Model checking applied to humanoid robotic soccer

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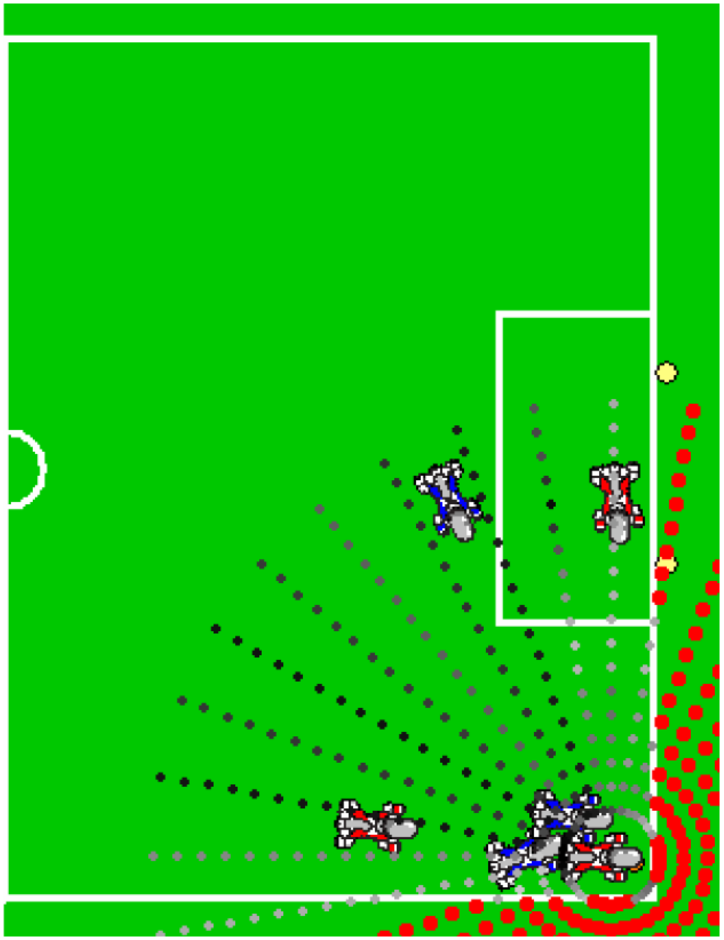
Summary

- Introduction
- MDP Parameter Estimation
- Model Checking for Strategy Evaluation
- Model Checking for Detecting the Weakest Link
- Conclusions

Introduction

- Probabilistic methods have proved to be good at deciding the most convenient action to be performed by a soccer robot under a specific game situation, based on maximizing or minimizing some scoring probability



Game Strategies

An interesting question expressed in linguistic terms would be:

- "Is it, in general, better to kick the ball before the opponent team does, even if there is a potential risk of scoring an own goal?"

