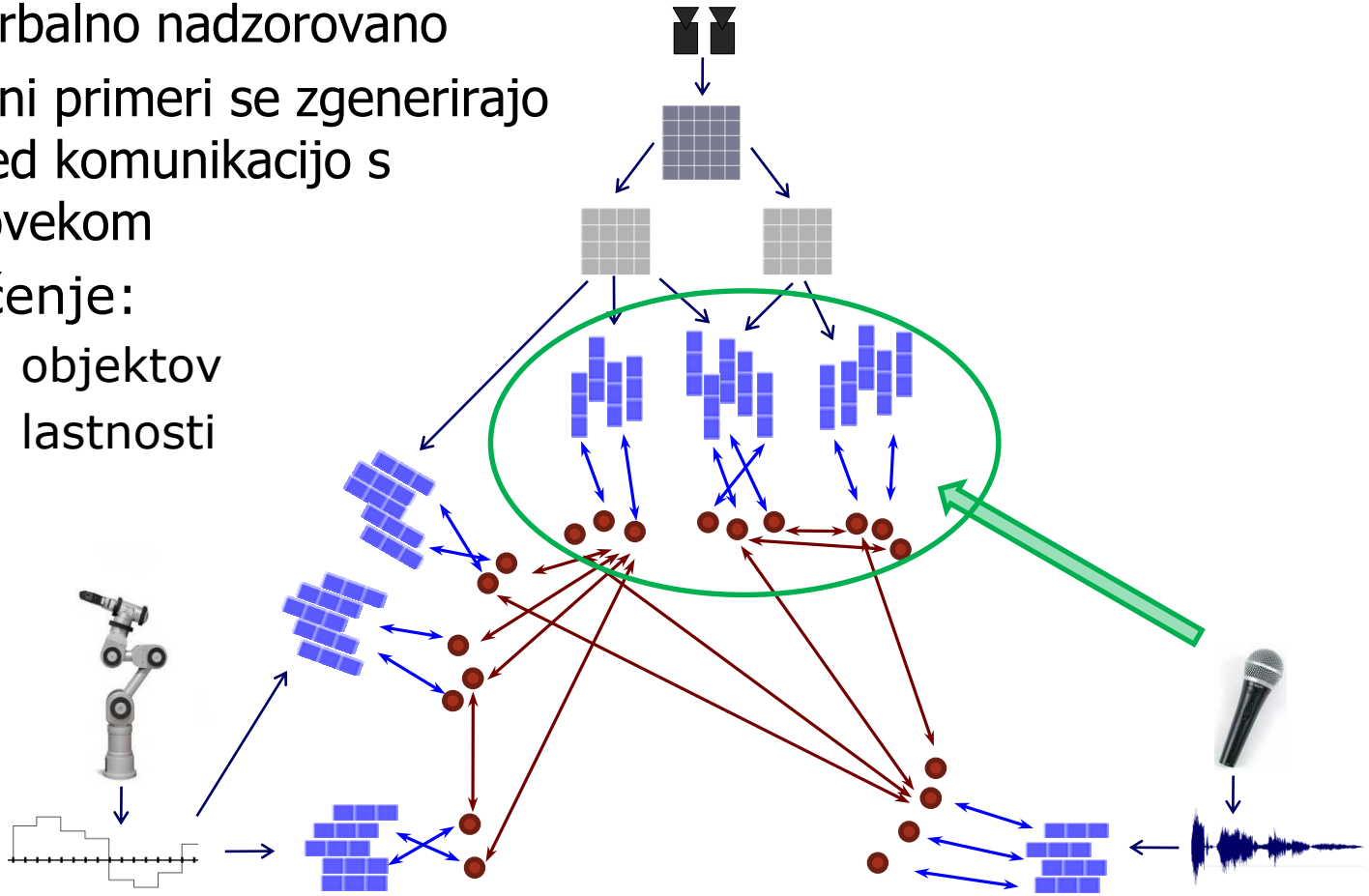
# Samo-nadzorovano učenje

- Učenje funkcionalnih lastnosti predmeta
- Učni primeri se zgenerirajo z izvajanjem akcij



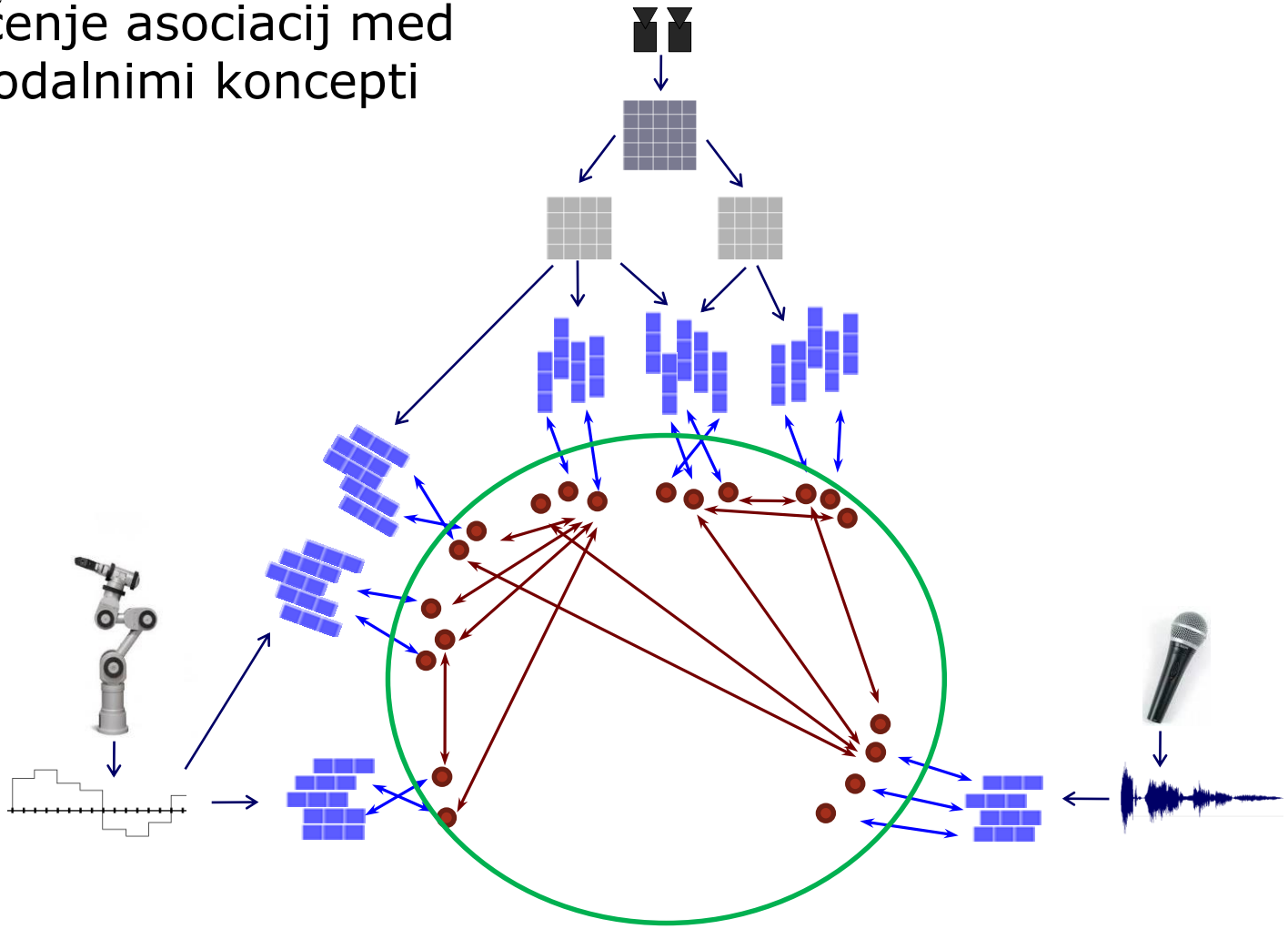
# Šibko nadzorovano večmodalno učenje

- Verbalno nadzorovano
- Učni primeri se zgenerirajo med komunikacijo s človekom
- Učenje:
  - objektov
  - lastnosti

