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Piaget and cognitive robotics : smart machines for the real world

Prof. Dr. Jean-Daniel Dessimoz, MBA, HES-SO / HEIG-VD

14.00 – 14.30, 6. Juni 2013

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VOLLBILD KLEINER EMPFEHLEN DRUCKEN SUCHEN

Industrieroboter: produktiv statt niedlich

Während Humanoiden vor allem herzig aussehen, ist das Design von Industrierobotern ganz auf Funktionalität ausgerichtet: Ihr einziger Zweck ist die Arbeit – hochpräzise und mit absolut gleichbleibender Qualität. Sie manipulieren, montieren, schweissen, prüfen oder verpacken und führen vor allem repetitive Arbeiten aus, die für menschliche Arbeitskräfte eintönig oder belastend wirken.

Damit leisten sie einen wichtigen Beitrag an die Erhaltung unseres Werkplatzes. Denn die Industrieautomation sichert qualifizierte Arbeitsplätze und hilft mit, dass unsere hochwertigen Produkte zu einem konkurrenzfähigen Preis-Leistungsverhältnis fabriziert werden können.

Forschungsroboter und Know-how-Transfer

Auch wenn ihre Funktionen nicht auf Produktivität ausgerichtet sind, legen Roboter wie der Roboy wichtige Grundlagen für industrielle Anwendungen. So können bei der Integration von Vision-Systemen mit Gesichtserkennung oder dem Einbau von Sen-

Programm swissT.box Robotic
Stand 3.E01

Von künstlicher Intelligenz zu humanoiden Robotern
Prof. Dr. Rolf Pfeifer, AI-Lab der Universität Zürich

YouBot – der Laptop der Robotik
Dr. Erwin Prassler, Locomotec UG

Tribologische Besonderheiten im Maschinenbau
Marco Buchwalder, Klüber Lubrication AG

Innovation – Bike Box
Heinz Müller, Elpex AG

Personalrobotik: Menschennah und lernfähig
Dr. Hansruedi Früh, F&P Personal Robotics

Technologieneutralität – Automatisierung der Zukunft
Michael Fraede, Festo AG

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Hes·so Haute Ecole Spécialisée de Suisse occidentale

heig-vd Haute Ecole d'Ingénieurs et de Gestion du Canton de Vaud

ceTT

Institut d'Automatisation Industrielle — LaRA Laboratoire de Robotique et Automatisation

Piaget and cognitive robotics : smart machines for the real world

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Re. J.-D. Dessimoz et al., HESSO.HEIG-VD, Int. Symp. on Rob. Conf., Taipeh, Taiwan, 2012

http://www.heig-vd.ch, http://lara.heig-vd.ch

Keywords: Cognitics, Cooperative Agent, Piaget, Real-time Intelligent Control, Industrial Robot

Content

Slides on website: http://lara.populus.org/rub/3

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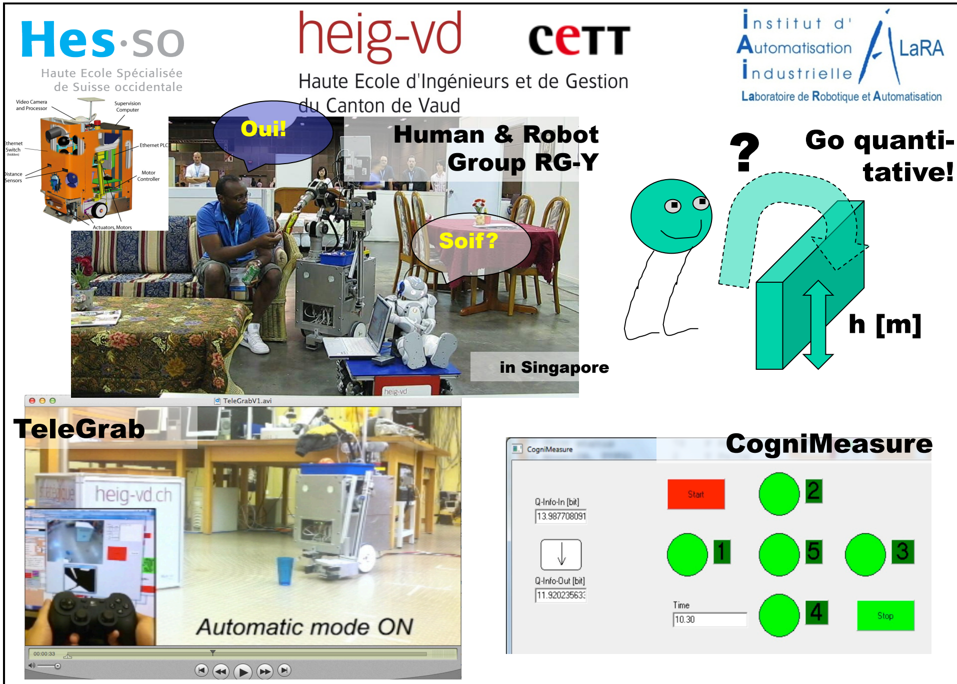

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1. Introduction 1 of 3

- **Make smart systems, change the world and human life!**
- **Much already done :**
  1. **Robots**
  2. **Information processing systems and techniques**
- **Current industrial robots : ok for power and accuracy**
- **But now for robots:**

  challenges in cognitive capabilities.

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1. Introduction 2 of 3

- Industrial environment more complex and changing; real-time cooperation with humans and other resources envisioned.
- Mankind now needs machines with their own knowledge, artificial cognition, cognitics.
- We had started, back in 1998, to design an environment, denoted Piaget: most competitive development and control of autonomous robots.

1. Introduction 3 of 3

- Then kept developing Piaget for the first 5 years of the "@Home league), the Robocup initiative:
  - "integrate robotics and AI"
  - Design of smart robots: individual initiative, collective cooperation with other robots and humans, fast locomotion and effective action in the real world.
  - Target performance levels comparable to best human soccer-players. Or best domestic helpers .
- Now : extend our successful proposals to new-coming industrial challenges.

Content

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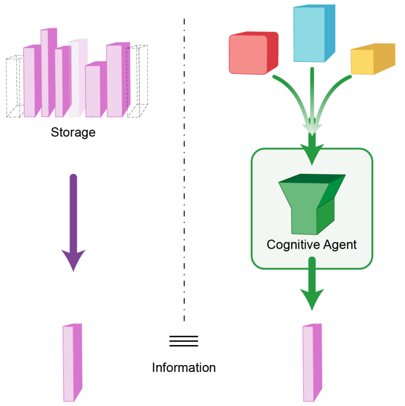
2. Requirements and theoretical aspects of intelligent control

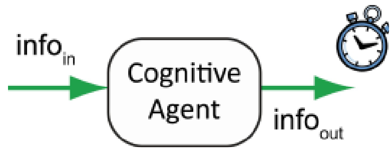
A. First stage in the exploration of cognition
B. Requirements for a new set: architecture and language
C. Metric estimation and benchmarks for best approaches
D. MCS theory for cognition

2.A. First stage in the exploration of cognition

A.1 What is Cognition? intelligence? and Intelligent Control?



