Reasoning for RoboCup

Non-Monotonic Reasoning for Localization in RoboCup

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Outline

- Reasoning and Localization
- Why reasoning and modelling with logic
  - The Software Engineering justification
  - The Hybrid Intelligent Agent justification
- Running reasoning on a AIBO ERS-7
- Model Development and Results
- Conclusion

Reasoning for RoboCup

Reasoning

- Deriving conclusions from facts
  - Apparently, a fundamental characteristic of intelligence
- An expected aspect of intelligent systems
- Withdrawing conclusions in the light of new evidence is a capability usually referred to as non-monotonic reasoning

Our environment

- RoboCup
  - A test-bed for Multi-Agent Systems
  - We know our environment, so one would expect to be able to construct a knowledge base and apply reasoning

RoboCup environment is hard

- Non-deterministic
  - I can not predict the state of the environment after I perform an action
- Not accessible
  - I can not sense all elements of the environment
- Dynamic
  - Environment changes while I decide what action to take
- Teams
  - I need to negotiate, collaborate, distribute tasks and goals
- Adversaries
  - Of unknown capabilities

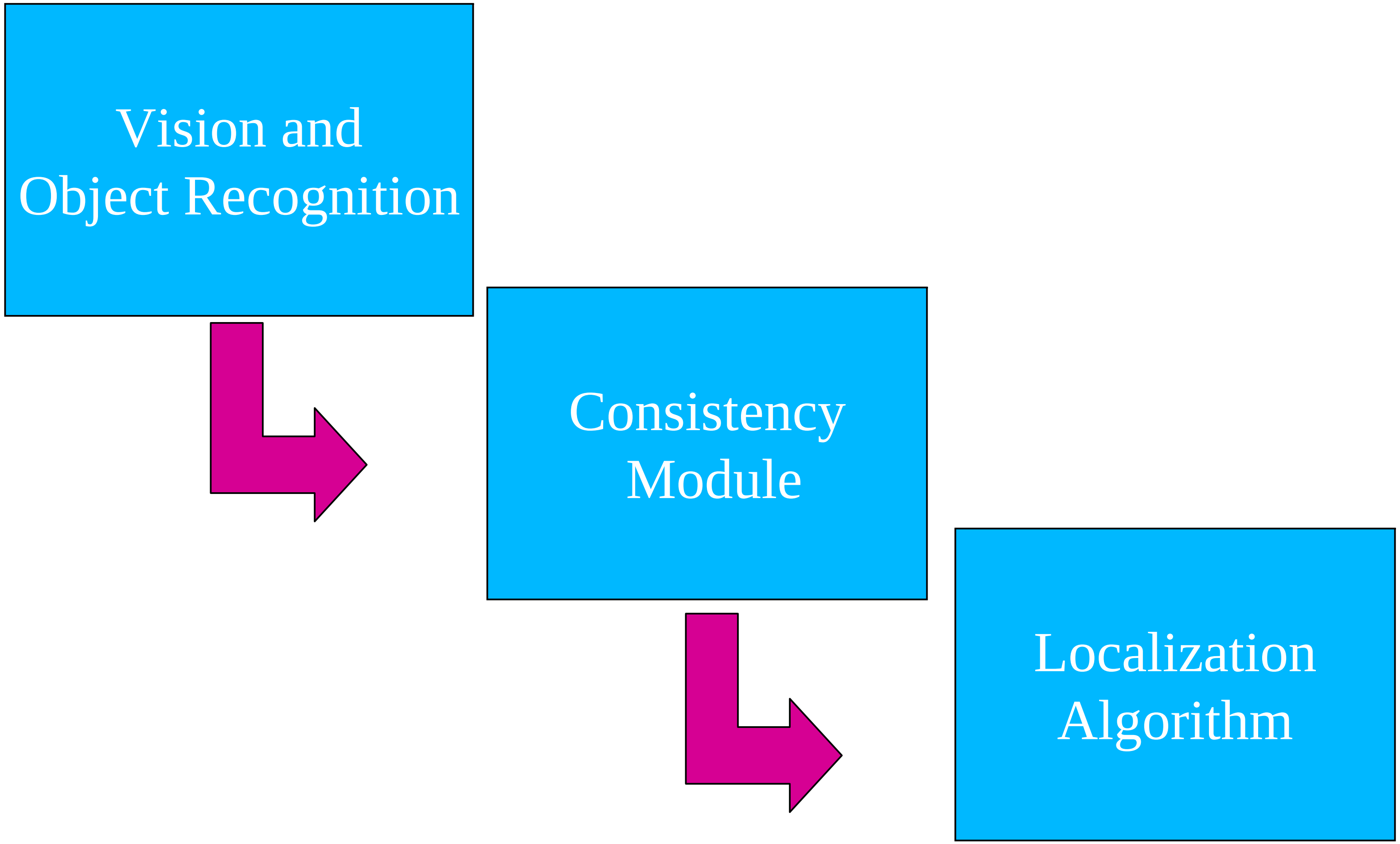
We demonstrate reasoning within the task of localization