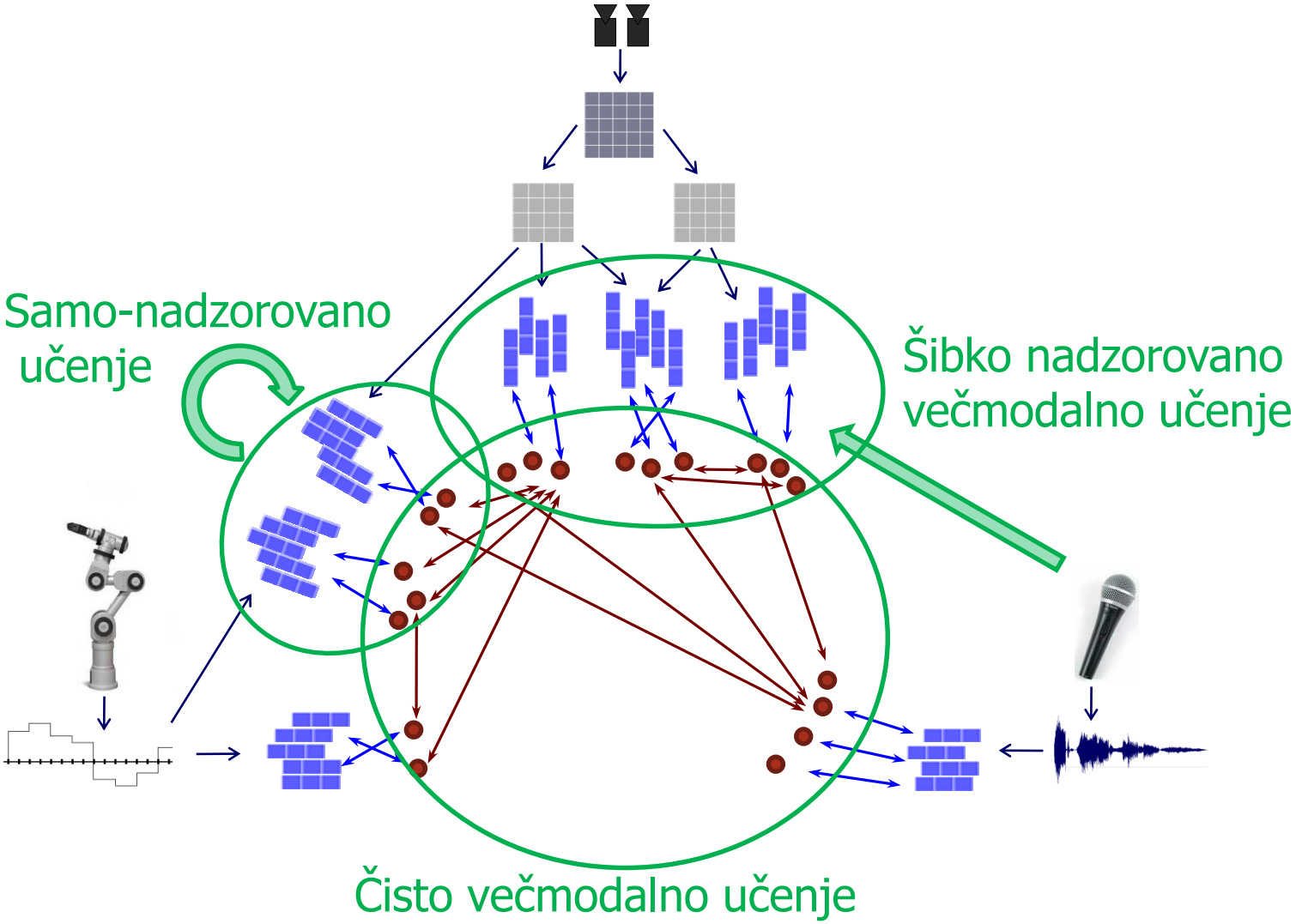


# Čisto večmodalno učenje

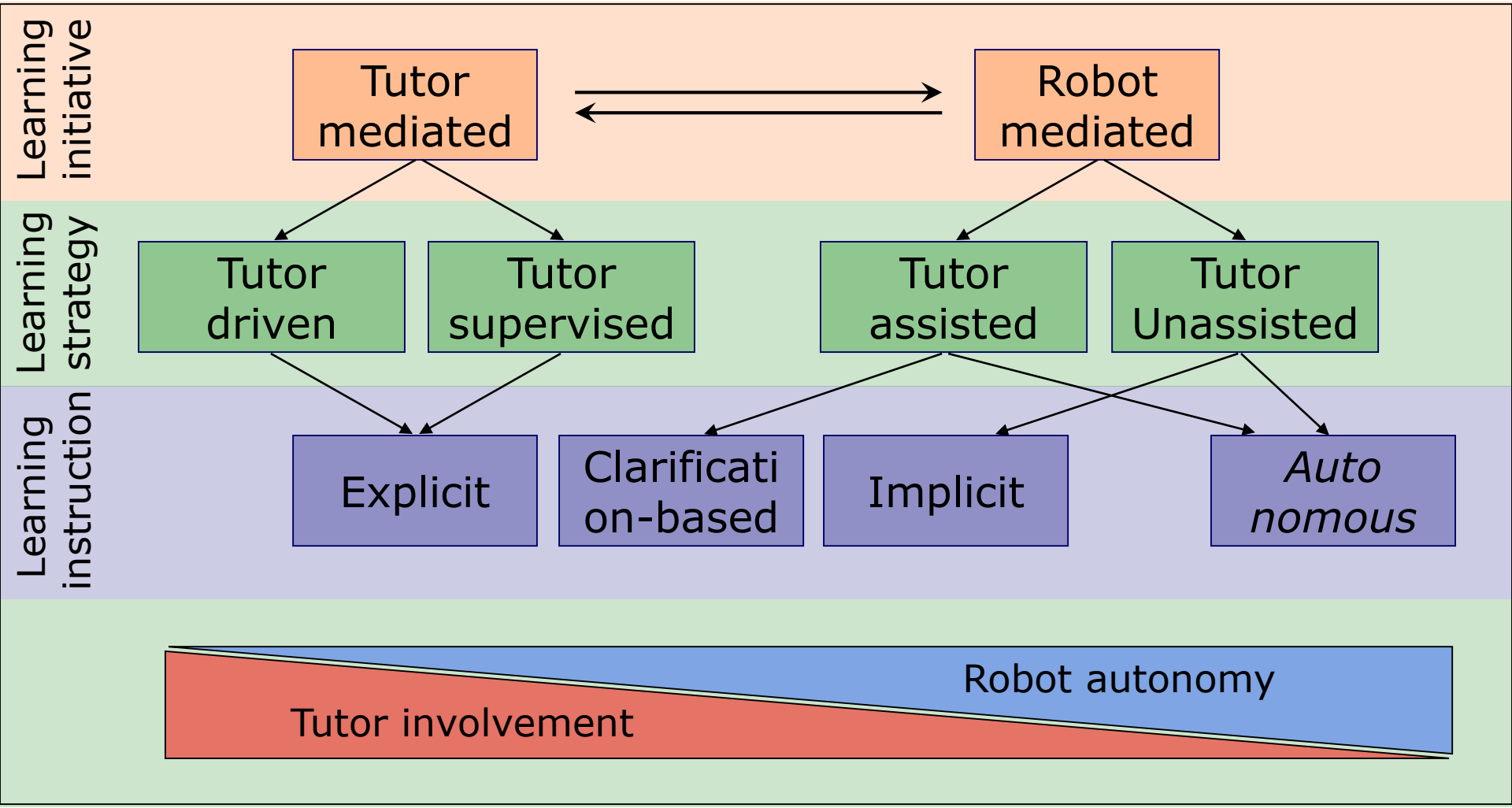
- Učenje asociacij med modalnimi koncepti



# Večmodalno učenje

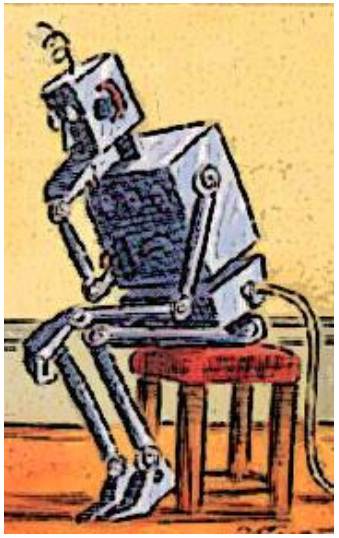


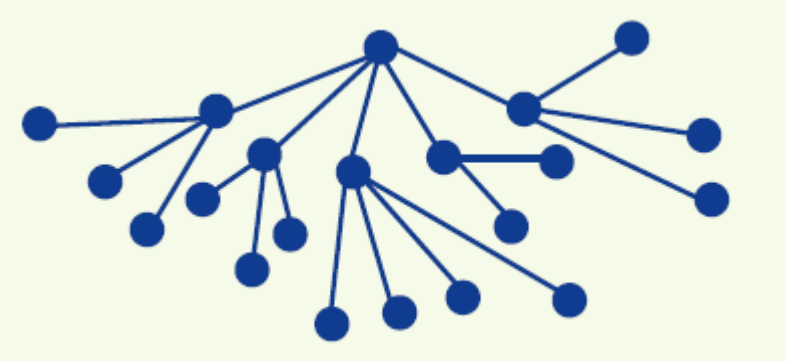
# Učne strategije

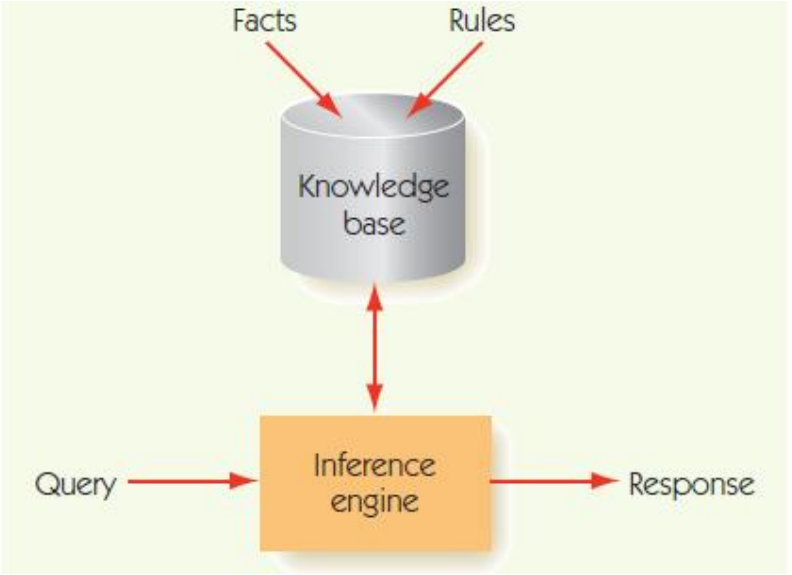


# Sklepanje

- Sklepanje
  - V nepredvidljivem okolju
  - Brez popolne informacije
  - Z določenimi omejitvami robota
  - V spreminjajočem se okolju
  - Upoštevanje različnih modalnosti
  - Samozavedanje, introspekcija, detekcija neznanja
  - Komuniciranje znanja, neznanja
  - Ekspertni sistemi







# Načrtovanje

- Načrtovanje
  - V nepredvidljivem okolju
  - Brez popolne informacije
  - Z določenimi omejitvami robota
  - V spreminjajočem se okolju

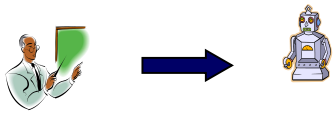
```
(:action move
 :parameters (?a - agent ?to - location ?d - door)
 :variables (?from - location)
 :precondition (and
       (pos ?a : ?from)
       (doorstate ?d : open)
       (entrance ?d ?from) (entrance ?d ?to))
 :effect (pos ?a : ?to))
```

# Komunikacija

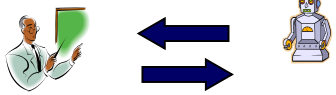
- Komunikacija
  - S človekom
  - Z drugimi (drugačnimi) agenti
  - V določenem okolju in času

  - Prenos znanja
  - Razčiščevanje razumevanja
  - Koordinacija
  - Prevzemanje iniciative v dialogu
  - Verbalna in neverbalna komunikacija

  - Prizemeljevanje simbolov – Symbol grounding
  - Semantično opisovanje zaznav



  - Učenje jezika
    - sintaksa
    - širjenje ontologije



  - Učenje z uporabo jezika

# Akcija

- Manipulacija s predmeti (robotska roka)
- Premikanje po prostoru (mobilni robot)
- Ostalo: zvok, svetlobni signali, druga prijemala, itn.

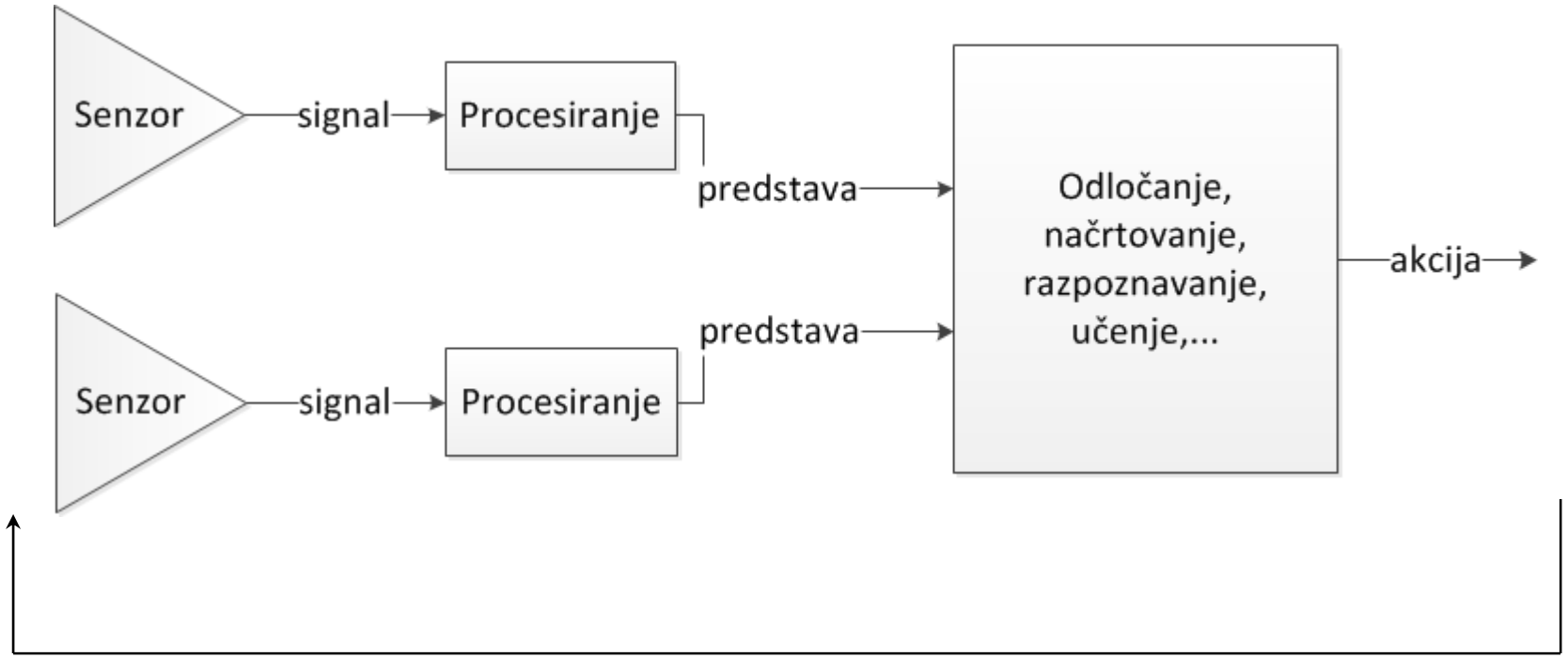
- Utelešenost (embodiment)
- Umeščenost v prostor (situatidness)
- Učinkovitost, robustnost, fleksibilnost,…