Cognition allows for generating relevant information

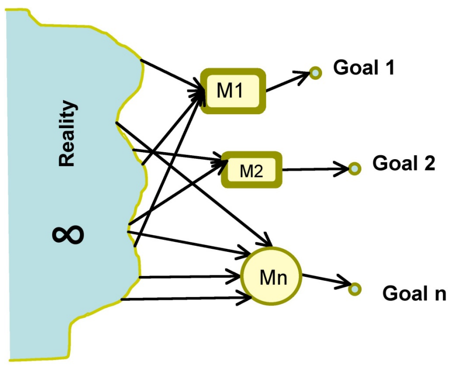


2.A. First stage in the exploration of cognition

A.2 What kind of applications is addressed?

Reality is very complex but selecting a goal typically allows for convenient, infinitely simpler models

We aim at designing smart cooperating robots



2.A. First stage in the exploration of cognition

A.3 What strategies are appropriate?

- **Organize a hierarchy of coordinated, specialized resources, contexts, and points of view**
- **Rely in as much as possible on existing elementary solutions – subsystems.**
- **Selecting components on their safe availability and operational robustness**
- **Main sources of components :**
  - **market,**
  - **scientific and technological publications,**
  - **where necessary, new proprietary developments**

2. Requirements and theoretical aspects of intelligent control

A. First stage in the exploration of cognition

B. Requirements for a new set: architecture and language

C. Metric estimation and benchmarks for best approaches

D. MCS theory for cognition

2. B. Requirements for a new set: architecture and language

Back in 1998, like today:

- **goal system not available elsewhere**
- **powerful components developed**

First necessary component, a novel set, "Piaget" :

- **architecture**
- **language**
- **Real-time interactive control environment**

The "Piaget" concept described in Section 3.

2. Requirements and theoretical aspects of intelligent control

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B. Requirements for a new set: architecture and language

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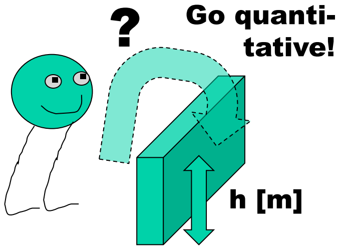
D. MCS theory for cognition

2.C. Metric estimation and benchmarks for best approaches 1 of 3



- Wall crossing : metric height!
- Cognition: metric assertion of complexity, knowledge, expertise, etc. (re. MCS in Section II.D).
- Implement in real-world systems

- Compete, thus encouraging active interaction with international experts. Our strategy :
  - Eurobot
  - Robocup@Home.

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2.C. Metric estimation and benchmarks for best approaches 2 of 3

- Same strategy - two apparently opposite benefits:
  - in the early days, industrial elements as reliable *components* for our systems
  - in recent time, industrial robotic *applications* benefit from our Piaget development,
    - Can effectively and efficiently develop/lead/steer/drive novel, complex applications
    - Can integrate, standard, industrial and/or commercial component.
- In industrial context, most relevant benchmarks:
  - open-market competition,
  - (along with the necessary legal framework)

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2.C. Metric estimation and benchmarks for best approaches 3 of 3

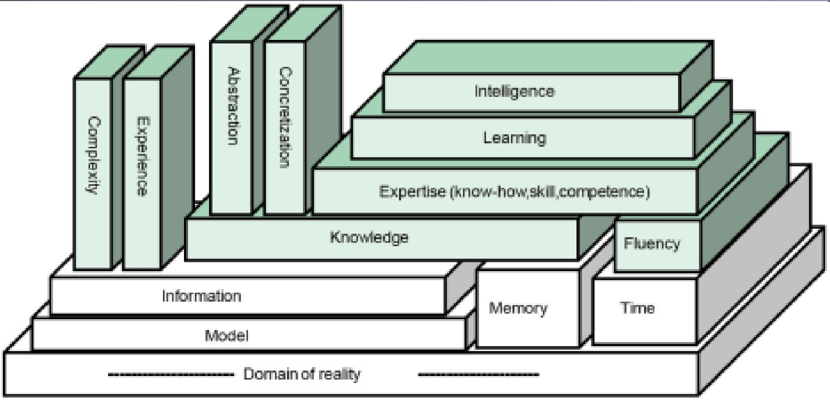

Fig. 3. On the basis of classical concepts (in white; to be revisited though) the green elements are introduced in the formal "MCS" theory for cognition [5]

Expertise is a particularly important property, which would deserve a B-Prize.

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2. Requirements and theoretical aspects of intelligent control

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2.D. MCS theory for cognition 1 of 6

Entity	*Brief description*
Model	**Goal oriented, elementary representation**
Information	**Builds-up receiver's opinion**
Complexity	**Amount of information required for description**
Knowledge	**Capability to crank out the right information**
Expertise	**Capability to crank *fast* the right information**
Learning	**Increasing the quantity of expertise**
Experience	**Amount of information witnessed**
Intelligence	**Ratio of learning versus experience**

Table 1 Brief intuitive description of cognitive concepts formally defined elsewhere, along with specific measuring equations and units.

2.D. MCS theory for cognition 2 of 6

Our developed, formal framework, "MCS", allows for the quantitative assessment of cognitive tasks, both as required or as operated by humans and machines.

Information:	$n = \sum p_i \log_2(1/p_i)$ [bit]
Knowledge:	$K = \log_2(n_{out}\ 2^{n_{in}}+1)$ [lin]
Fluency:	$F = 1/\Delta t$ [s^{-1}]
Expertise:	$E = K \cdot F$ [lin/s]
Learning:	$\Delta E = E(t_1)-E(t_0)$; >0 [lin/s]
Experience:	$R = r(n_{in}+n_{out})$ [bit]
Intelligence:	$I = \Delta E/\Delta R$ [lin/s/bit]
relative Agility:	$A_r = \tau/T$

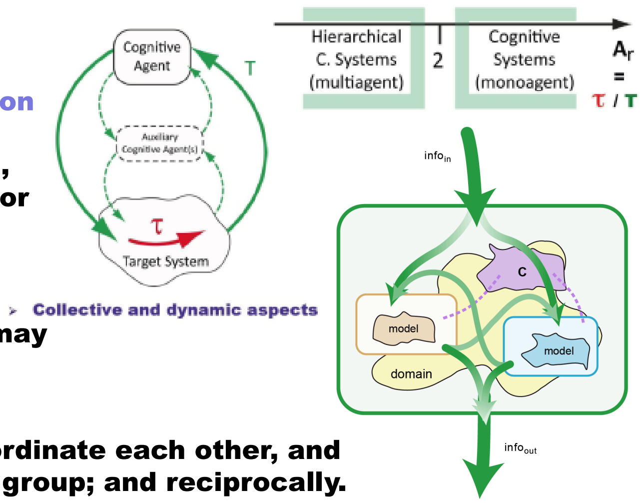
T: Fluency^{-1} and communication delays
τ: Reaction time of target system, to be controlled
r: number of withnessed experiments

Fig. 4. Equations for assessing quantitatively the core properties in cognition; re [5]. Information is classical though (re. Shannon).