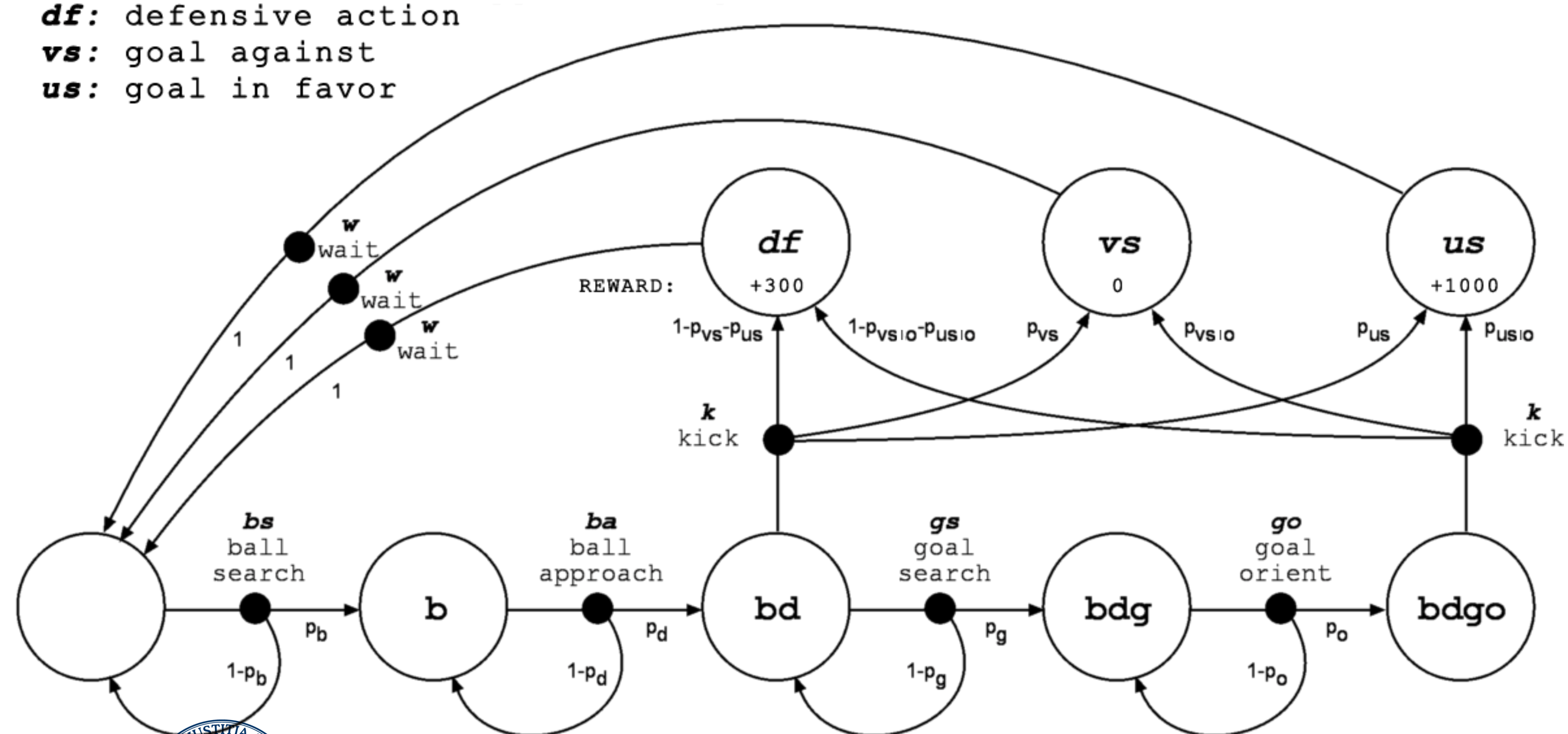
Game Strategies

1. locating the ball (*ball searching* action),
2. approaching the ball (*ball approaching* action),
3. positioning for kicking, which implies:
   (a) locating the opponents' goal (*goal searching* action) and
   (b) orienting the kick towards that direction (*goal orienting* action),
4. kicking (*kick* action), and
5. ability of standing up if the robot falls over.

To answer this question, the first thing we have to do is to build a model.

b: ball located
d: having kicking distance
g: opponents' goal located
o: oriented towards opponents' goal
df: defensive action
vs: goal against
us: goal in favor

p_{vs}: prob. of marking a self-goal w/arbitrary kick
p_{us}: prob. of marking a goal w/arbitrary kick
$p_{vs|o}$: prob. of marking a self-goal w/oriented kick
$p_{us|o}$: prob. of marking a goal w/oriented kick