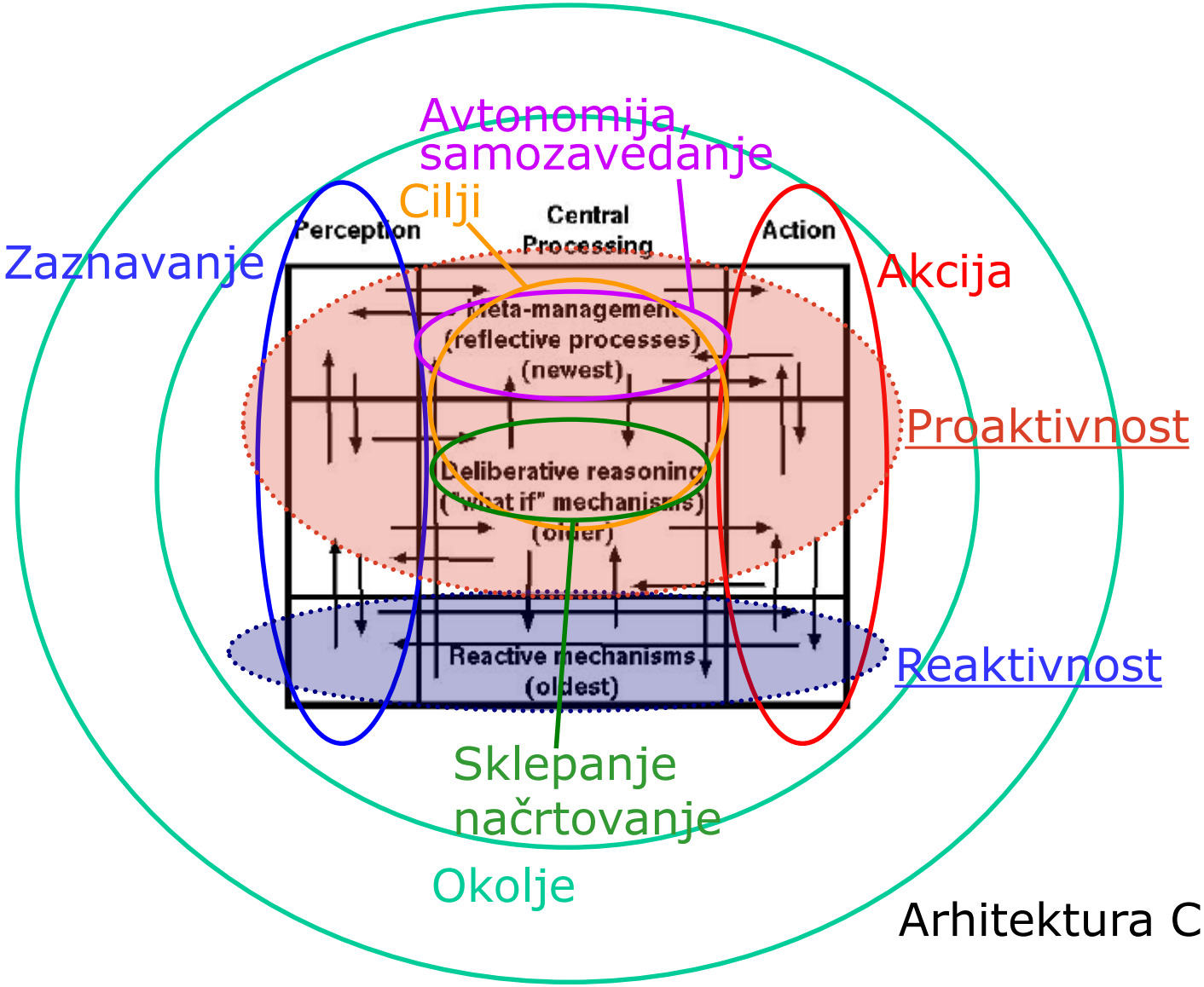


# Cikel zaznavanje - akcija




- Velika abstrakcija realnega sveta

# Arhitektura

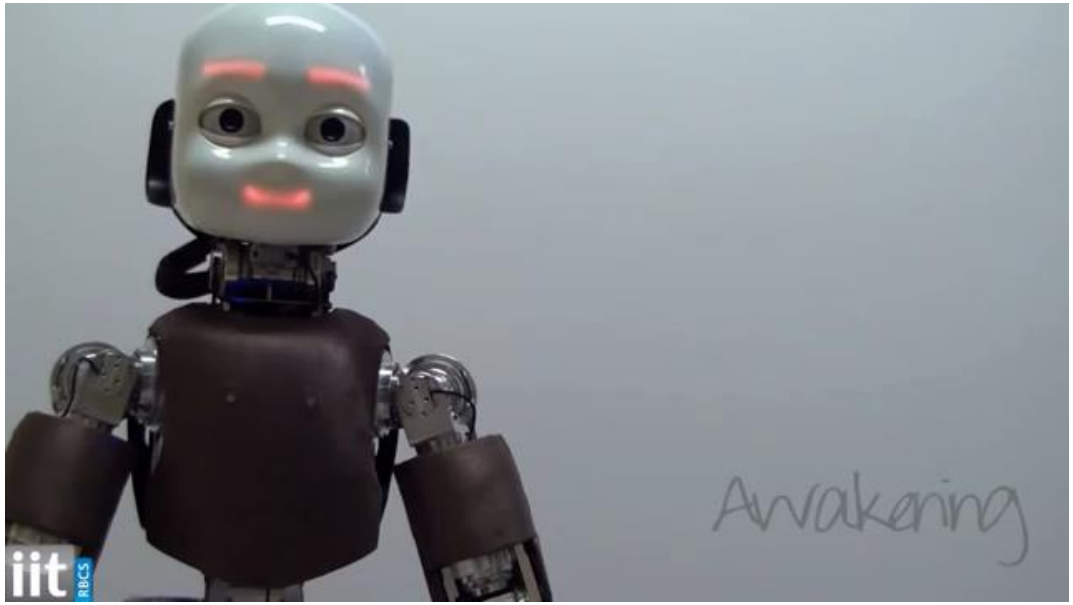



Arhitektura CogAff

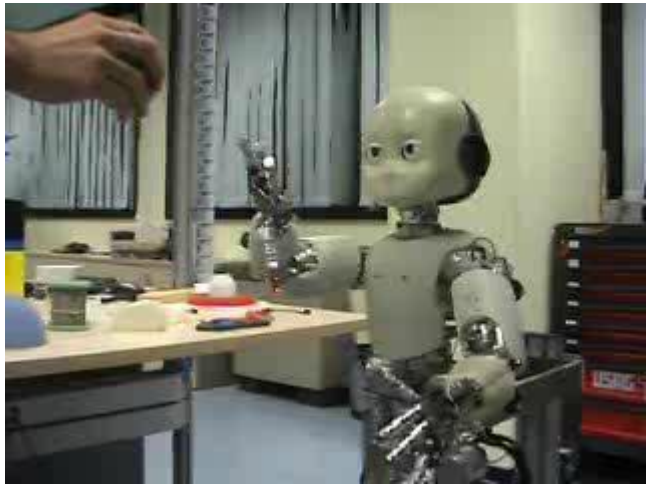
# Primeri – PR2

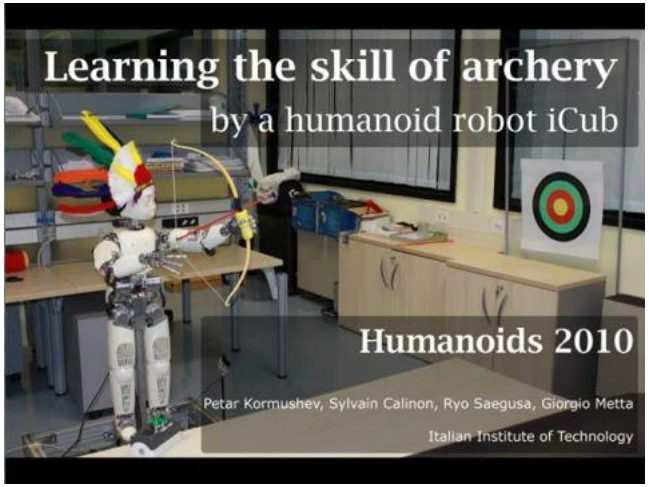

U Tokyo, TUM
Willow Garage
UC Berkley

# Primeri - iCub




IIT



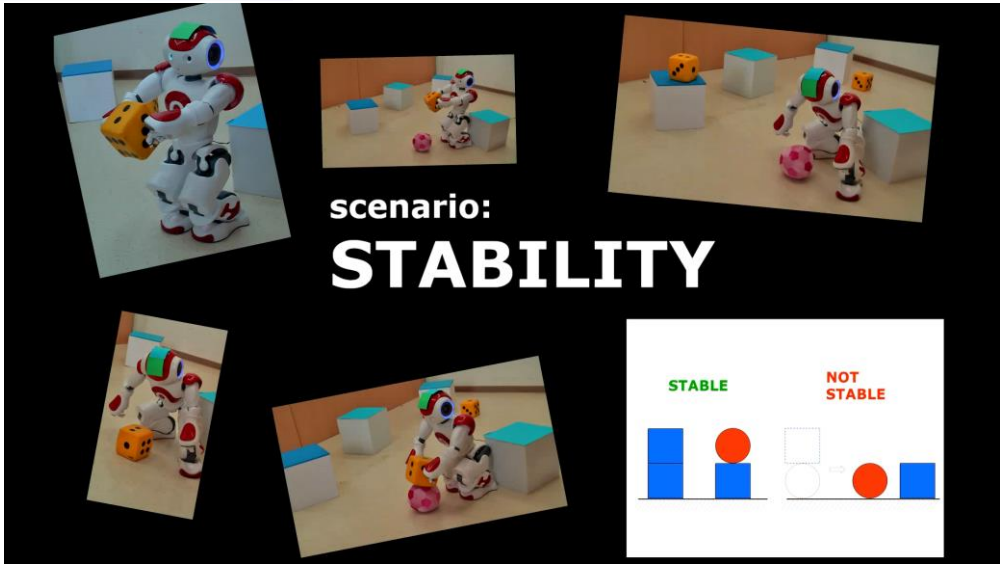


# Primeri - Asimo



# Primeri - Nao

Aldebaran Robotics



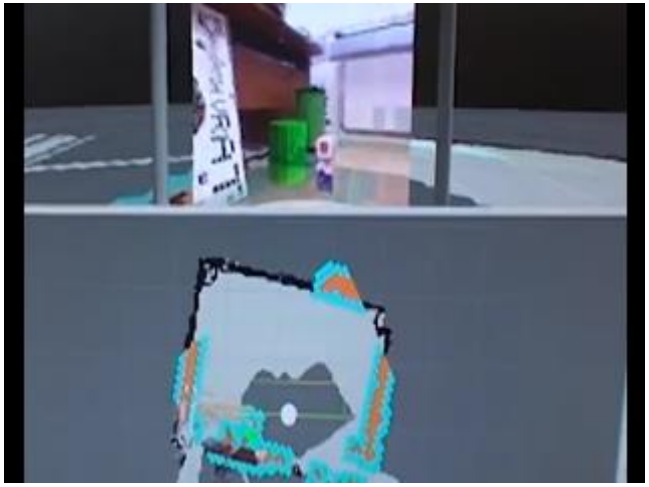

Expero, FRI LUI

# Inteligentni Roomba

RInS 2012

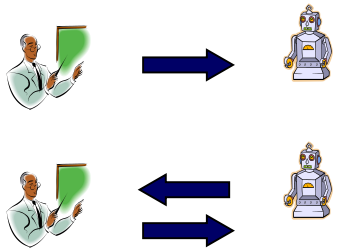
Diploma G. Pušnik

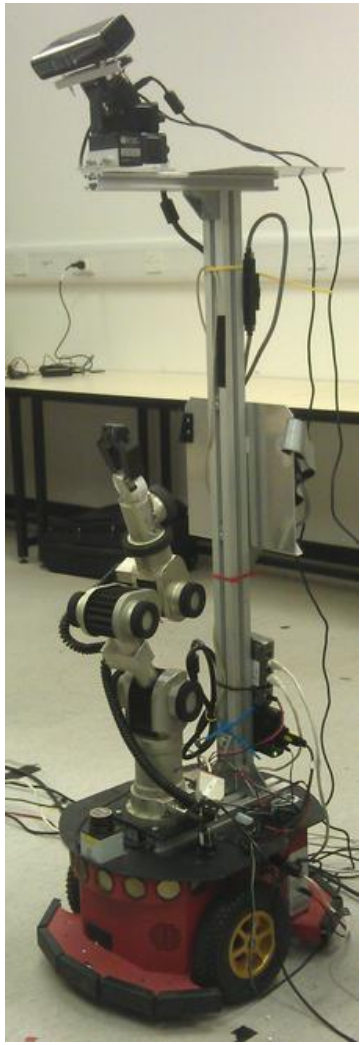
Diploma J. Bizjak



# Radovedni robot George

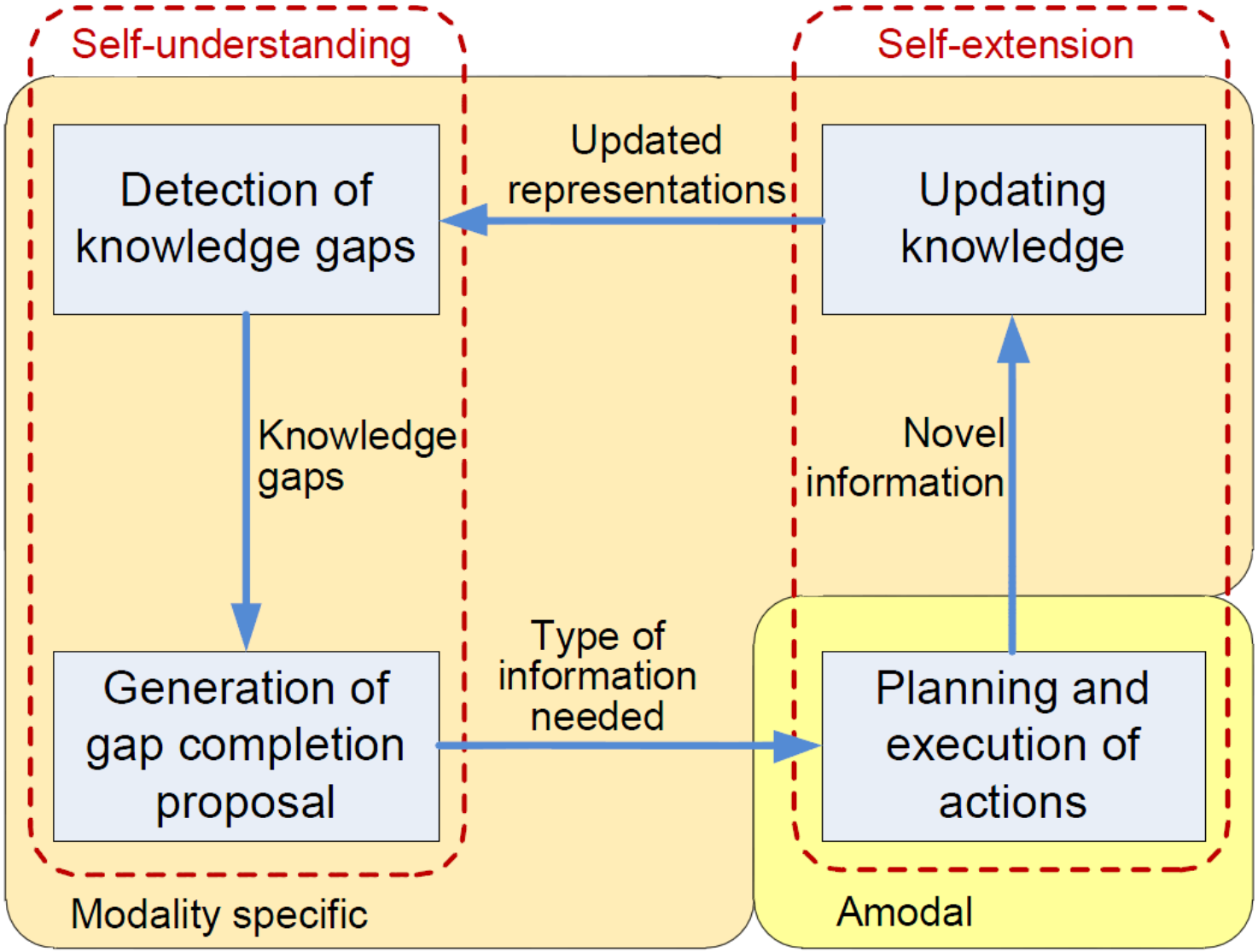
- Interaktivno učenje v dialogu s človekom