2.D. MCS theory for cognition 3 of 6

Time and scale important in cognition

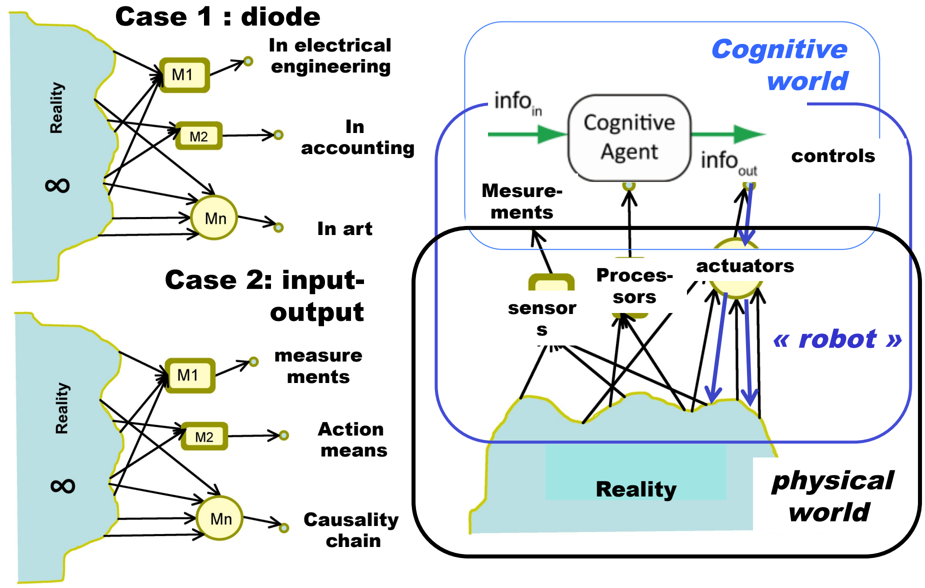
- In all control loops, (with single agent or multiple agents), strict dynamic constraints
- Partial autonomy may be required.



Individuals can coordinate each other, and collectively yield a group; and reciprocally.

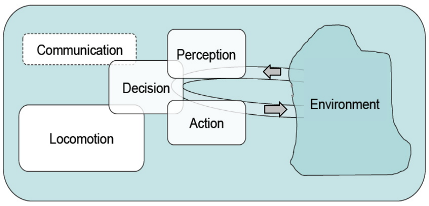
2.D. MCS theory for cognition 4 of 6

«*Embodiment*»

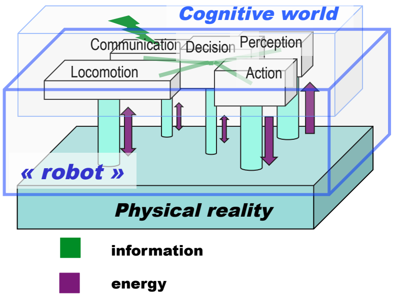


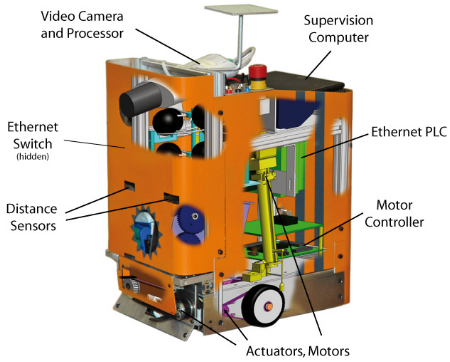
2.D. MCS theory for cognition 5 of 6

Embodiment .....



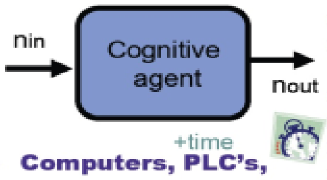

```
11:  SleepAGN(0.05);                                    brea
12:  if(!SignalIn(NSIStart))
       GoState(6);
       else
        GoState(20);                                    brea
 20:  DemarrerMatchAGN();                  // start 90 s tin
                                                        brea
 21:  SignalOutAGN(NSOAspirateur, true) ;  // start n
                                                        brea
 22:  SignalOutAGN(NSORouleauIN, true) ; // start mo
                                                        brea
 23 : ApproAGN(HoleNb1, 15);                           brea
```





2.D. MCS theory for cognition 6 of 6

- **Sense and perceive!**
  - **Switches**
  - **Microphones and receivers**
  - **Color camera**
  - **« 3D » camera**
  - **Thermal camera**
  - **Planar rangers**
  - **US sensors**
  - **Tactile surfaces**
  - **Force and Torque sensors**
  - **Position encoders**
  - **Etc.**
- **Think,**
  - **Understand, decide, plan, design, etc.!**



  - **Computers, PLC's, FPGA's, Specialized devices and circuits, distributed architecture**
- **Act**
  - **incl. move, communicate!**
  - **Loudspeakers and transmitters**
  - **Color display**
  - **Stepper and DC motors**
  - **Locomotion devices**
  - **Grasping tools**
  - **Manipulator arms**
  - **Lights and numerous actuators**
  - **Etc.**

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Fig. Smart systems sense, perceive, think and act. The cognitive components of these processes typically relate to large amounts of information (>> 1 Mb), in high speed (up to 10^7 [1/s] and more).