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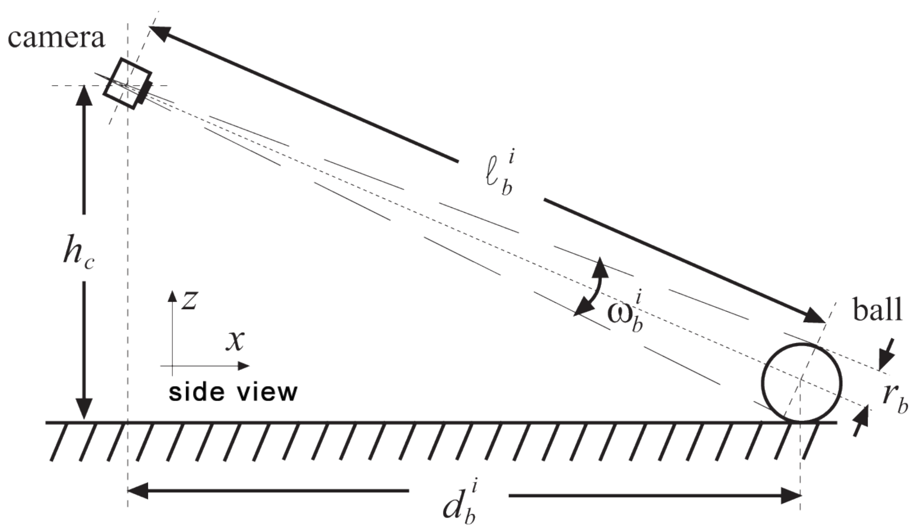
1. $p_b = p(\text{finding the ball} \mid S)$,
2. $p_d = p(\text{reaching the ball} \mid S)$,
3. $p_g = p(\text{finding the opposing goal} \mid S)$,
4. $p_o = p(\text{turning around the ball towards the opposing goal} \mid S)$,
5. $p_{goal} = p(\text{scoring a goal} \mid S)$.

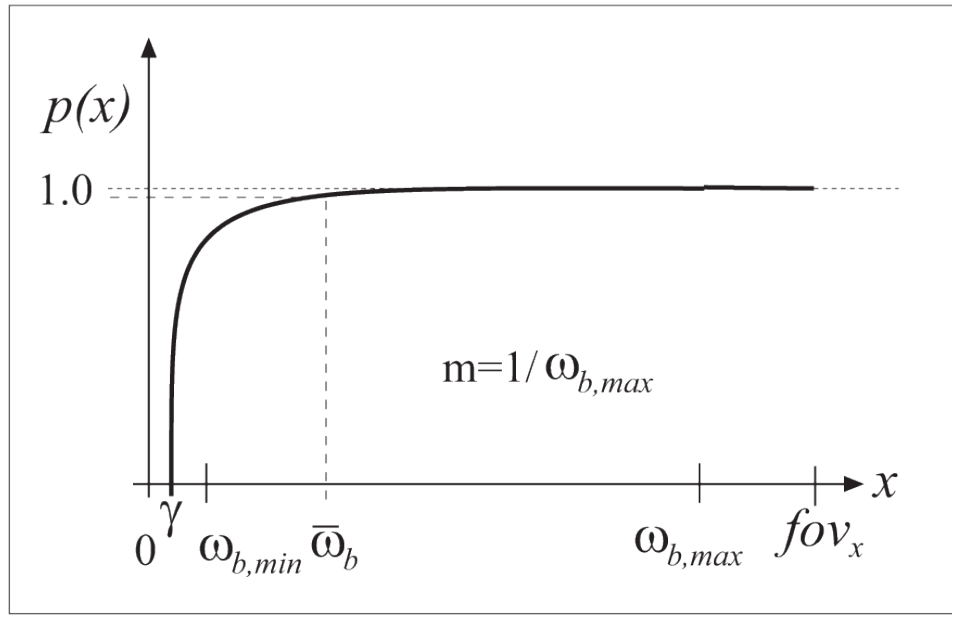
Then, the overall probability of detecting and hitting the ball towards the opposing goal given a game situation S can be calculated as:

$$p_{goal} = p_b \cdot p_d \cdot p_g \cdot p_o$$

Probability p_b of locating the ball

$$p_b = p_{c_b} \cdot p_{v_b}$$



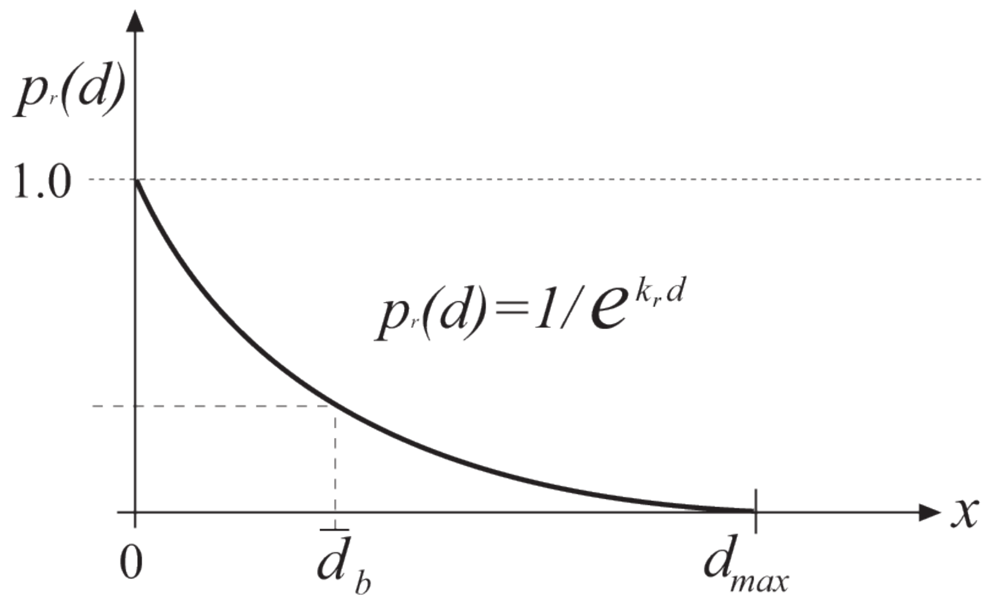


Probability p_d of approaching the ball

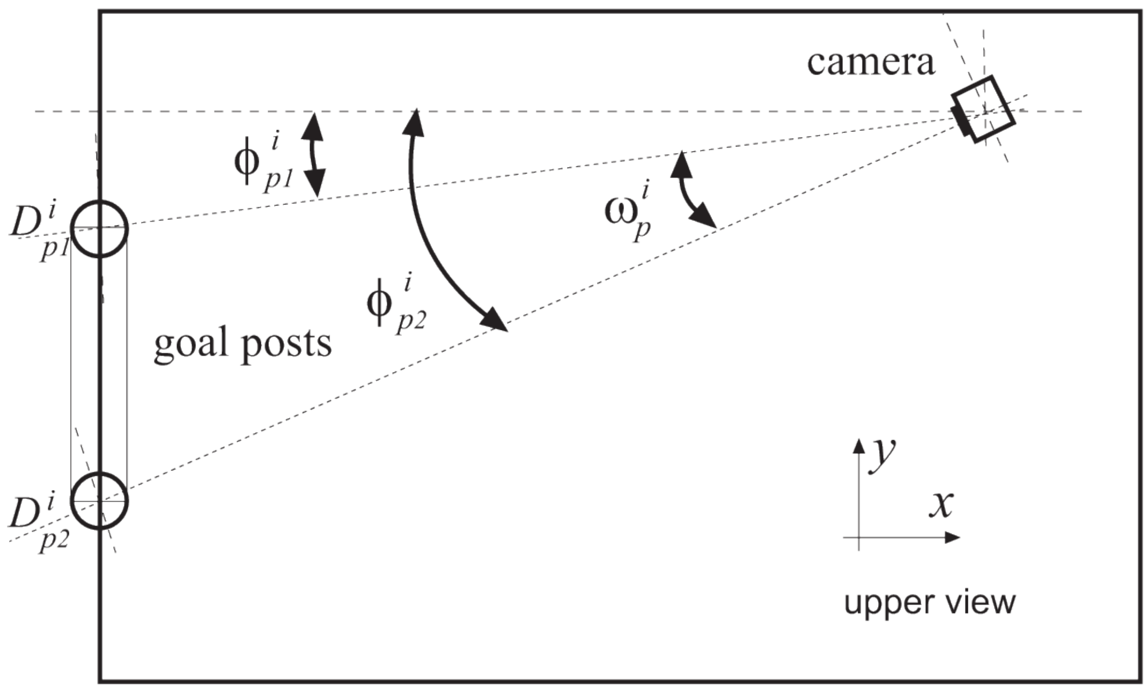
$$p_d = p_t \cdot p_r \cdot p_s \cdot (1 - p_{fall})$$

$$\vartheta_t = \frac{t_{\pi,vs}}{t_{\pi,us}}; \qquad \vartheta_r = \frac{r_{100,vs}}{t_{100,us}}$$