- Dynamically selecting proper inputs for localization
  - The classical example in RoboCup for the Aibo league is that
    - A frame where both goals are visible indicates something wrong with the object recognition task

Possible solutions

- Introduce sanity checks
  - Filter out the frame if both goals are visible
- Pass it out to localization and expect the sophistication of the algorithm (capacity to handle error in sensor input) to handle these cases
  - Kalman Filter
  - Markov Localization
  - Monte-Carlo localization

Our approach



Our approach

Consistency
Module

Non-monotonic logic that combines facts known about the environment with what is reported as visible in this frame

Why non-monotonic logic

- To reason about the inconsistent information provided by the sensors (vision)
- Without reasoning, all localization methods must determine
  - *Prob*(visible scene | position)

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Problem with localization methods

- Illustration
- *Prob* (front goal visible & back goal visible | position) =0
  - Not the best answer, or defines a large set of special cases
  - It is hard to express it as function of

  Prob (front goal visible | position)

  and

  Prob (front goal visible | position)

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Plausible logic

- Only non-monotonic logic with an efficient non-looping algorithm
- Can prove using factual information and also plausible information
- 3 types of rules
  - $A \rightarrow l$ (factual information)
    - $Human(x) \rightarrow Mammal(x)$ [All humans are mammals]
  - $B \Rightarrow f$ (plausible situations)
    - $Bird(x) \Rightarrow Fly(x)$ [Birds usually fly]
  - $A \leadsto \neg l$
    - $\{sick(x), Bird(x)\} \leadsto Fly(x)$ [Sick birds may not fly]

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Plausible logic (cont)

- Rules are in an acyclic hierarchy
  - $R_i > R_j$
    - Rule *i* is more informative that rule *j*.
- Conclusion with one rule may be defeated by the more informative rule

Why reasoning and modelling with logic

- The Software Engineering justification
  - All the ``intelligence'' (logic) about what makes sense in an image (or sequence of images) is properly encapsulated in a human understandable logic
    - Not a a series of "if ..then …else" statements of C++ in the code
    - Can test completeness and correctness
    - Can be updated easily
- The Hybrid Intelligent Agent justification
  - A higher level description that allows reasoning

Illustration

- Naturally to develop rules systems where the new rules redefine exception to the previous ones
  - 3 laws
    1. A robot may not harm a human
    2. A robot must obey a human unless it contradict law 1
    3. A robot must protect itself unless contradicts rule 1 or 2
  - Ripple down rules
    - Rules are defined and new rules are subsequently added to revise the cases not covered by the more general rules
    - A tree that is a hierarchy of rules
      - No formal reasoning

Modelling with standard logic

- A first model

$$\{See(x)\} \cup \{\neg See\{y\} : y \in Landmarks\text{-}\{x\}\} \rightarrow Cs(x)$$

  - If I only see one object, then it is consistent

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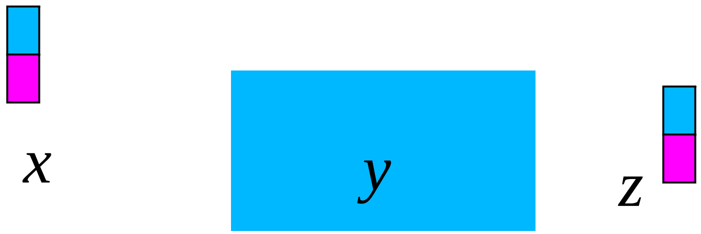
Modelling with standard logic

- A second model

$C(x,y)=\{See(x),See(y)\} \cup \{\neg See\{z\} : z \in Landmarks\text{-}\{x,y\}\}$