Content

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3. Piaget

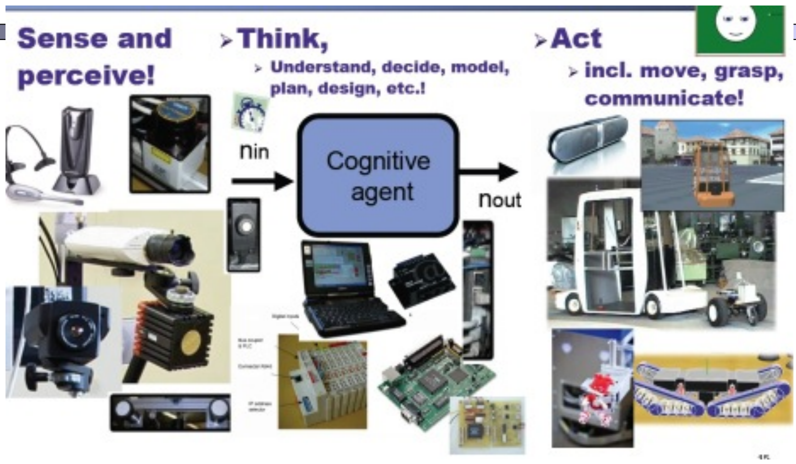

Fig. Smart cognitive systems sense, perceive, think and act. This relies on a variety of powerful components to flexibly integrate, (re-)configure and operate. Therefore, Piaget!

3. Piaget

A. Core aspects
- A.1 Parallelism, real-time, and "open" resources.
- A.2 Piaget and VAL
- A.3 Hardware support

B. Aspects of particular interest
- B1. Simulation capabilities
- B.2. Interactive actions and language interpreter
- B.3. Four levels of programming techniques "plus".
- B.4. Multiple degrees of inter-cooperation performance.
- B.5. Test instruction and Test task
- B.6. Examples of application – Piaget for Cognitics

3. Piaget

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3.A.1 Parallelism, real-time, and "open" resources 1 of 6

- Computers, standard products in electronics, precision engineering and microtechnology well developed.
- Crucial missing component though:
  - application-oriented environment, with parallelism and real-time capabilities,
  - very open possibilities for integration with numerous, heterogeneous, products and services.
- Therefore we created Piaget.
- Other approaches with similar goal: ROS, Microsoft Robotics (Developer) Studio, URBI, Webots [7], or many proprietary solutions developed by SME's.
- For our types of applications, Piaget is still unmatched.

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3.A.1 Parallelism, real-time, and "open" resources 2 of 6

- multitask kernel : switching contexts in ordinary memory ("minimal use of stacks and registers", re. progress in cache-memory and improved compilation).
- Piaget instructions :
  - numbered
  - metalevel program counter defined for each task
  - typically realized as a switch paradigm.
  - possible "AGN" suffix: for the next allocated time slot, the program proceeds at the next numbered Piaget instruction

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3.A.1 Parallelism, real-time, and "open" resources 3 of 6

Fig. Example of instructions in Piaget language

```
.....
 11:  SleepAGN(0.05);                          break; case
 12:  if(!SignalIn(NSIStart))
        GoState(6);
        else
        GoState(20);                           break; case
 20:  DemarrerMatchAGN();              // start 90 s timer etc.
                                               break; case
 21:  SignalOutAGN(NSOAspirateur, true) ;  // start motor vacuum
                                               break; case
 22:  SignalOutAGN(NSORouleauIN, true) ; // start motor brush
                                               break; case
 23 : ApproAGN(HoleNb1, 15);                   break; case
 24:  MoveAGN(HoleNb1);                        break; case
 25:  MoveAGN(Trans(173,90,-90));              break; case
 26:  ObserverLigneAGN(NL, NCStart, NCStop)  //  Visual analysis of a row
      if (N2Jaune>0)              // totems are yellow; balls are white
          {PositionTotemOuBalle[1].TypePosition=Totem;
          nbTotem = nbTotem+1;}
          else
          PositionTotemOuBalle[1].TypePosition=Balle;
                                               break;  case
 27:  ...
```


3.A.1 Parallelism, real-time, and "open" resources 4 of 6

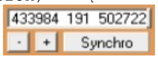
- **Typical use of about 20 parallel agents,**
- **In average, each task is run in 100 nanosecond long individual, respective time chunks.**
- **Piaget task switching performed many thousand times more often than with the standard threading tools of typical operating systems (e.g. Windows)**

3.A.1 Parallelism, real-time, and "open" resources 5 of 6

Control kept in kernel loop for thousands of iterations before returning to operating system.

Here the loop was visited 502' 272 per second, as estimated on a 191 second basis

```
while (! DesiredInteraction)      {
```




```
  Ticks+=1;        //
  //Task01();      // Music
  Task02();        // Move one step
  Task03();        // Read keyboard
  Task04();        // Perform point to point wheel
                           // motion
  Task05();        // Define strategy (typical user
                           //   programming context)
  Task06();        // Update Inputs/Outputs
  Task07();        // Display real and simulated
status
                           //   and current
configuration
  Task08();        // Compute inverse kinematics and
                           //   spatial motions
  Task09();        // Flash control LED
  Task10();        // Analyze images
  Task11();        // Manage reflex or USB
servocontroller
  //Task12();      // Manage ball operations (pick,
                           //  store and shoot)
  //Task13();      // Test inputs
  Task14();        // Communicate
  Task15();        // Manage ranger perception
  Task18();        // Interpret "Piaget" primitives
  Task19();        // Manage voice dictation
  Task20();        // Manage dialogue
  Task21();}       // Manage maps
```


3.A.1 Parallelism, real-time, and "open" resources 6 of 6

- **In our terminology:**
  - **task code when running on the computer is knowledge**
  - **the system becomes the cognitive agent.**
- **A "TicksPerSecond" parameter plays a key role**
  - **for fast event timing in Piaget (about microseconds)**
  - **can be adjusted manually, or automatically synchronized on the basis of experience.**

3.A.2 Piaget and VAL 1 of 3

The Piaget language includes

- **very specific, application-oriented instructions, (e.g."ChooseTheBridgeVisually" instruction).**
- **a subset of the excellent VAL language for robotics. Therefore two main advantages:**
  1. **VAL : general view at robotic and automation level (e.g. "Signal i" instruction): useful for the early phases.**
  2. **This paves the way to a common standard for novel, mobile agents and classical, industrial robots**

Piaget supports

- **direct and inverse kinematics**
- **extensive support for transformation and frame ancillary computations (in matrix form and homogeneous coordinates)**

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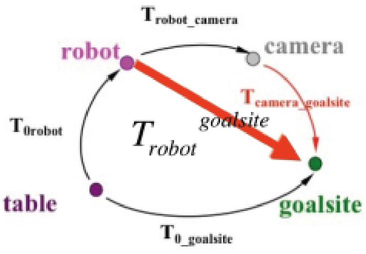
3.A.2 Piaget and VAL 2 of 3

The



$$T_{robot}^{goalsite} = T_{robot}^{camera} \cdot T_{camera}^{goalsite}$$

Robot applications require extensive location, frame and trajectory computations.

Piaget supports transformation graphs reasoning and homogeneous matrices computations

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3.A.2 Piaget and VAL 3 of 3

Motion control is typically hierarchized in three levels:
programming,
coordination and
joint control,
with elementary cycle speed respectively situated at about 500, 15, and 0.5 milliseconds.