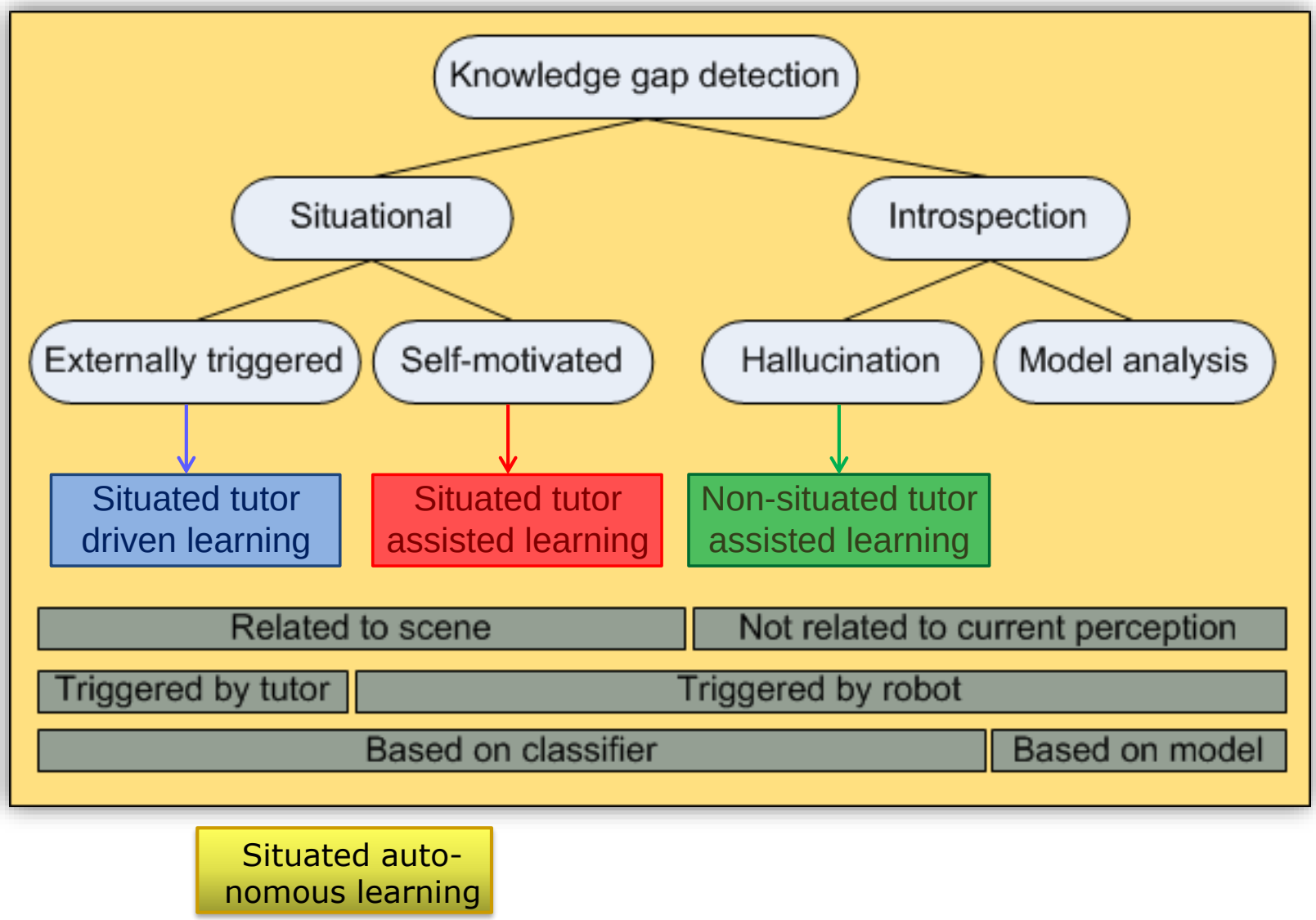


COGNITIVE SYSTEMS THAT SELF-UNDERSTAND AND SELF-EXTEND

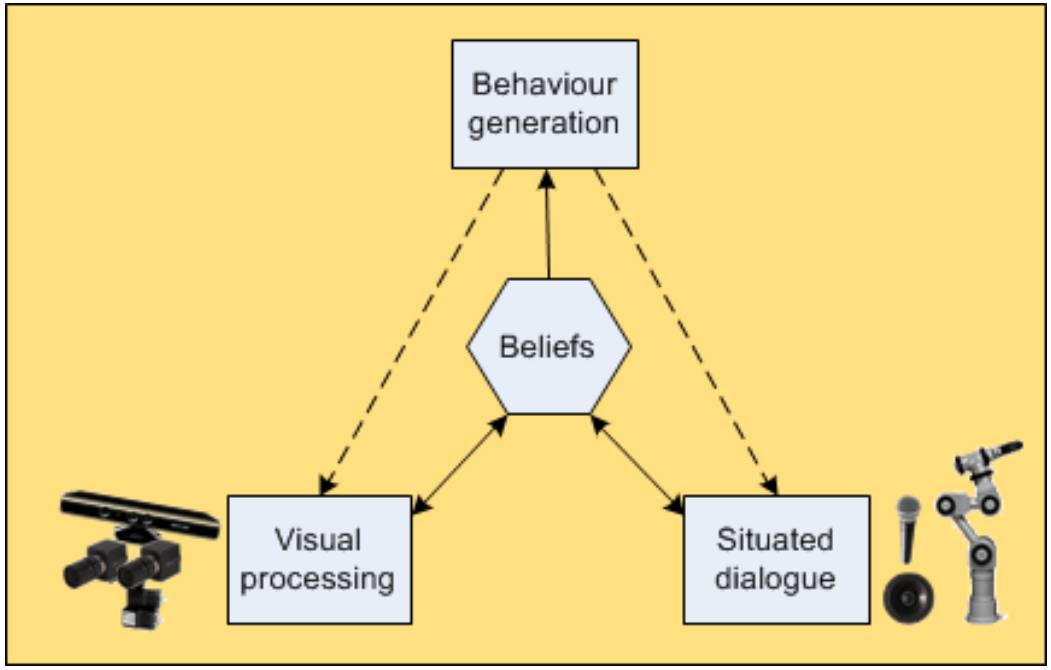
# Samo-razumevanje in samo-razširitev



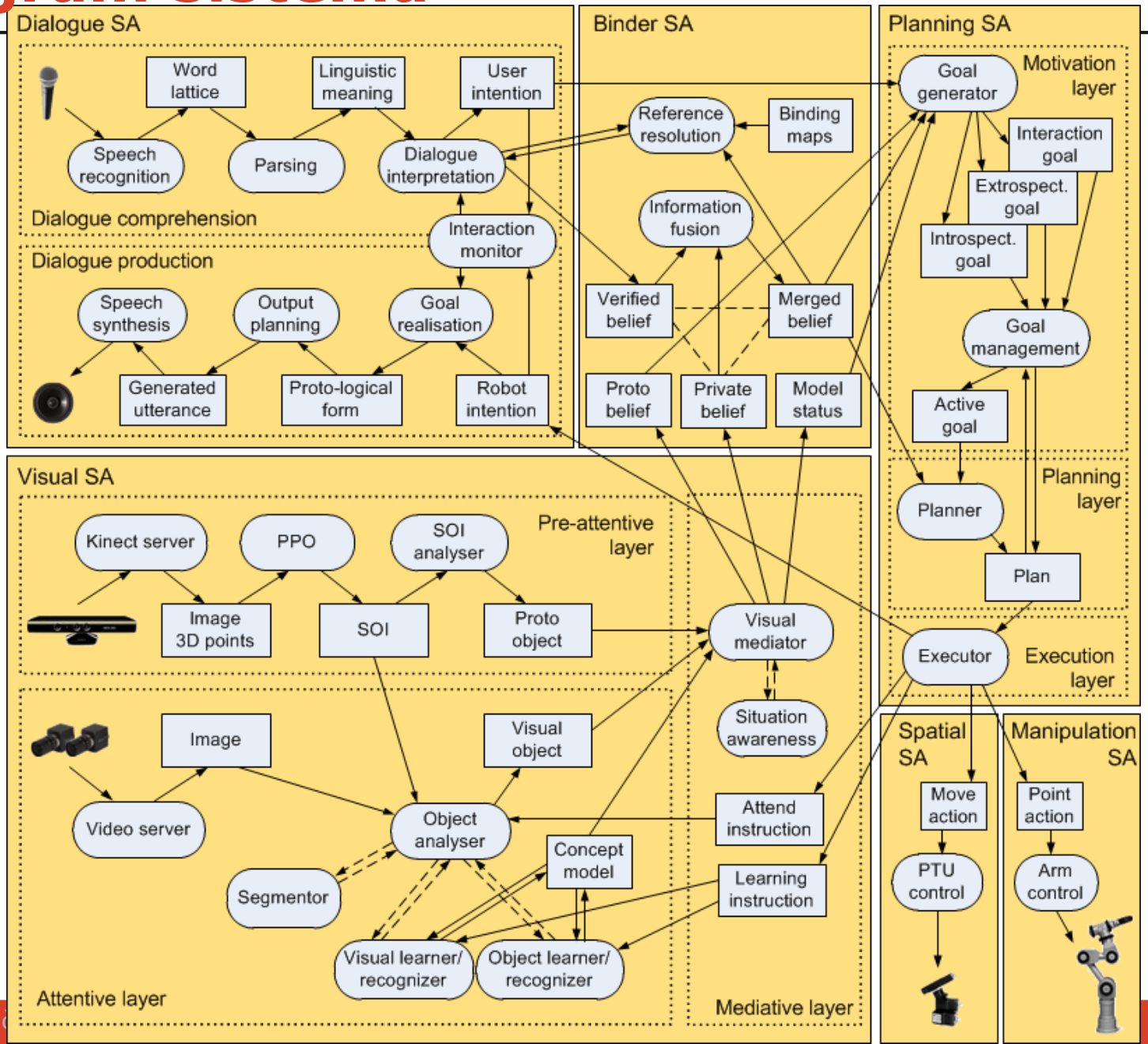
# Učni mehanizmi



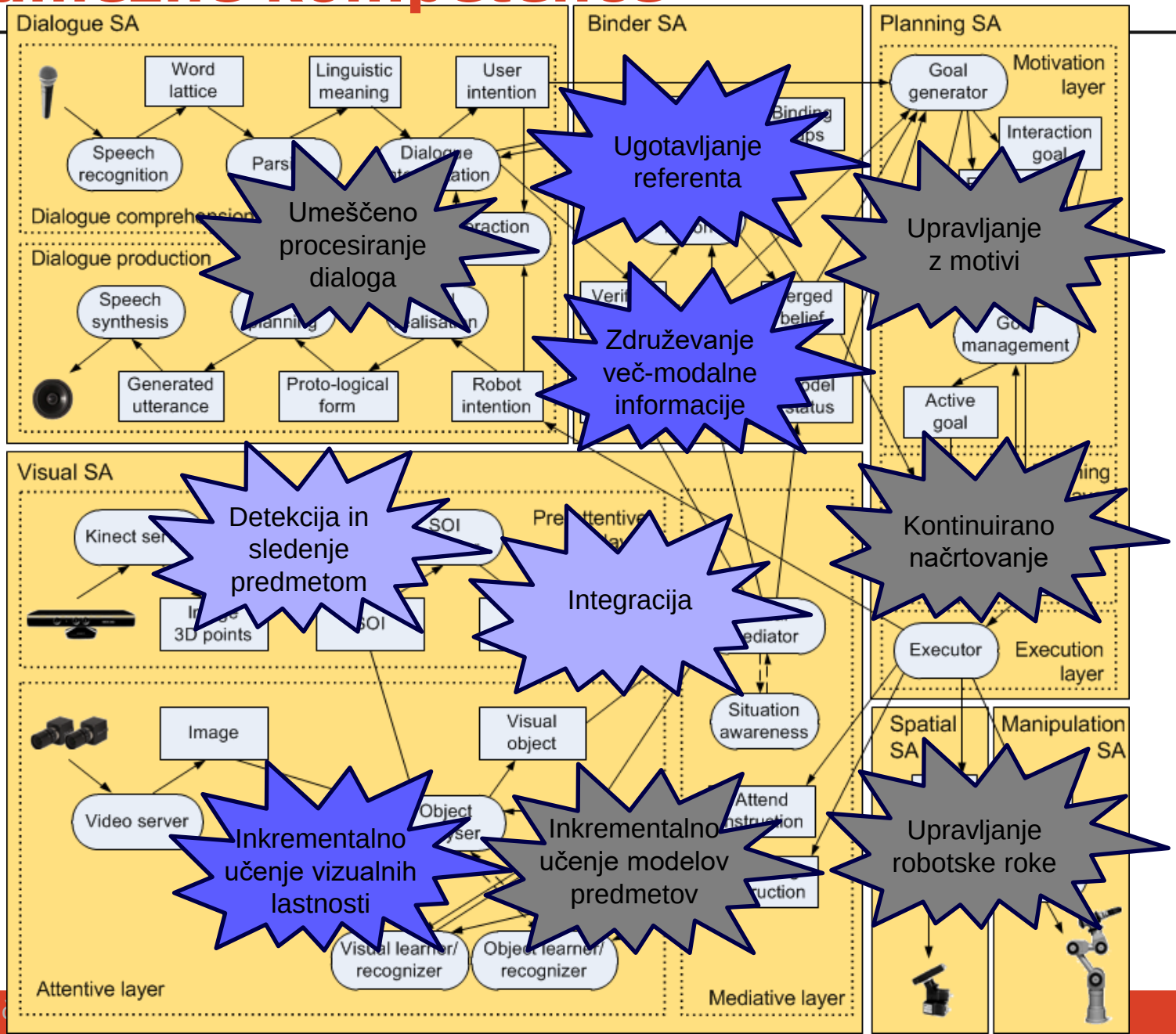
# Oris sistema



# Diagram sistema

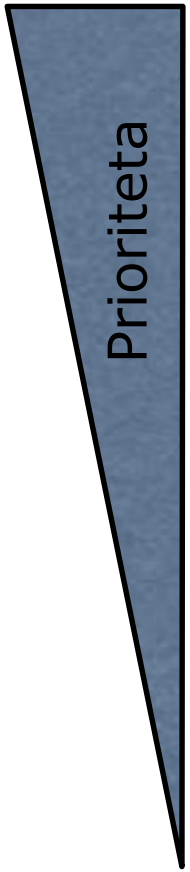


# Posamezne kompetence



# Obnašanje sistema

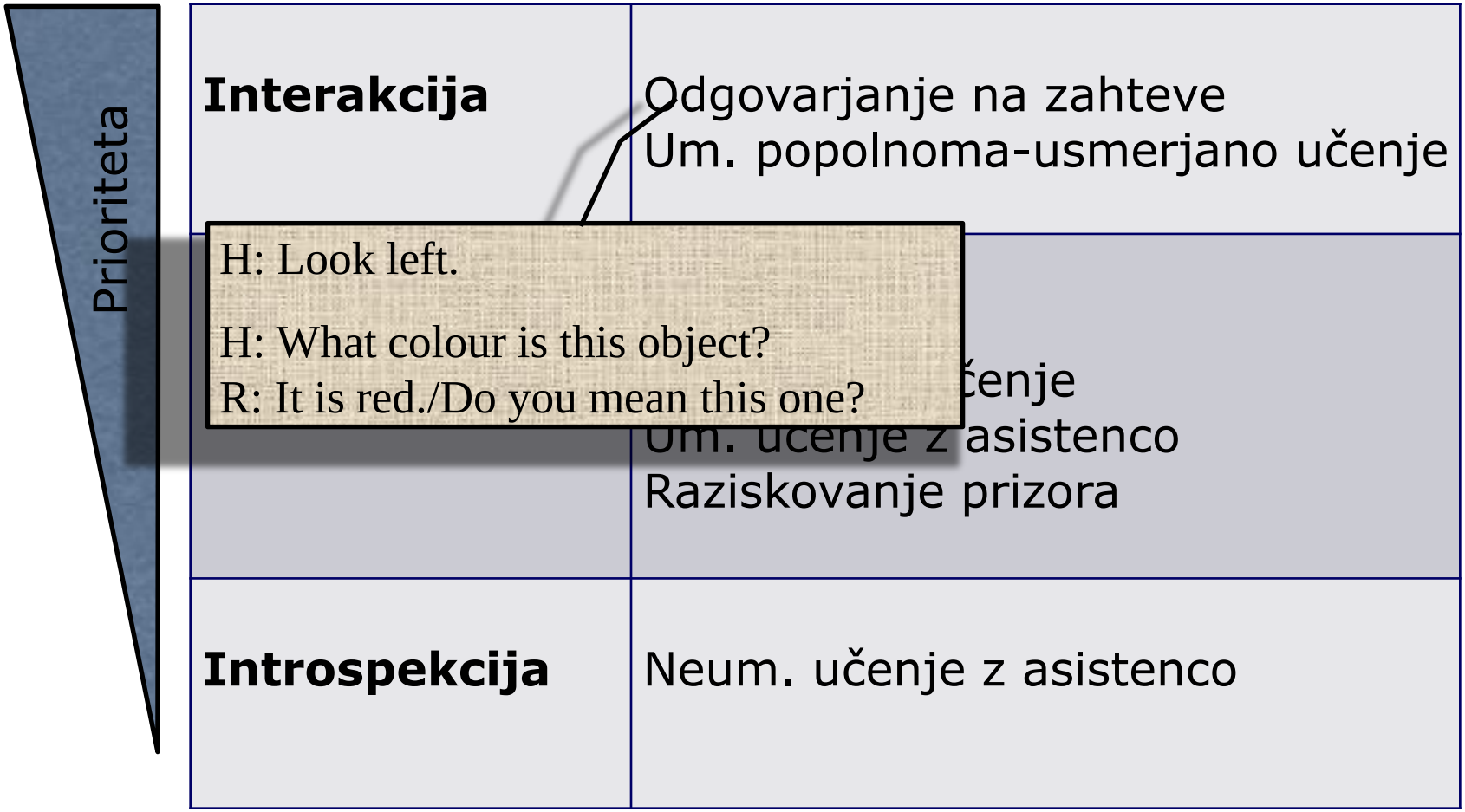
- Glavni nagoni in mehanizmi obnašanja




| | |
|---|---|
| **Interakcija** | Odgovarjanje na zahteve<br>Um. popolnoma-usmerjano učenje |
| **Ekstrospekcija** | Pozornost<br>Avtonomno učenje<br>Um. učenje z asistenco<br>Raziskovanje prizora |