1. $\{SeeLtoR(x,y),FactLtoR(x,y,z)\} \cup C(x,y) \rightarrow Cs(x,y)$
2. $\{SeeLtoR(y,x),FactLtoR(x,y,z)\} \cup C(x,y) \rightarrow Cs1(x,y)$
3. $\{Cs1(x,y),Post(x),Goal(y)\} \rightarrow Cs(x)$
4. $\{Cs1(x,y),Post(x),Post(y),BigSmall(x,y)\} \rightarrow Cs(x)$



The world

Reasoning for RoboCup

Modelling with standard logic

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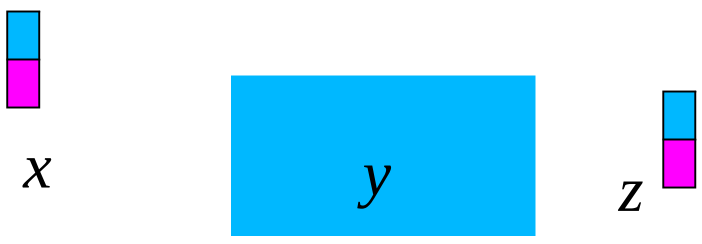

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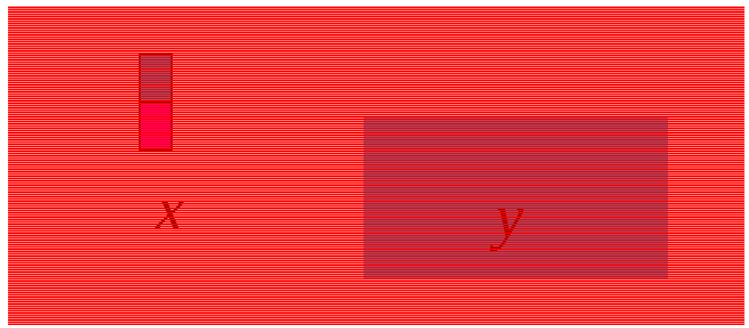

Vision

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Modelling with standard logic

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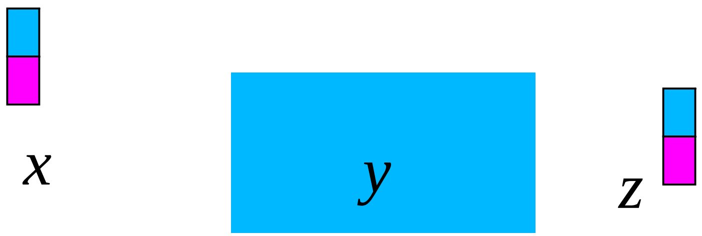

The world

Vision

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Modelling with standard logic

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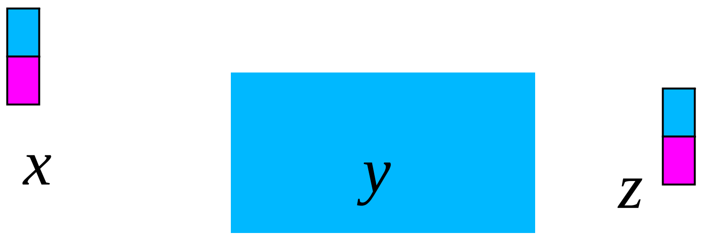

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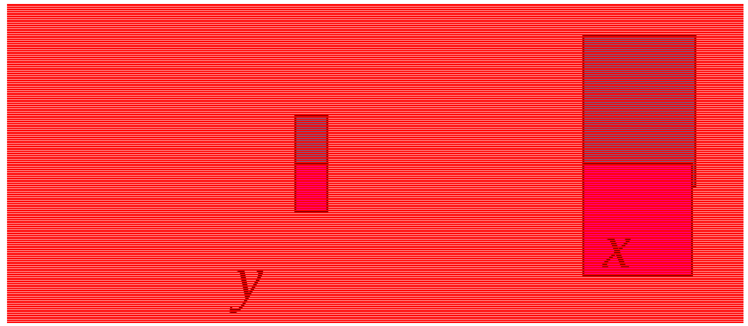

Vision

Problems with standard logic

- Rapidly we have the same situation
  - Many different cases coded essentially independently
    - Seeing exactly 3 objects need 26 rules
    - Seeing exactly 4 objects needs 120 rules
  - Proves most C++ is incomplete
    - (and perhaps inconsistent)
    - Survives because of the frame rate
    - Concerns on correctness/reliability of intelligent systems