The Piaget "CallAGN(number)" particularly important: allows for parallelism, and stepping for debugging purpose in the single, strategy agent of major interest.

3.A.3. Hardware support 1 of 4

Our Piaget environment has been operational in three main configurations.

1. **Initially, a PC-base with parallel port capabilities was used, under DOS or Windows OS, for its large basis of compatible products and services, protocols and drivers.**
2. **Then a Piaget-light version has been implemented on a tiny integrated PC (Beck IPC) with an additional, proprietary FPGA, for encoder management and PWM motor control, under constraints of small volume availability [11].**

3.A.3. Hardware support 2 of 4

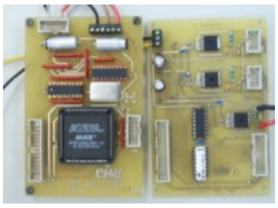
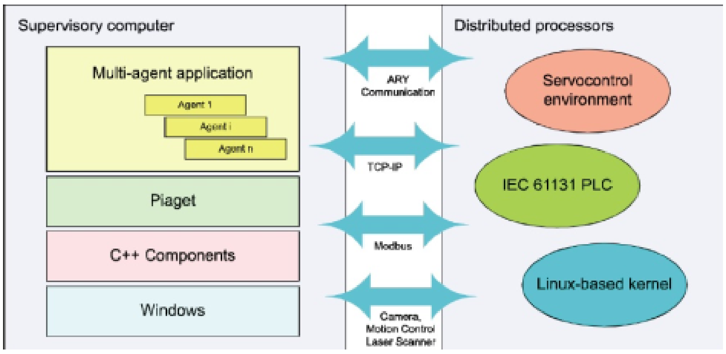


Fig. Integrated PC and FPGA for Piaget-light implementation in small volume robots [11].

3.A.3. Hardware support 3 of 4

3. **Now Piaget is typically running on an heterogeneous system including powerful components in principle interconnected with Ethernet and TCP-IP capabilities; or USB mode.**
   - **At supervisory level, a PC in Windows context is the rule, still for reasons of compatibility with complementary existing resources.**
   - **Closer to physical action, specialized components such as**
     - **motioncontrollers, PLC, cameras, rangers provide their own information processing resources, with power and robustness, in their own environment**

3.A.3. Hardware support 4 of 4



- high cognitive and action requirements of complex applications in real world =>great sophistication of structures
- contingent heterogeneity of resources, communication channels, and protocols

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3. Piaget

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3.B.1. Simulation capabilities in Piaget
1 of 4

- **Extensive simulation capabilities,**
  - **globally, or by segments**
  - **things are simpler**
  - **easily replicated,**
  - **more robust,**
  - **precious in some development phases.**
- **Nevertheless, can, when the corresponding physical resources are available, be turned operational in the real world.**
- **In-situ automata are no alternatives**
  - **past and future must be considered,**
  - **if-worlds**
  - **ubiquitous presence**
  - **accounting of non-physical dimensions.**

3.B.1. Simulation capabilities in Piaget
2 of 4

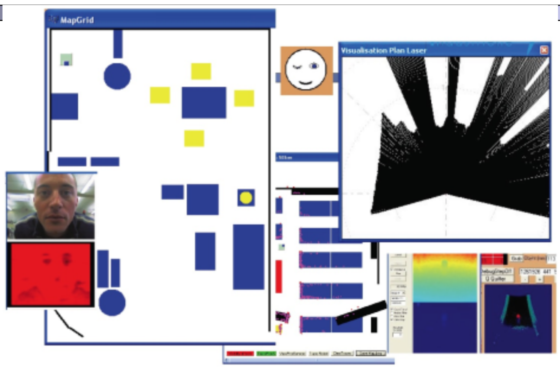
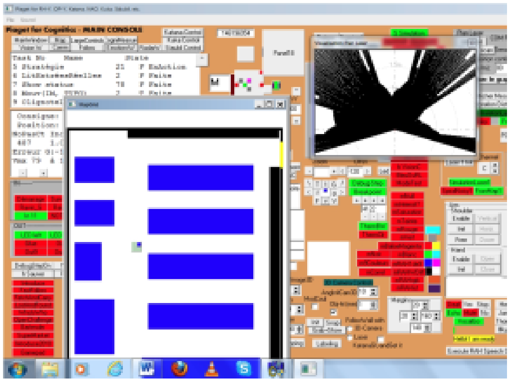


Fig. 13. Piaget includes numerous possibilities in simulation mode.
- **5 pictures when the camera is not online**
- **noisy spirals are generated for virtual rangers,**
- **maps for motion analysis,perception in virtual world**

3.B.1. Simulation capabilities in Piaget
3 of 4



Example: ranger data computed from virtual robot motions and objects represented in the map

3.B.1. Simulation capabilities in Piaget
4 of 4

Piaget environment brings uncomparable advantages:

- ***alternative*** **to direct access to reality**
- **also for complementing techniques, *augmented reality*.**

For Piaget, simulation possibilities keep being developed

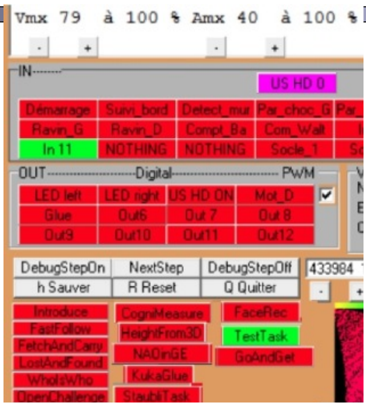
- **with focus on results,**
- **i.e. when and only when it is expected to bring more effective and efficient results in real-world target application.**

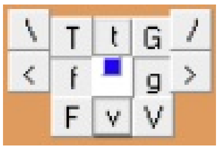
3.B.2. Interactive actions and language interpreter in Piaget 1 of 3

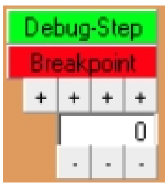
Our Piaget environment:

- **Extensive interactive control capabilities,**
  - **under the responsibility of programmers, when programs are written.**
  - **also, often by hitting a single key or clicking the mouse,**
- **Can be turned operational, autonomous and possibly cooperative in the real world**

3.B.2. Interactive actions and language interpreter in Piaget 2 of 3







- **Many actions ordered by hitting a single key (e.g. "h") or clicking on a button or panel.**
- **Program can be debugged with Piaget steps and breakpoints on Piaget instructions.**

3.B.2. Interactive actions and language interpreter in Piaget 3 of 3

- **Hundreds of immediate actions**
- **Possibility of storing the current configuration**
- **Controls are interpreted in real-time**
- **Can also be referenced in pre-compiled programs**

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3.B.3. Four levels of programming techniques in Piaget. And more.