| **Introspekcija** | Neum. učenje z asistenco |

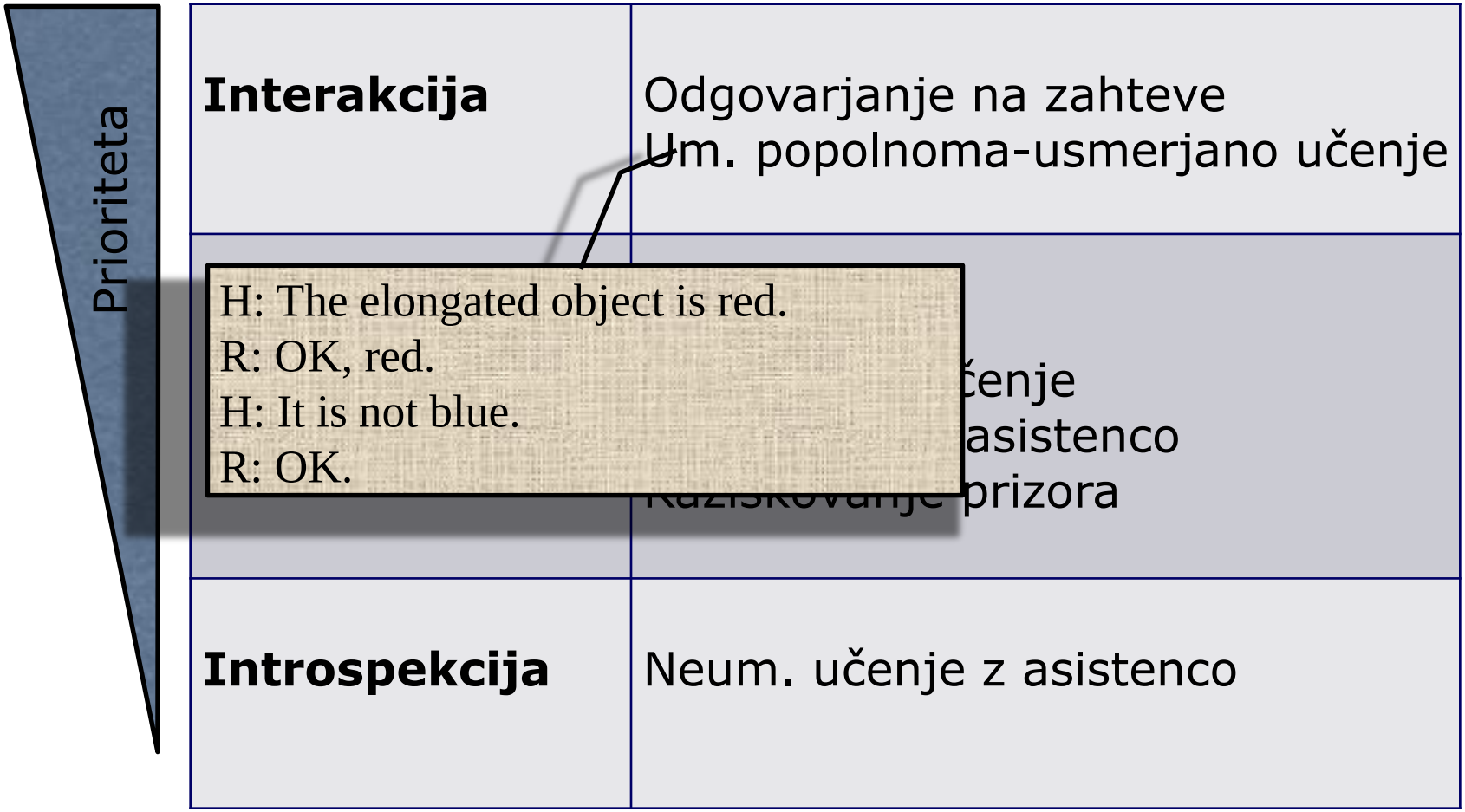
# Obnašanje sistema

- Glavni nagoni in mehanizmi obnašanja



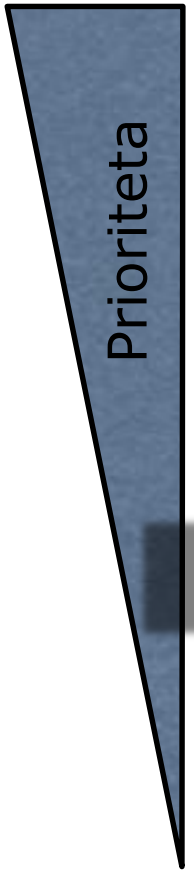
# Obnašanje sistema

- Glavni nagoni in mehanizmi obnašanja



# Obnašanje sistema

- Glavni nagoni in mehanizmi obnašanja

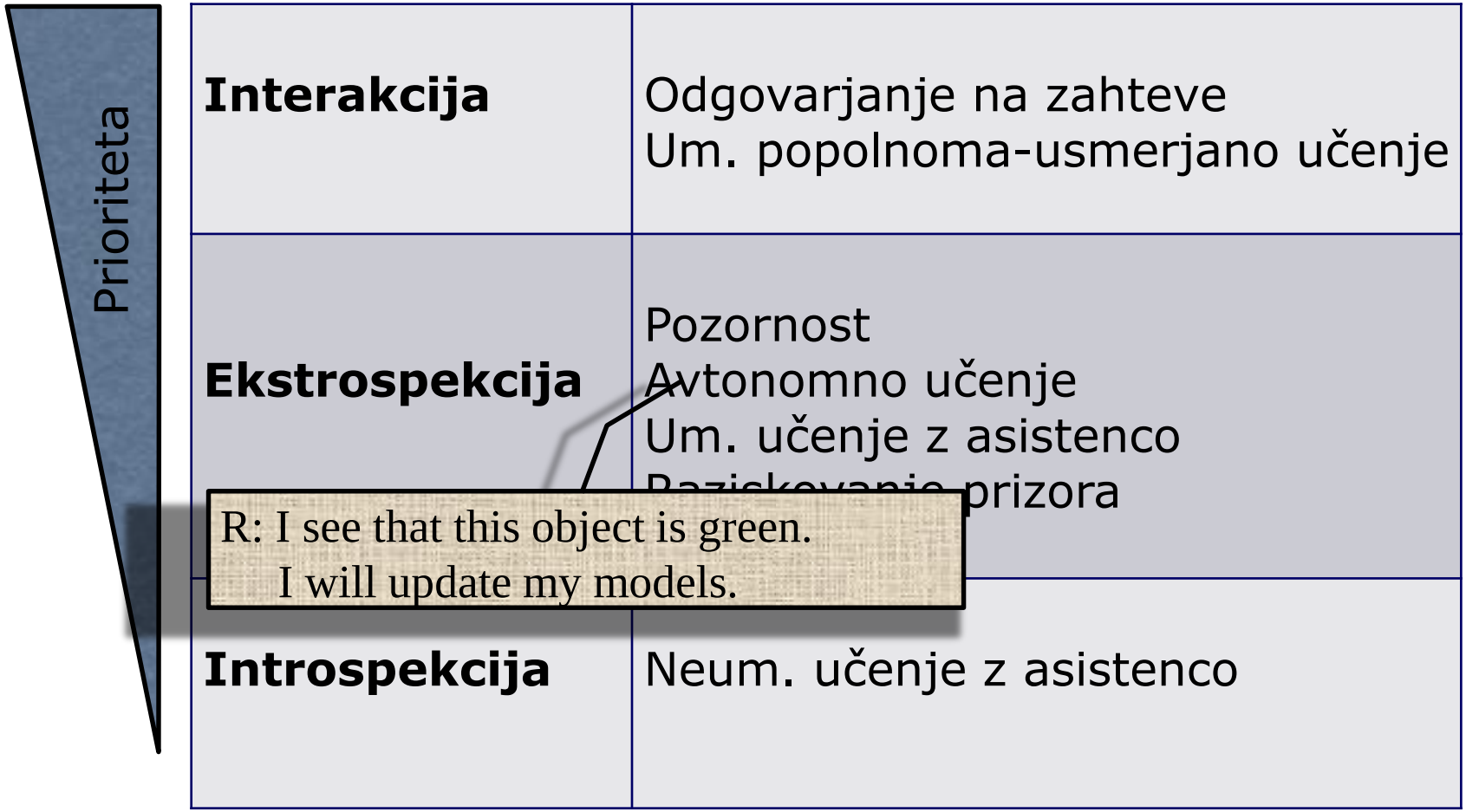



| | |
|---|---|
| **Interakcija** | Odgovarjanje na zahteve<br>Um. popolnoma-usmerjano učenje |
| **Ekstrospekcija** | Pozornost<br>Avtonomno učenje<br>Um. učenje z asistenco<br>prizora |
| **Introspekcija** | Neum. učenje z asistenco |

Detect and attend the objects.