Implementing Plausible Logic on SONY Aibo

- Besides Plausible Logic we develop a Logic Programming Language - DPL
  - Create definitions, macros, determine what to prove
- A HASKELL implementation of the inference algorithm of plausible logic
  - A program in DPL that proves off-line
    - Finds the equivalent logic expression to Cs(Front goal) in terms of World predicates and Test predicates
- A simulator for validation of-line and gluing code
- A Template method in the consistency module on the Aibo

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Model 1

- `R1:   => ~Cs(x).`
- `R2: See(x) => Cs(x).`
- `R2>R1.`

- Validates the system and implementation process

Model 2

- R1: => ~Cs(x).
- R2: See(x) => Cs(x).
- R2>R1.
- R3: {See(x),See(y),Opp(x,y) => ~Cs(x).
- R3>R2
- R4: {See(x),See(y),SeeLtoR(y,x),LR(x,y)} =>~Cs(x)
- R4:{See(x),See(y),SeeLtoT(y,x),LR(x,y)=>~cs(y)
- R4>R2

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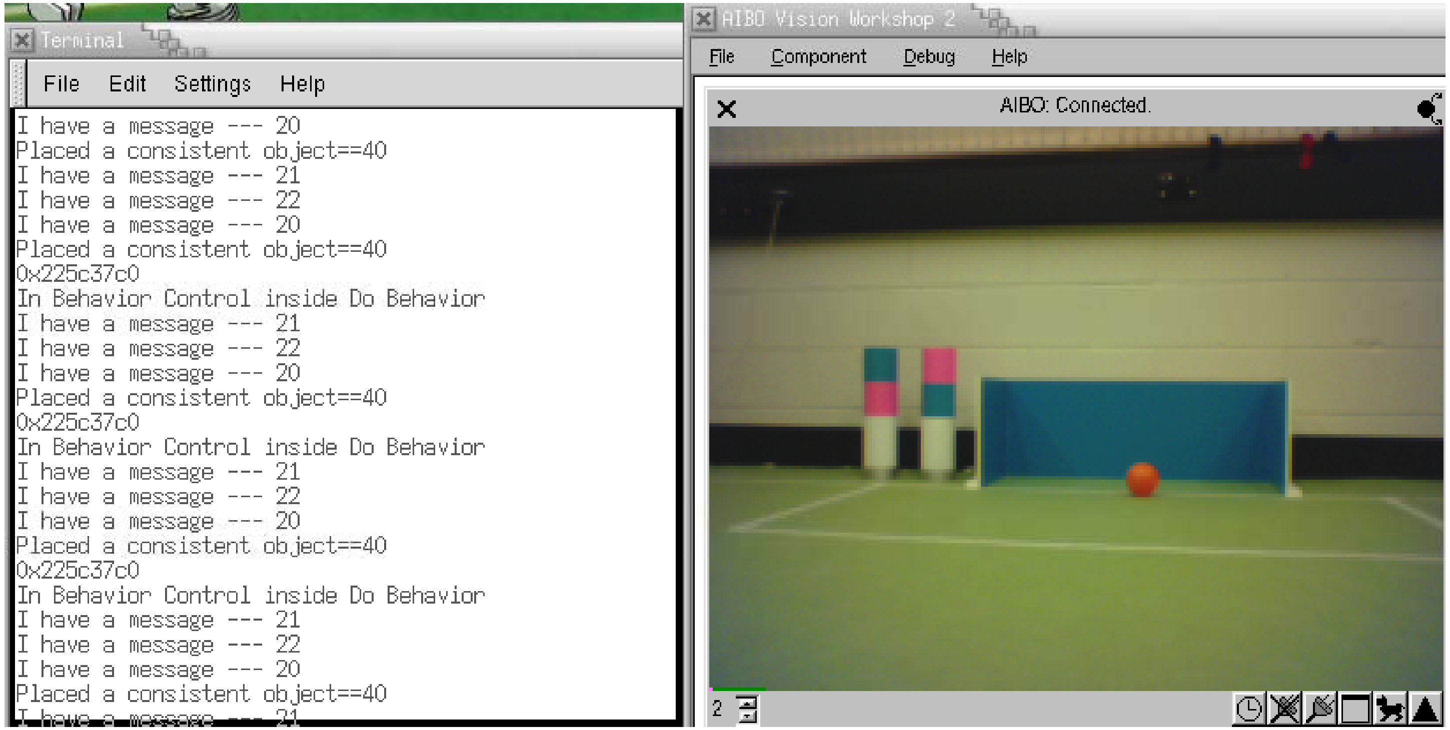
Illustration