Programming modes in 4 levels of increasing complexities:

1. ***interactive* mode**
2. **application-oriented Piaget language;**
   - **allows typical users to express novel strategies,**
   - **optionally allows users to integrate commands of the implementation language (i.e. from case to case, C#, C++, C or Pascal).**
   - **all controls interactively practiced at level 0 can be reused as instructions in level 1.**
3. **adding or removing specific parallel agents**
4. **developing and implementing Piaget language and environment, in standard contexts (implementation language, OS, computers, sub-systems)**

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3.B.4. Multiple degrees of inter-cooperation performance in Piaget 1 of 2

Piaget schematically allows for five degrees of synchronicity:

1. ***Multitask kernel*. Fastest cycle of coordination, in average about 2 microsecond (µs) for synchronizing Piaget agents.**
2. ***Implementation OS level*. Typical changes in 10 ms periods or more.**
3. ***Shared local files*. For different programs on the supervisory computer; cycles probably better, i.e. shorter, than 50 ms.**
4. ***Transfers via TCP-IP or USB*. With peripheral resources such as smart sensors, other computers, or robots delays on the order of 0.1 second.**
5. ***Application-level loops*.**

For our typical applications:

- **cooperating robots in domestic environment, or**
- **industrial robots exploring complex situations,**

Typical processes:

- **physical exploration,**
- **visual-gestures**
- **possibly vocal dialogues**

May last for a time span on the order of 1 to 10 seconds, or even more.

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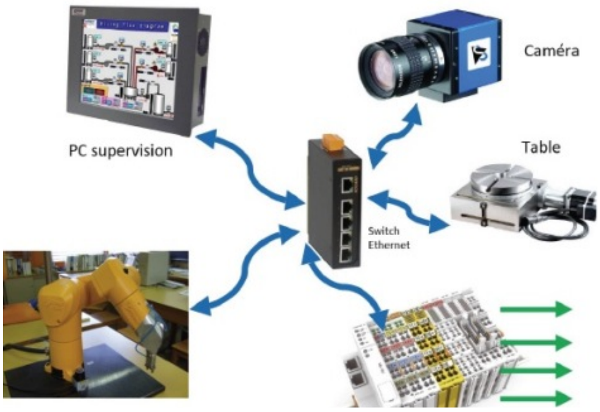
3.B.4. Multiple degrees of inter-cooperation performance in Piaget 2 of 2



Communication between main components in Piaget environment typically relies on TCP/IP and/or USB; here via a hub (or switch).

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3.B.5. Test instruction and task in Piaget 1 of 2

Programming can be performed gradually in terms of complexity.

1. **a single instruction located in "900".**
   Typical applications
   - **start with a preparation phase in the strategy task;**
   - **undergo an application-dependent launching phase :**
     - **real boolean input,**
     - **simulated input ("D" key or similar click),**
     - **vocal command ("Go", "Yes", etc.;**
     - **clicking or speaking in robot's microphone.);**
     - **"*ModeTest*" control to launch the code in area 900.**
   - **Deploy as programmed and adapting to circumstances**
2. **a few instructions. Code can be expanded as several instructions from the same 900 address.**

3.B.5. Test instruction and task in Piaget 2 of 2

3. **An application "*TestTask*" is available, as a simple programming example that can be freely modified for new users to acquire experience (re. so-called "sandbox" in other contexts).**
4. **Typically, at this point a user is ready to create a specific application, e.g. a test in Robocup@Home context or an industrial task in manufacturing.**
5. **Experience accumulating, expertise also increases and programming becomes more sophisticated, e.g. including the definition of novel elements in Piaget-implementing context (C ++, C#, etc.).**

3.B.6. Examples of application – Piaget for Cognitics 1 of 13

Consider 5 examples of Piaget applications, in automated cognition, in cognitics

First three , re. successive areas of Piaget:

Eurobot, Robocup@Home, and industrial robotics;

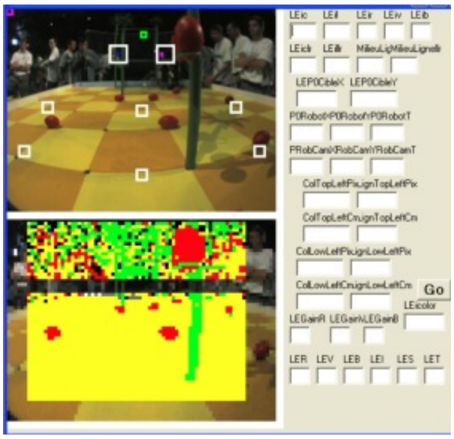
Next two :

robust vision techniques and quantitative cognitics.

1. Piaget was concretely created for Eurobot competitions.

- **In "Coconut-rugby", sets of 2 robots had 1.5 minute to defeat an opponent robot set :**
  - **catch coconuts,**
  - **bring or throw them in opposite net or blue "essai" zone,**
  - **block own goalsite,**
  - **possibly retrieve balls scored by the opponent.**
- **One typical skill :**
  - **visually locating coconut trees and coconuts**
  - **capabilities: fast (0.1 s) perception of 9 robust colors, recognition of coconuts and trees, coordinate transform from picture to the field**

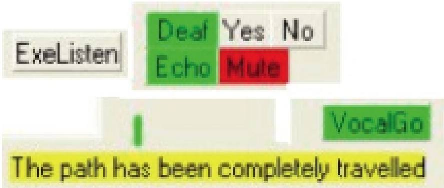
3.B.6. Examples of application – Piaget for Cognitics 2 of 13



Skilled capabilities include the fast perception of robust colors and recognition of objects, as well as coordinate transforms from picture onto field.

3.B.6. Examples of application – Piaget for Cognitics 3 of 13

2. Moving to Robocup@Home : more complexity. For ex. vocal and dialogue management as typically supported in Piaget, as well as a vision-based face recognition



Piaget panels and text-typed fields illustrate typical vocal items: yes/ no can simulate microphone inputs; recognized commands are shown in green (here " ") and synthetized text in yellow.