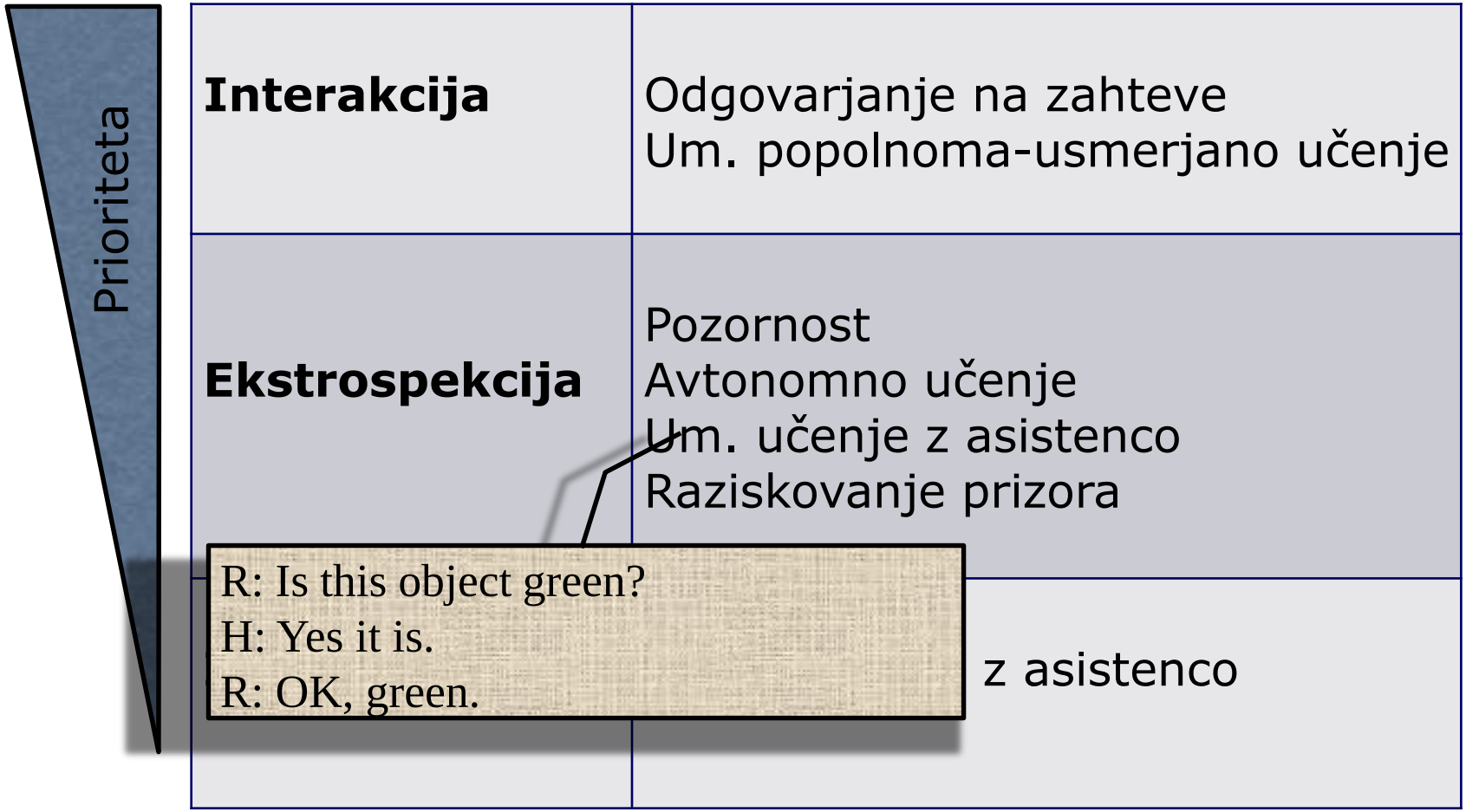
# Obnašanje sistema

- Glavni nagoni in mehanizmi obnašanja



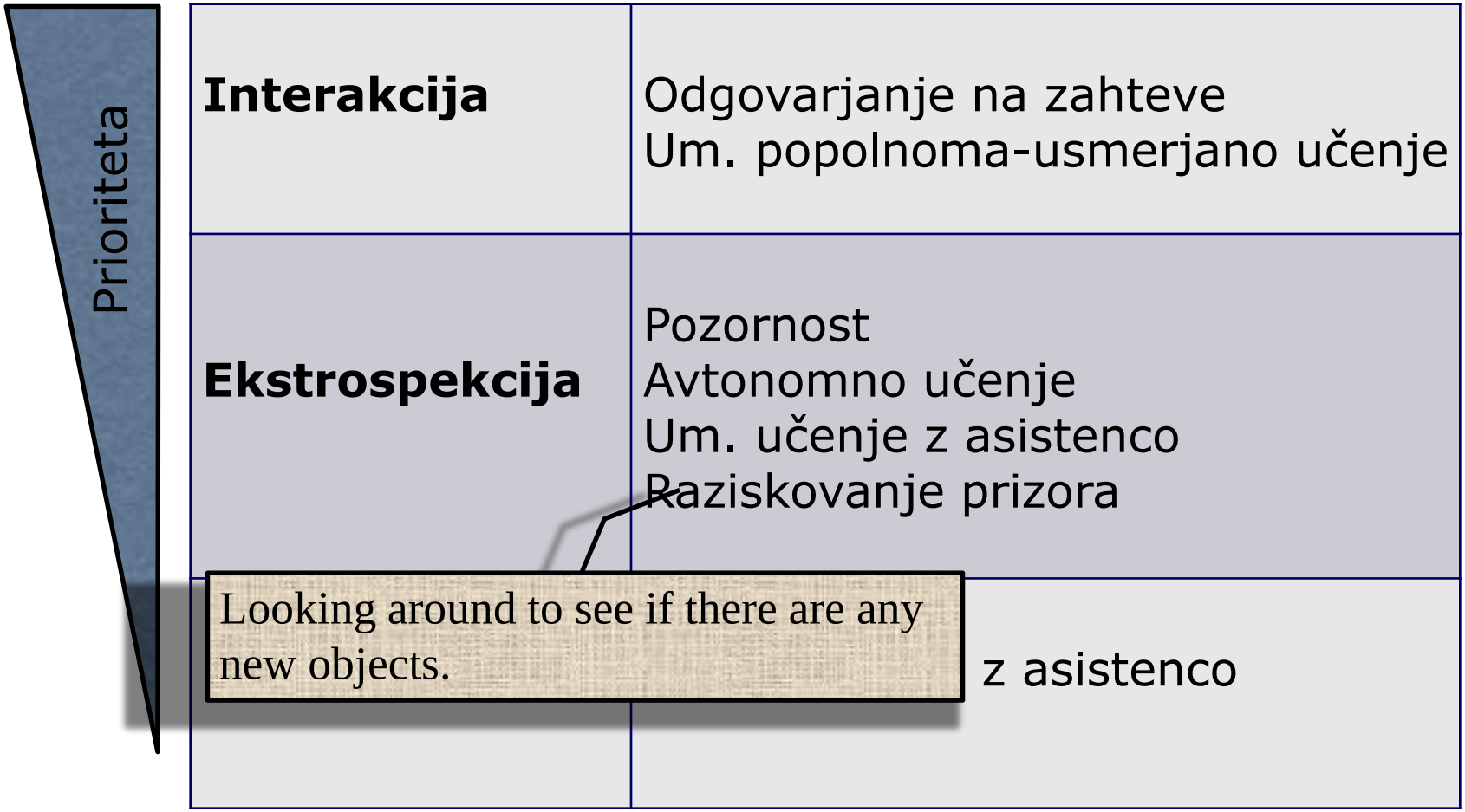
# Obnašanje sistema

- Glavni nagoni in mehanizmi obnašanja



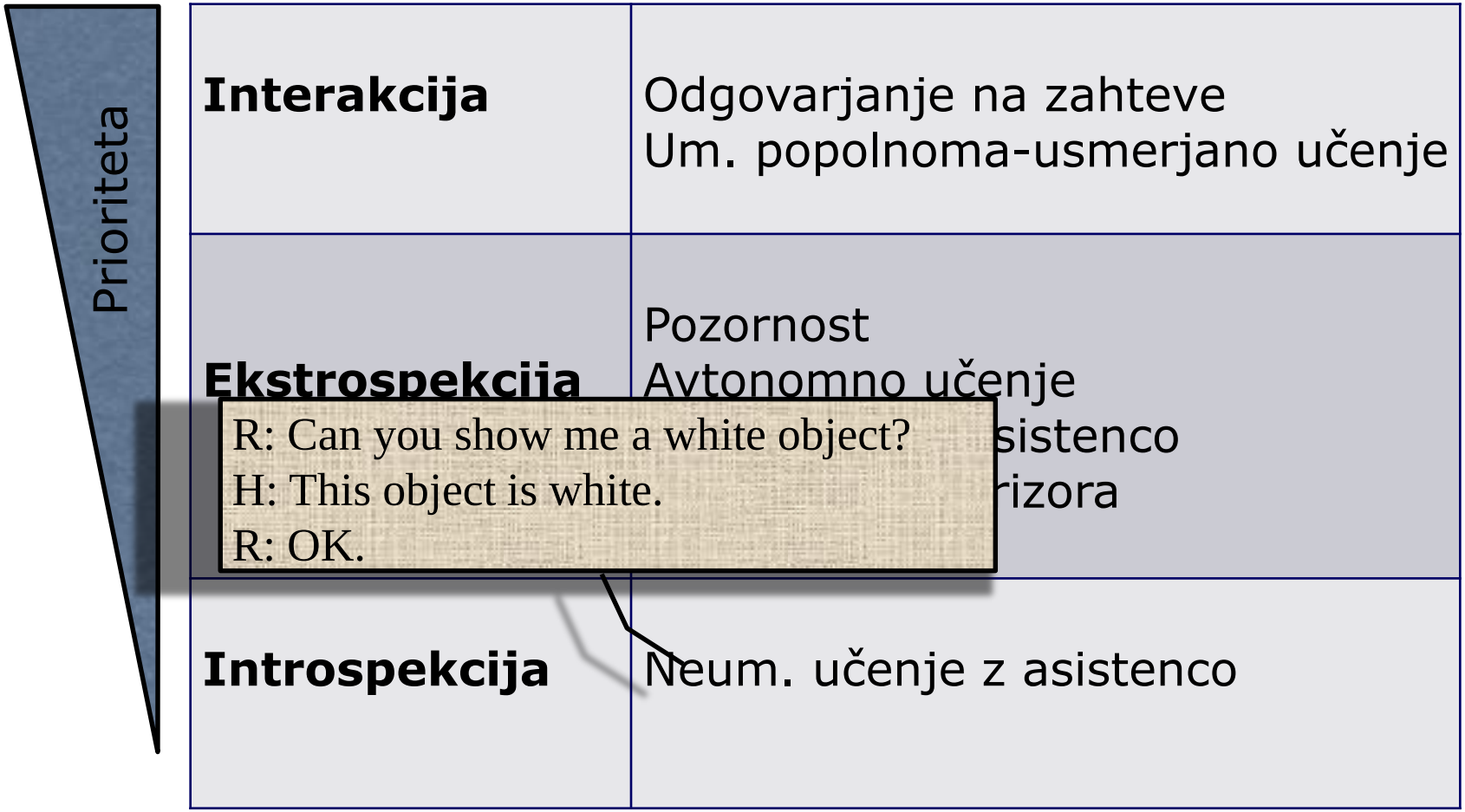
# Obnašanje sistema

- Glavni nagoni in mehanizmi obnašanja



# Obnašanje sistema

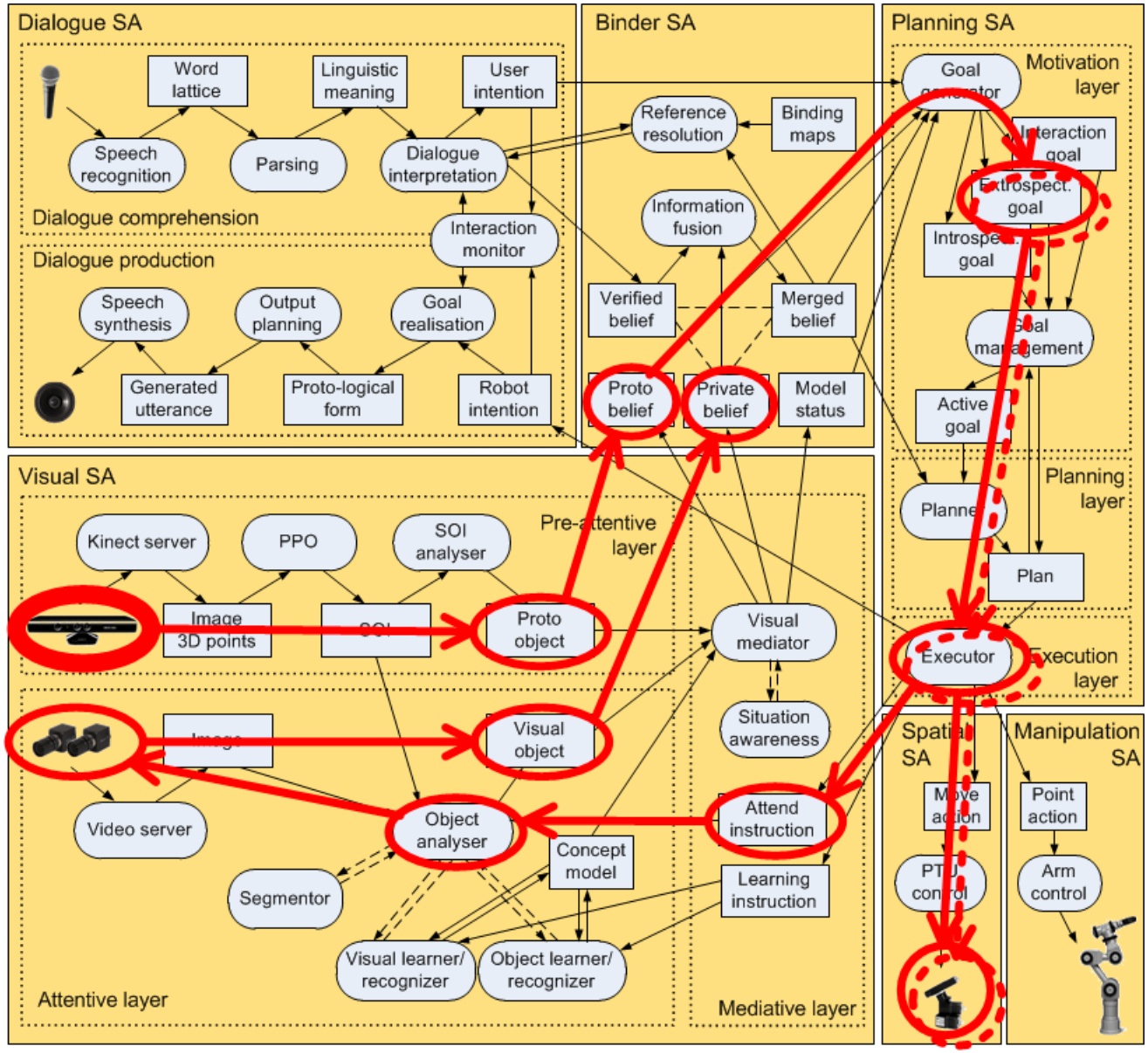
- Glavni nagoni in mehanizmi obnašanja



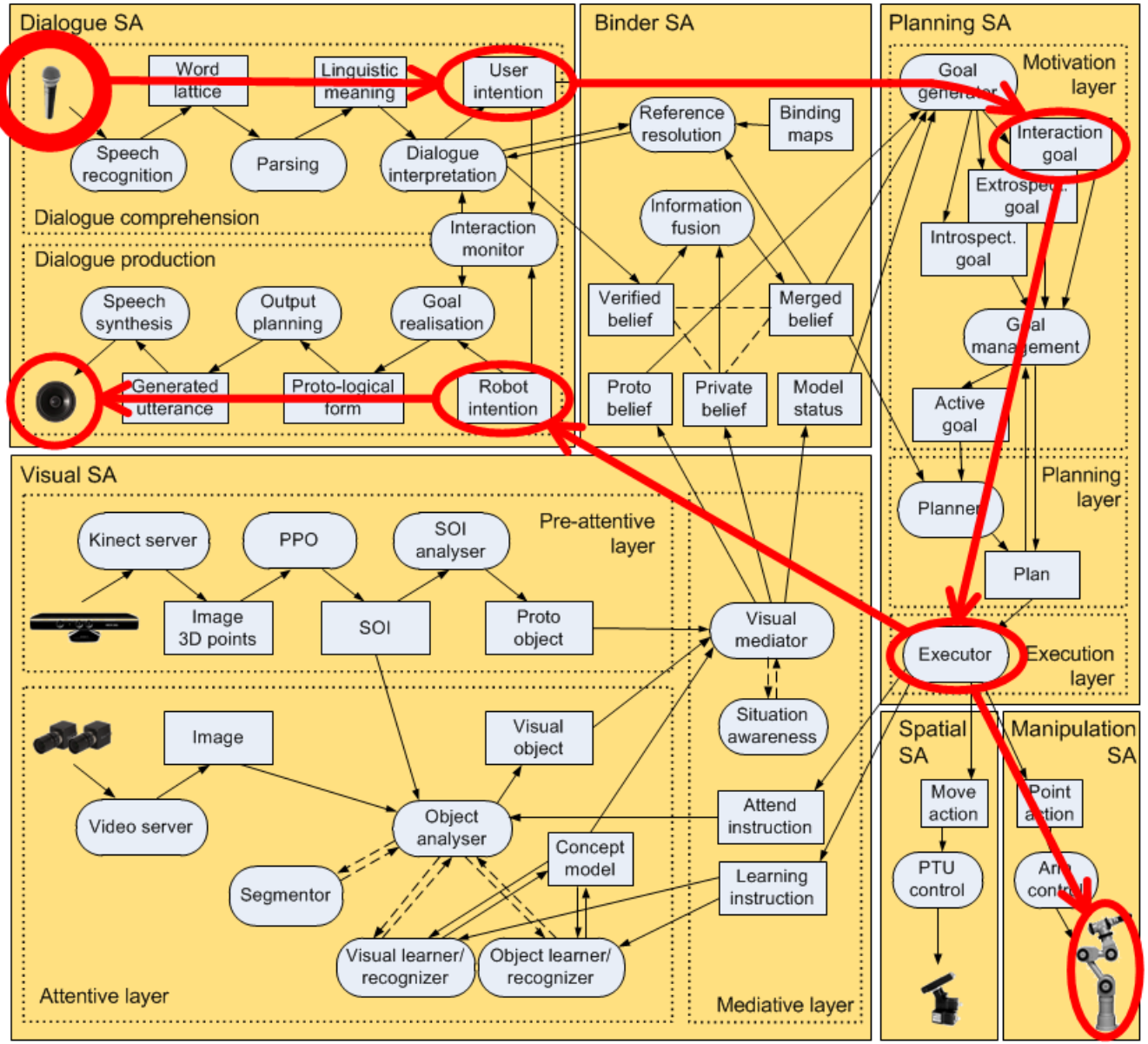
# Video


http://cogx.eu/results/george

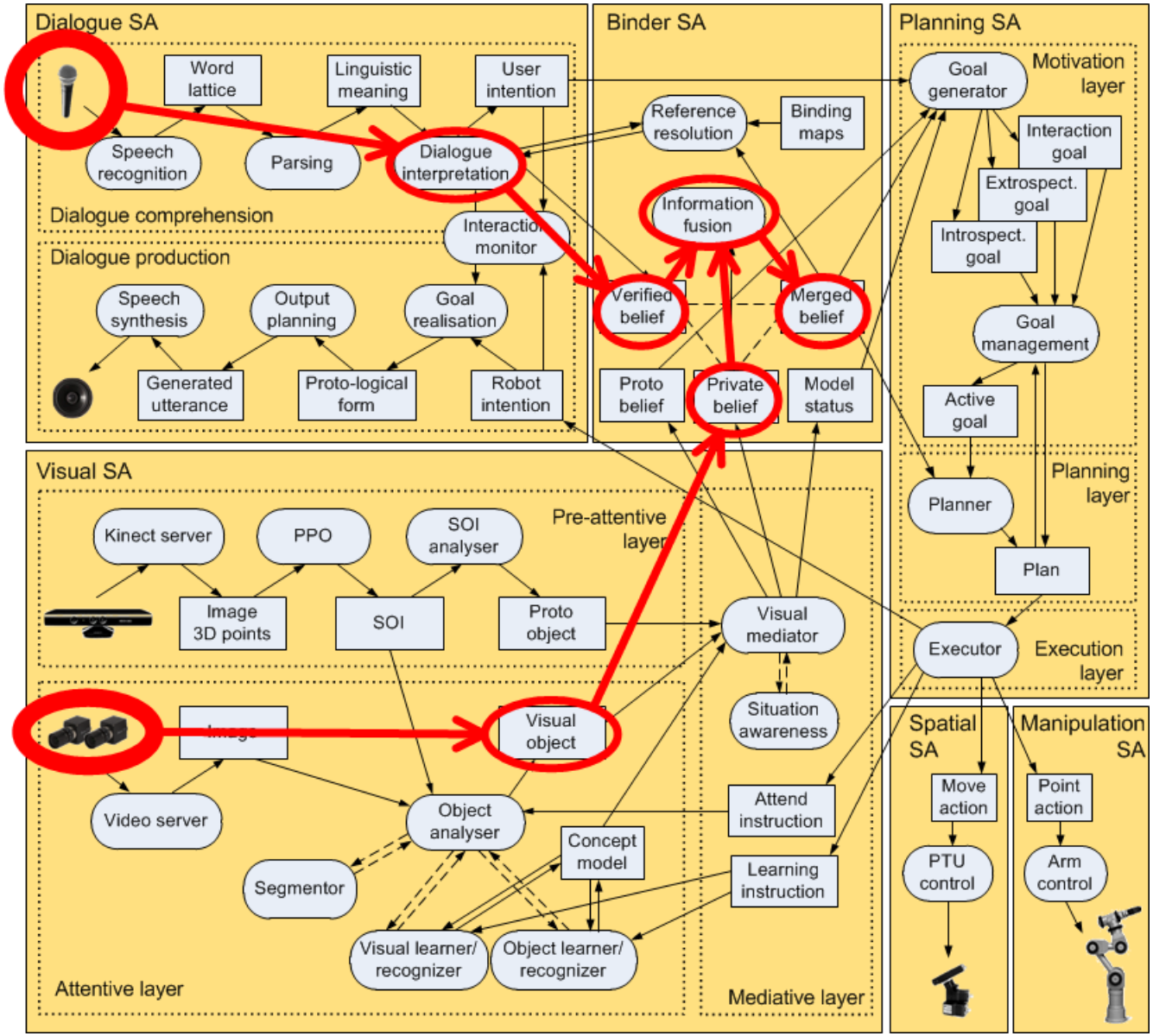
# Pozornost in raziskovanje



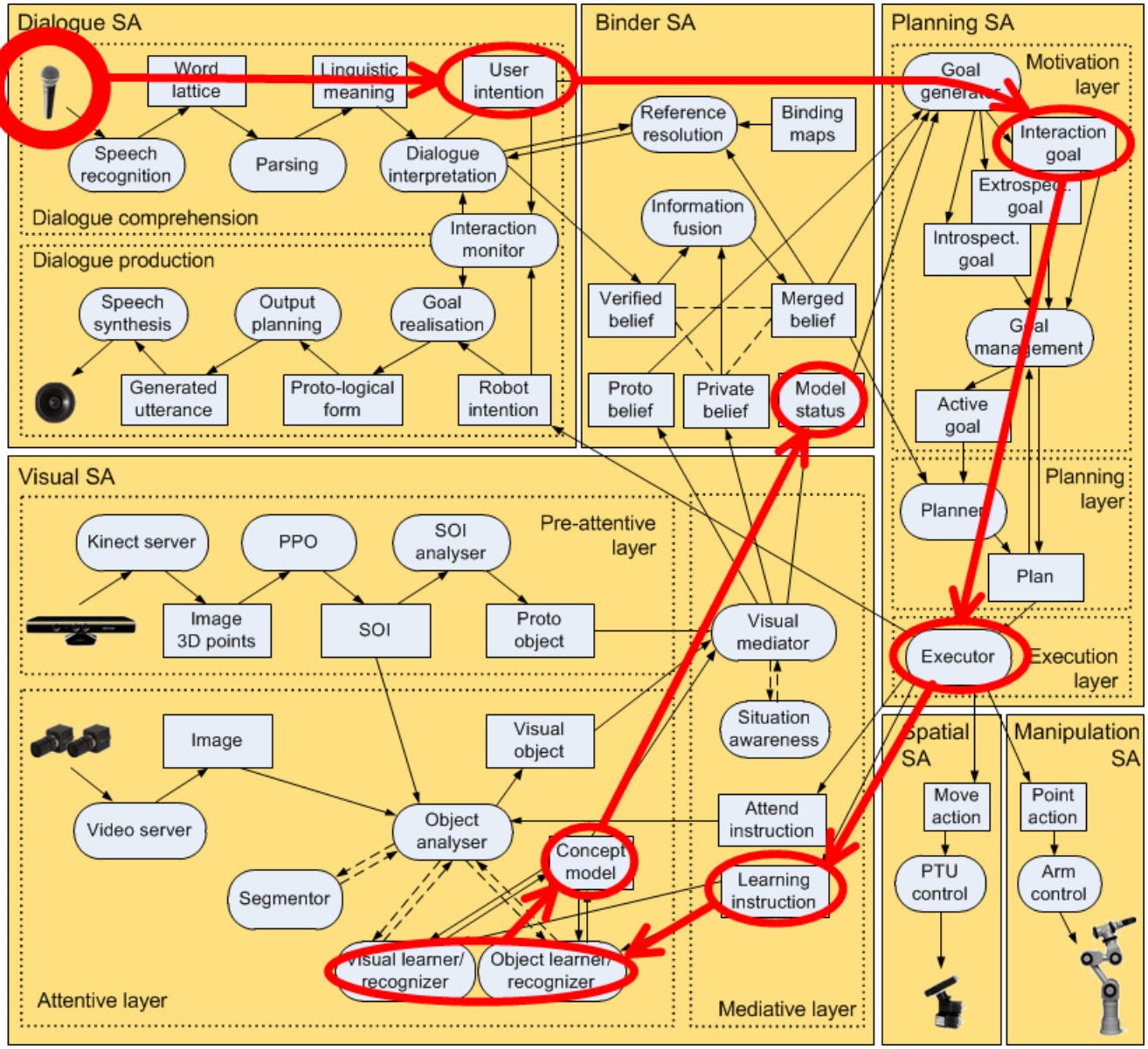