The left post is correct but the right post and goal are inverted

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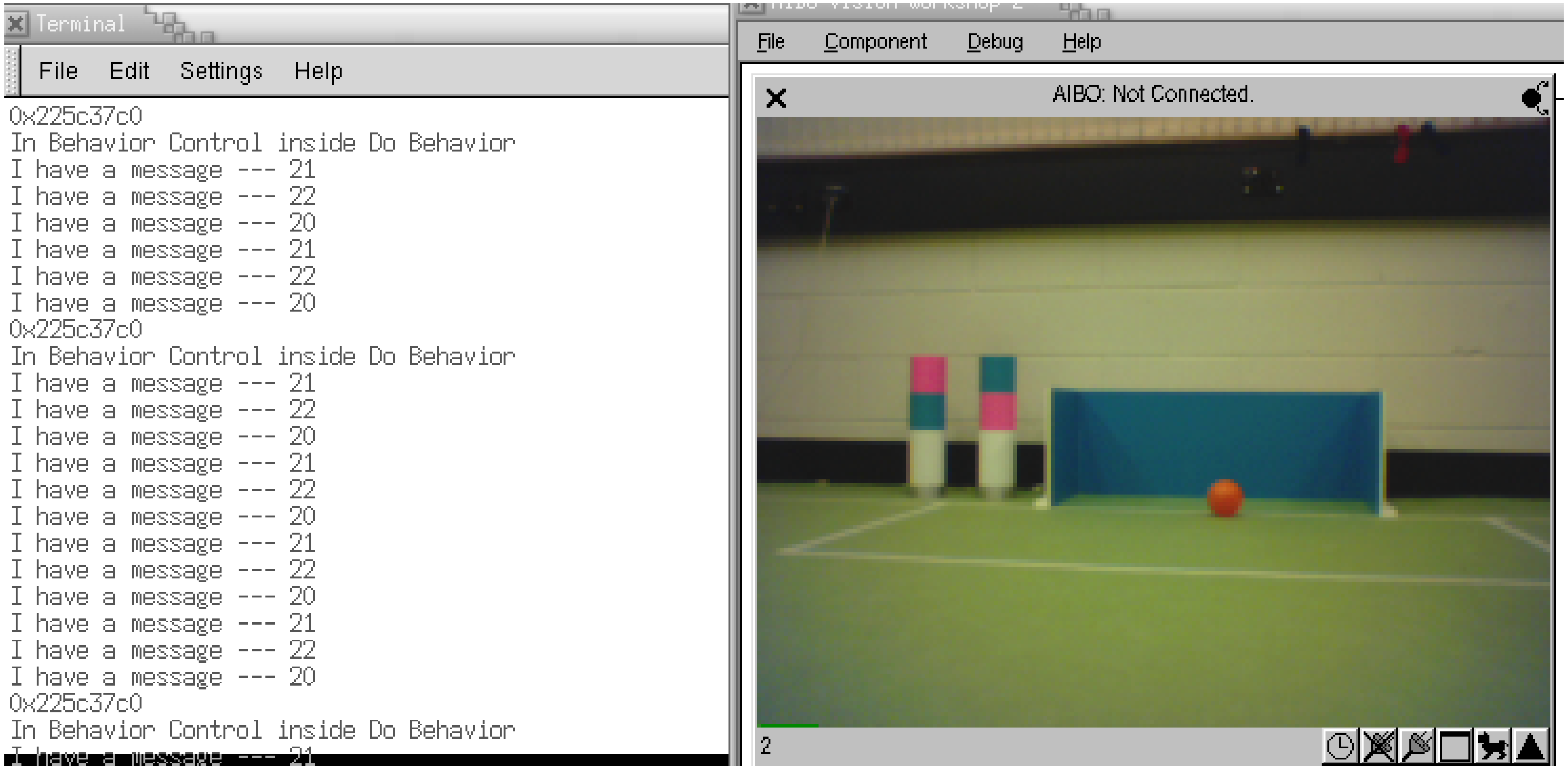
Model 3