A face is recognized for "Who is Who" test

3.B.6. Examples of application – Piaget for Cognitics 4 of 13

Advanced tests in terms of cognitive and human robot interaction capabilities have been demonstrated in Robocup@Home world competitions, e.g. :

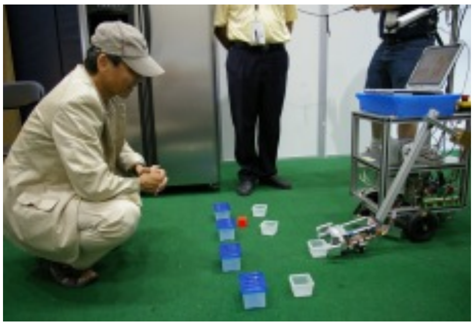
"CopyCat": programming by showing

"FastFollow": leading a robot in new homes just by walking

"Walk'nTalk": training a robot in new homes just by walking and defining vocally key objects or locations

"OpenChallenge": in Singapore our robotic group included three coordinated robots, and in particular a humanoid for the purpose of mediation between human and machines, re. http://rahe.populus.ch and YouTube

3.B.6. Examples of application – Piaget for Cognitics 5 of 13



CopyCat - Our RH-Y robot visually analyzes and replicates each of the object displacements manually performed by President Asada.

FastFollow - RH-Y moves fast, following its guide, crossing another team, and completing first the imposed visit of a home.

3.B.6. Examples of application – Piaget for Cognitics 6 of 13

- **Human and robots share their representations**

- **On the left, the robot follows first the human, and then they vocally synchronize their respective English names for describing specific locations, such as the plant in the living room (*"Walk'nTalk"*, *Graz, Austria*).**
- **On the right, Nono-Y, our Nao-typed humanoid mediates humans and other machines (OP-Y platform where Nono-Y sits; and RH-Y robot, which has brought drinks and snacks) (*"Open Challenge"*, *Singapore*)**

3. B.6. Examples of application : Piaget for Cognitics 6b de 13

- **Robots for help at Home**
  - **Example: RH-Y at Robocup@Home (2009, *in Graz, Austria*).**
  - **RockIn (EU, 2013-2016)**

2009, RH-Y in Austria, Robocup@Home

2013

3.B.6. Examples of application – Piaget for Cognitics 7 of 13

3. Industrial applications can also been driven by Piaget .

In two cases, the robot arms are driven, at elementary, lowest level, by manufacturers' controllers (incl. KRL for Kuka; Val3 for Stäubli) and, at higher levels, by a program developed in Piaget environment and expressed in Piaget language

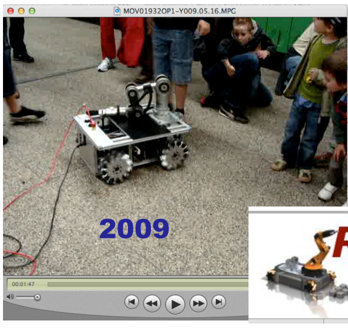
3.B.6. Examples of application – Piaget for Cognitics 7b of 13

(Industrial applications in mobile robotics – gaining momentum)

-2009, OP-Y and Katana, at Yverdon-les-Bains and at the "Festival de robotique" (Lausanne)

- cf. Robocup@Work with Kuka standard resources , 2012-currently, (+omniMove and Moiros 2013).

2009



2009

2013

RoboCup @Work

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3.B.6. Examples of application – Piaget for Cognitics 8 of 13

"Chip count and accuracy test": Application mostly developed and programmed in Piaget, including a Stäubli industrial robot arm, and other resources: optical fiber, PLC, camera, motorized rotating table, servocontroller, Ethernet switch, PC and other components yet.

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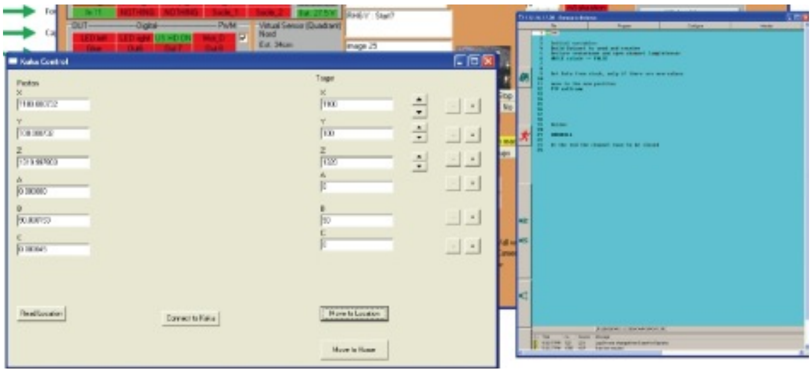
3.B.6. Examples of application – Piaget for Cognitics 9 of 13



Three windows relating to an industrial application involving a Kuka robot (The first two belong to Piaget environment; the third one is a remote desktop linked to Kuka controller)

3.B.6. Examples of application – Piaget for Cognitics 10 of 13

4. Piaget supports fast and robust vision, in many modes

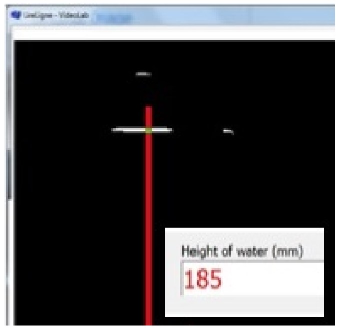
(infrared/BW, color, thermal cameras, 3D-time of flight, RGB-D sensors; various processes)

In the first year edition already (Eurobot context), it could acquire and process 300 pictures per second to locate opponent's robot in real-time.

Example illustrates a key paradigm by which , care is first taken to analyze applications in full physical space (here "capillarity" is the most discriminating dimension) then appropriately mapping them into common light domain and processing them specifically.

3.B.6. Examples of application – Piaget for Cognitics 11 of 13

Example: quality control of liquid/water level



Piaget discourages naïve vision, supporting goal-oriented image acquisition, processing and analysis.

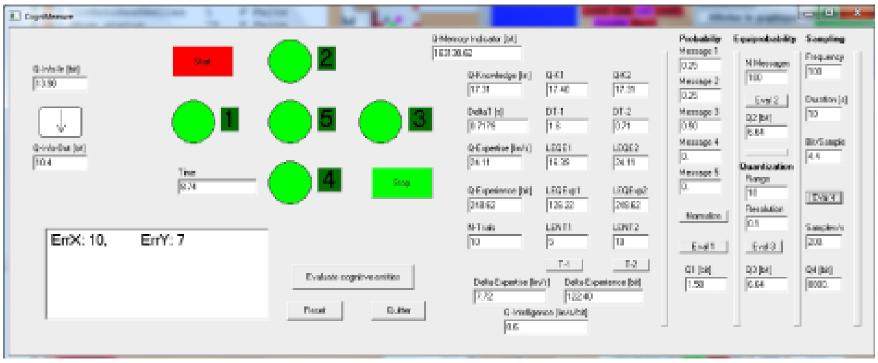
Visual, fast real-time, robust quality control of liquid/water level.