# Odgovarjanje na zahteve tutorja



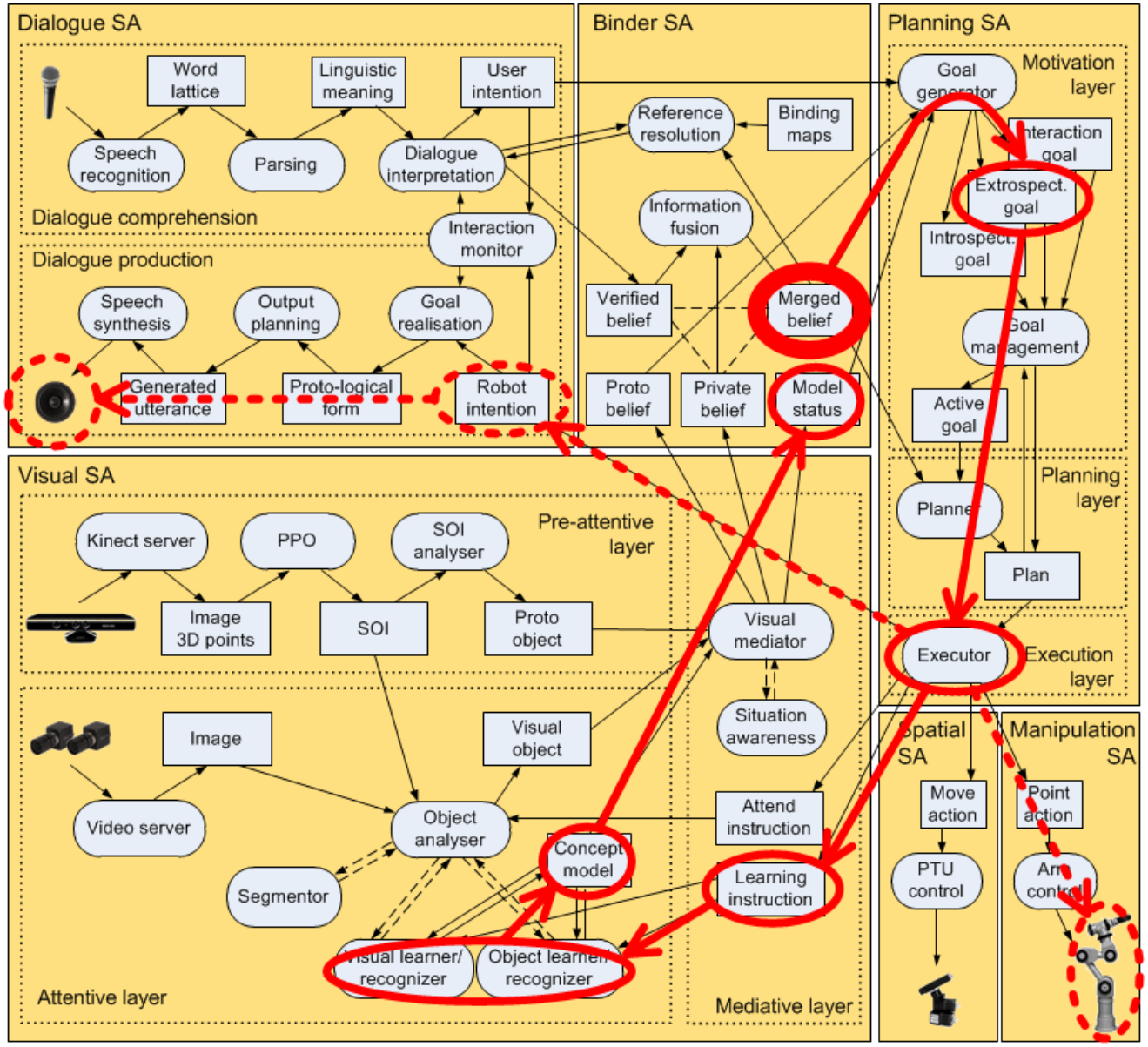
# Spajanje več-modalne informacije



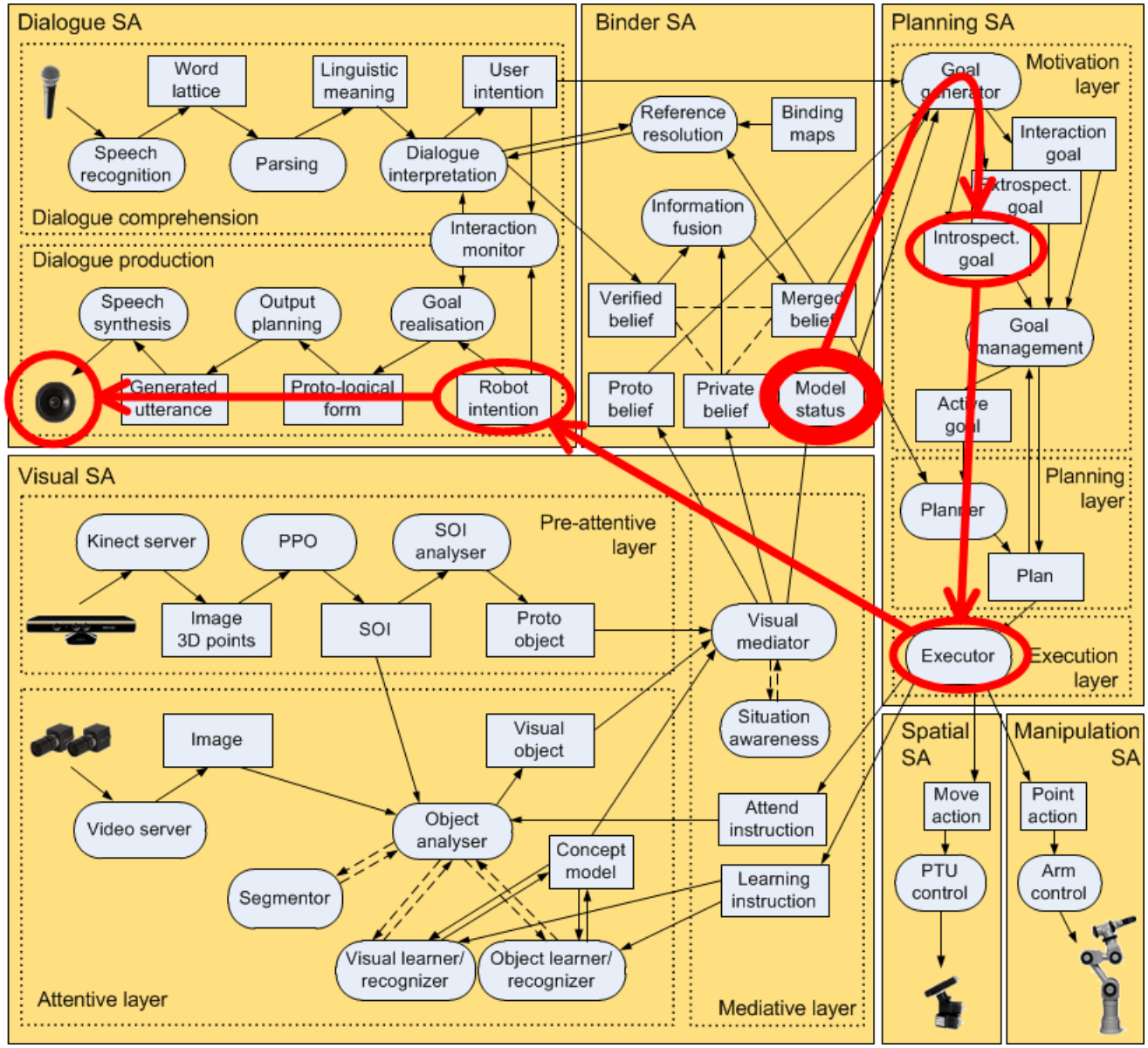
# Umeščeno popolnoma-usmerjano učenje



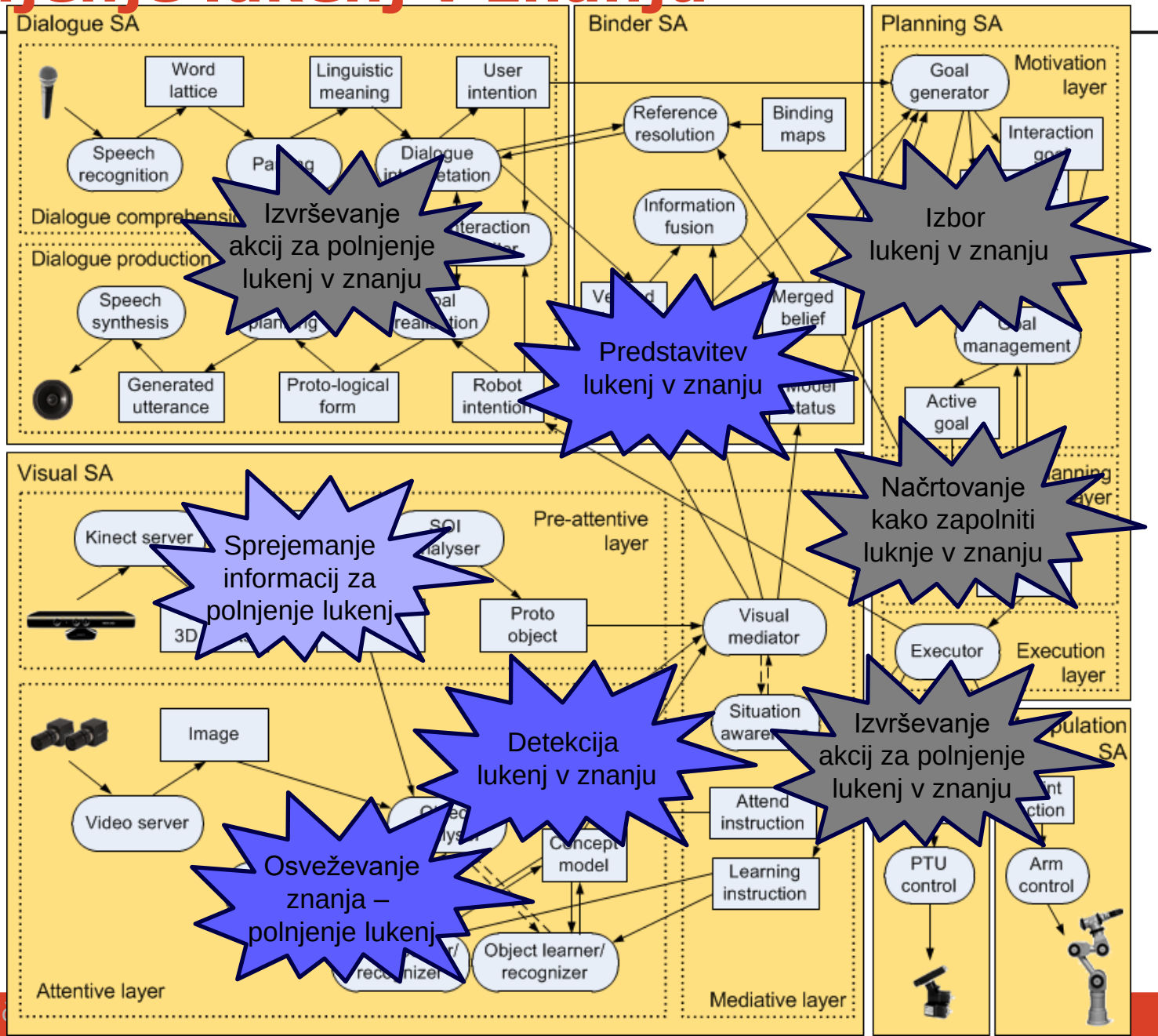
# Avtonomno učenje in učenje z asistenco



# Neumeščeno učenje z asistenco



# Polnjenje lukenj v znanju



# Zaključek

- Spoznavni sistemi so
  - inteligentni
  - zelo heterogeni in asinhroni
  - delujejo koherentno
  - upravljajo z veliko različnimi modalnimi predstavitvami
  - združujejo modalne informacije
  - nadgrajujejo svoje znanje z učenjem
  - komunicirajo s človekom
  - so sposobni interakcije z okoljem, se lahko premikajo po prostoru
  - so sposobni avtonomnega razmišljanja in odločanja
- Literatura:

Literature: SKOČAJ, D., VREČKO, A., MAHNIČ, M., JANÍČEK, M., KRUIJFF, GJ, HANHEIDE, M., HAWES, N., WYATT, J., KELLER, T., ZHOU, K., ZILLICH, M., KRISTAN, M. An integrated system for interactive continuous learning of categorical knowledge. *Journal of experimental & theoretical artificial intelligence*, ISSN 0952-813X. [Print ed.], 2016, vol. , no. , str. 1-26

# Zaključek

D-60

D-30

D

D+30