- R1: => ~Cs(x).
- R2: See(x) => Cs(x).
- R2>R1.
- R3: {See(x),See(y),Opp(x,y) => ~Cs(x).
- R3>R2
- R4: {See(x),See(y),SeeLtoR(y,x),LR(x,y)} =>~Cs(x)
- R4:{See(x),See(y),SeeLtoT(y,x),LR(x,y)=>~cs(y)
- R4>R2
- R5: {See(x),See(y),See(z),SeeLtoR(y,z),SeeLtoR(z,x),Adj(x,y,z)} => Cs(y)
- R5:{See(x),See(y),See(z),SeeLtoR(y,z),SeeLtoR(z,x),Adj(x,y,z)} =>Cs(x)
- R5:{See(x),See(y),See(z),SeeLtoR(z,x),SeeLtoR(x,y),Adj(x,y,z)=>Cs(x)
- R5:{See(x),See(y),See(z),SeeLtoR(z,x),SeeLtoR(x,y),Adj(x,y,z)=>Cs(y)
- R5>R4
- R6:{See(x0<see(y),See(z),SeeLtoR(x,z)SeeLtoR(z,y),LR(x,y),LR(y,z),Opp(x,z)}=>Cs(x)
- R6:{See(x),See(y),See(z),SeeLtoR(x,z),SeeLtoR(z,y),LR(x,y),LR(y,z),Opp(x,z)}=>Cs(y)
- R6>R3
- R6>R4

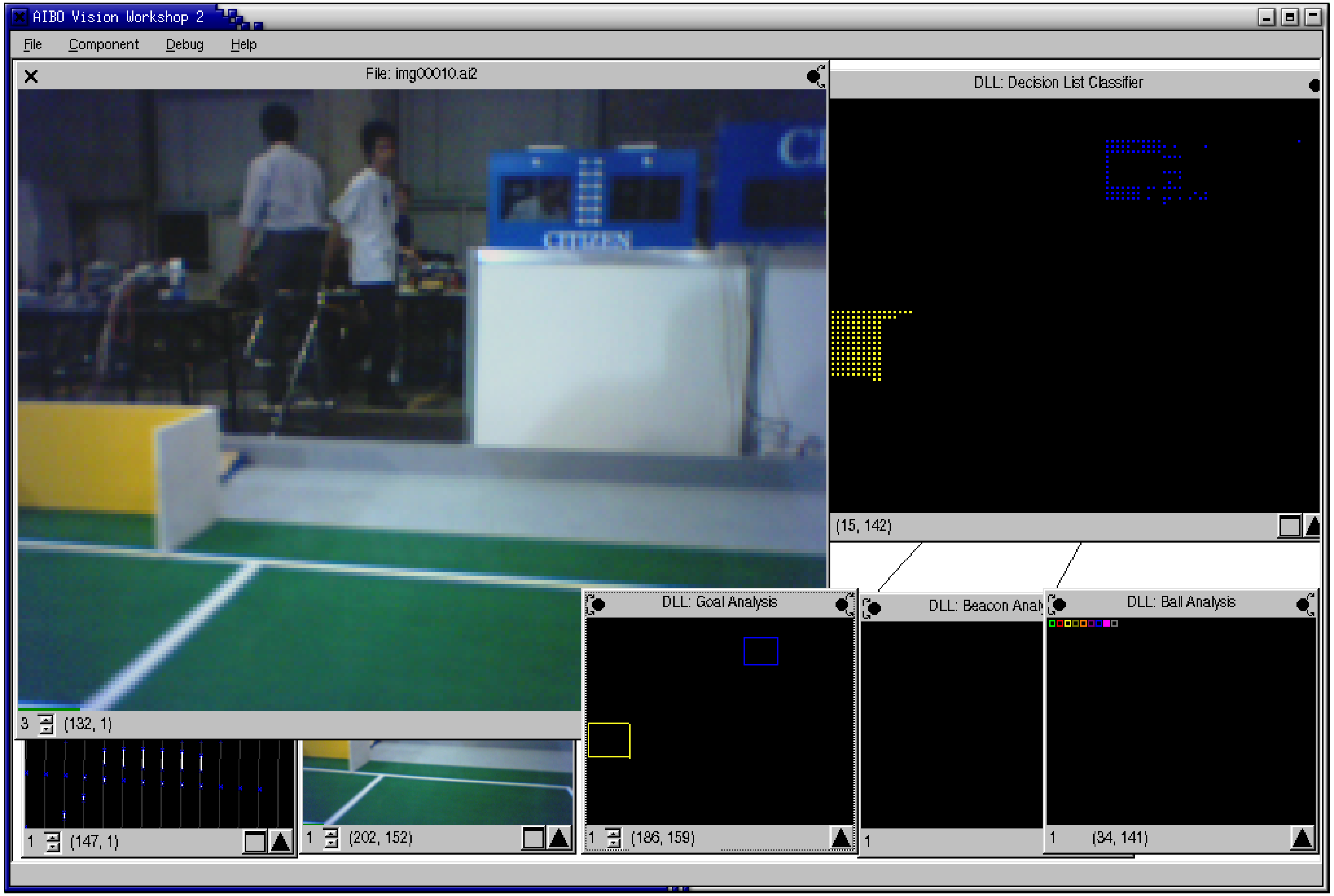
Mi-PAL

Illustration



The left post and goal appear in the correct order, but the right post appears left most