3.B.6. Examples of application – Piaget for Cognitics 12 of 13

5. A particular interest of Piaget environment is to provide a tool for convenient, quantitative estimation of core cognitive properties:

- **knowledge, expertise, experience, speed/fluency, intelligence, as well as low-level ingredients:**
  - **probability calculus, quantization, sampling rate, input and output information signals and quantities,**
- **all this along with an interactive example**

3.B.6. Examples of application – Piaget for Cognitics 13 of 13



Piaget environment includes a form for the quantitative estimation of cognitive properties in general, along with a specific example: learning how to accurately and quickly click in the center of 4 green targets.

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Content

1. **Introduction**
2. **Requirements and theoretical aspects of intelligent control**
3. **Piaget**
4. **Conclusion**

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4. Conclusion 1 of 4

- Scientific and technical progress now reaches cognition.
- Our first stage in the exploration of cognition has been to define concepts formally and to develop metrics.
- The second stage has been
  - to select an architecture and
  - to develop an environment for the real-time, real-world control of complex systems,
- With the goal of addressing the most advanced applications in terms of automation and cognitive, human-related tasks.

4. Conclusion 2 of 4

All this has been done with the following concern

- keep connected to world-level expertise and international best practices, for all aspects,
  - from the boundaries of scientific and human theories
  - to the ones of the market, as involving commercial components and services.

4. Conclusion 3 of 4

- Wall crossing? re. metric height.
- Similarly, metric assertion of cognitive aspects (complexity, knowledge, expertise, etc.)

Besides,

- conference attendance and state of the art monitoring bring useful new information.
- the methodology of realizing real-world systems allows for concretely implementing proposed theories
- and leads to actual competitions, thus encouraging active interaction with international experts.

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4. Conclusion 4 of 4

- Our "MCS" framework => quantitative assessment of cognitive tasks,
  - both as required or as operated
  - both by humans and by machines.
- Our "Piaget" environment ensures,
  - the convenient control of mobile robots,
  - "naturally" cooperating with humans,
  - and the integrated control of Kuka and Staubli industrial robots
  - along with numerous other integrated resources

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Thanks for your attention!

Slides on website: http://lara.populus.org/rub/3

More text in comment fields

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  - **numerous engineers and students,**
  - **visiting interns,**
  - **funding partners,**
  - **and members of technical services at HEIG-VD**

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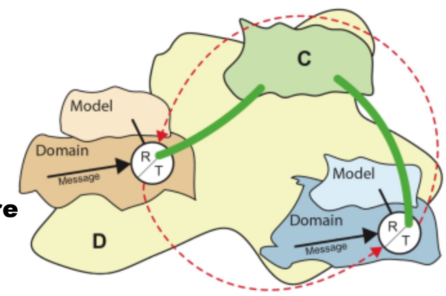
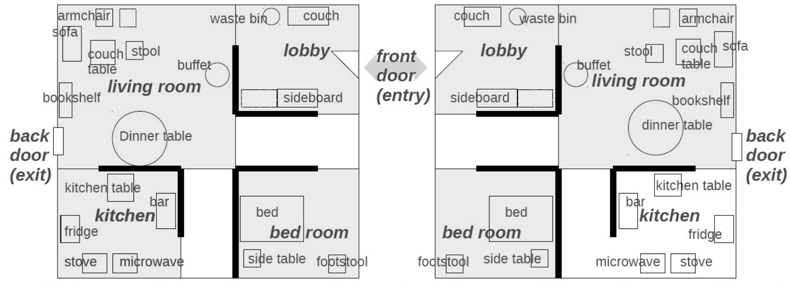
Appendix 1 – « Robot sociology »

Group.

- **Individual cognitive agents (blue, brown) may coordinate each other, and thus may collectively form a group.**
- **For this purpose,**
  - **a common culture (C, green),**
  - **in reference to some common domain of interest (D, yellow) and**
  - **some communication media are required among agents (R: receive; T: transmit).**
- **At a meta-level, the individual members may be considered as merging, to yield a new individual (the group) with its own collective model (C). (From [6])**



Appendix 2 « Standard »



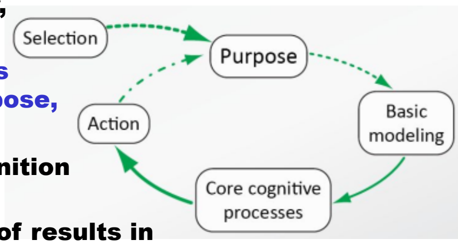
[12]

#	location	category	manipulation in GPSR	category placing
1	sofa	seat	no	
2	couch table	table	yes	
3	armchair	seat	no	
4	stool	seat	no	
5	dinner table	table	yes	
6	bookshelf	shelf	yes (2nd height)	
7	buffet	shelf	yes	
8	fridge	appliance	yes	
9	stove	appliance	no	
10	microwave	appliance	yes (table)	

#	location	category	manipulation in GPSR	category placing
11	kitchen table	table	yes	food
12	bar	shelf	yes	drinks
13	couch	seat	no	
14	sideboard	shelf	yes	snacks
15	wastebed	seat	yes	
16	side table	table	yes	
17	waste bin	bin	yes (placing)	unkown
18	bed	seat	yes	bath stuff
19	side table	table	yes	
20	footstool	seat	no	

Appendix 3 « Purpose-driven modeling »

- **From a cognitic perspective, the strong modeling limit illustrated previously, calls for a pragmatic process**
  - **the complexity of reality requires first the selection of a goal (purpose, ethics)**
  - **only then, can modeling and cognition proceed**
  - **finally, the symmetric necessity of results in the real world requires action (operability, agency), for example by robots**
    - **cognitive results must be put to work, with energy etc.,**
    - **thereby closing of the loop (iteration, and ultimately, in general, survival); from [3].**



Abstract

Scientific and technical progresses now reach cognitive domains. Current industrial robots face new challenges, in terms of cognitive capabilities. The first stage in the exploration of cognition has been to define concepts clearly and to develop metrics. The second stage has been to select an architecture and to develop an environment for the real-time, real-world control of complex systems, capable of addressing the most advanced applications in terms of automation and cognitive, human-related tasks; with the concern of keeping connected to world-level expertise and international best practices.

Consider jumping over a wall: the metric height of the wall is a critical parameter for success. Similarly, the novel possibility of metric assertion of cognitive aspects (complexity, knowledge, expertise, etc.) is very useful. Our developed, comprehensive framework "MCS" now allows for the quantitative assessment of cognitive tasks, both as required or as operated by humans and machines.

The proprietary environment "Piaget" has been created, proving to ensure, initially, the convenient control of mobile robots, then "naturally" cooperating with humans. Implemented in different languages (C, C#, C++), with different Operating Systems (incl. RTDOS and Windows) and platforms, "Piaget" has now been successfully added Kuka and Stäubli industrial robots to its numerous integrated resources.