The module in action



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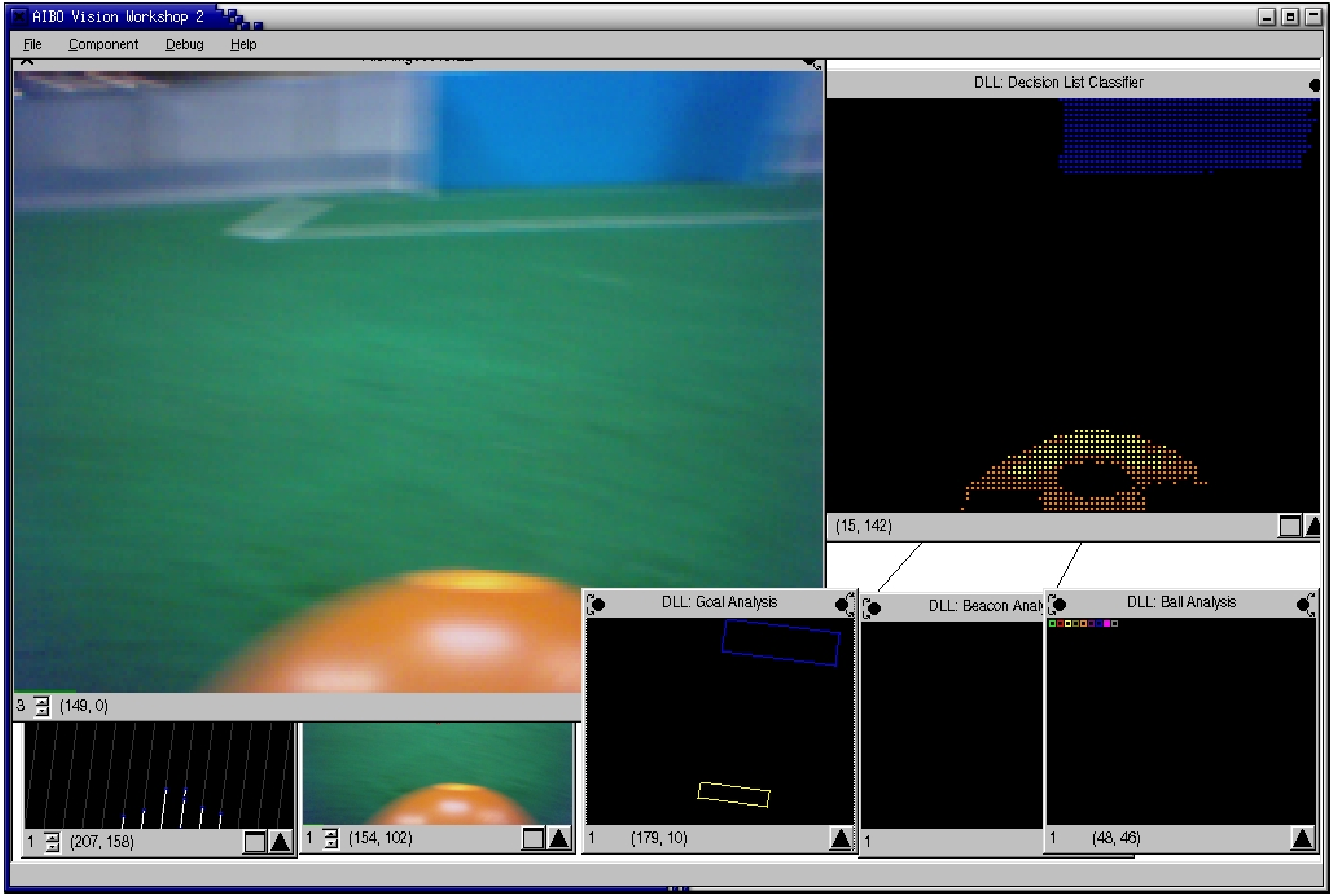

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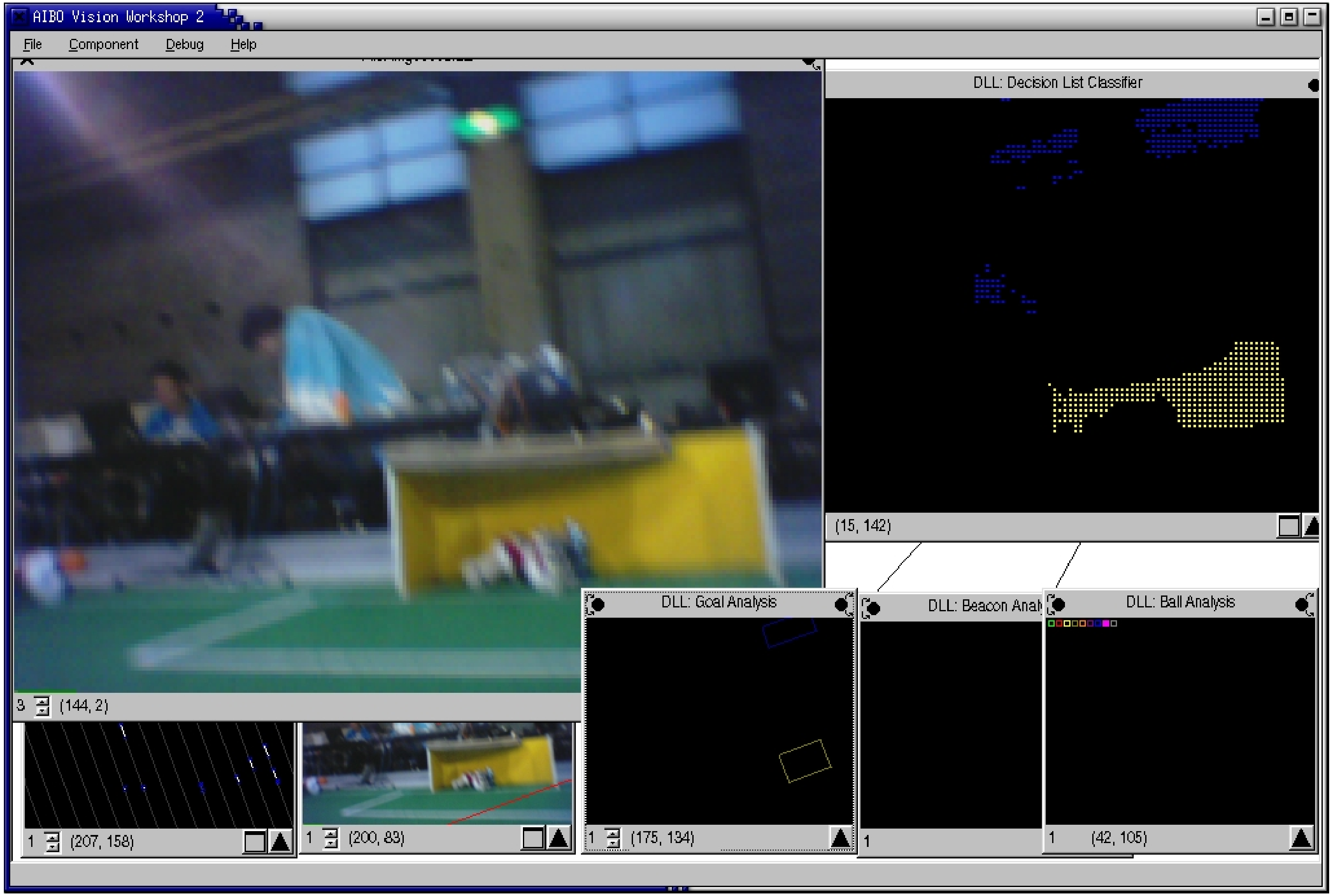

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Discussion

- CPU times were very positive
  - Model 1 : 44 microseconds
  - Model 2 : 60 microseconds
  - Model 3: 110 microseconds
    - On ERS-7 SONY Aibo

Conclusion

- The initial progress on logic and reasoning within AI has largely been discarded from mobile robotics in favour of reactive architectures
- We demonstrate the use of non-monotonic reasoning in the challenging application of RoboCup
- Plausible logic is the only non-monotonic logic with an algorithm that detects loops

THANK
YOU