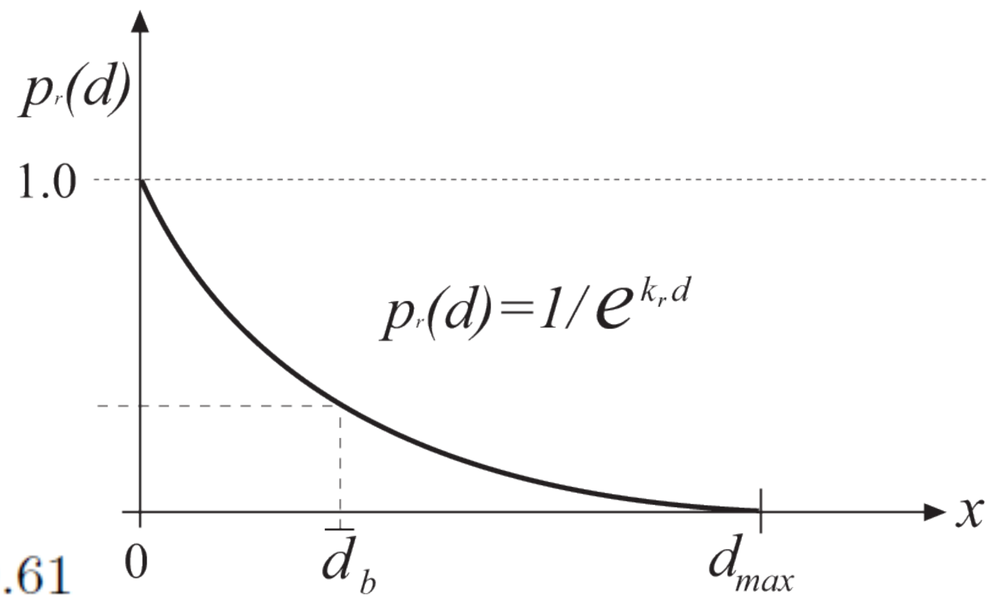
$$\vartheta_t = 2.0; \qquad \vartheta_r = 1.0$$



Probability p_g of finding the opposing goal



Probability p_o of orienting a goal while keeping the kicking distance



$$p_o = p_t(\overline{\phi}_p^{abs}) = \frac{1}{e^{0.5}} = 0.61$$

Probabilities of scoring a goal

$$p_{uso} = 1/6 \cdot 0.28 \cdot 1/6 \cdot 0.61 = 0.0047$$

$$p_{us} = p_{vs} = 1/6 \cdot 0.28 \cdot 1/12 = 0.0039$$

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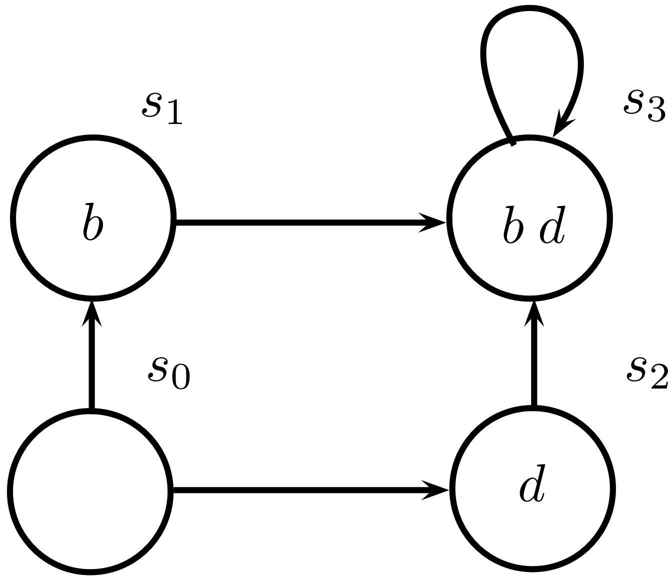
Model Checking

A key idea of model checking is the use of temporal logics for specifications, where the truth of statements can vary in time. Perhaps a reason for the success of model checking lies in the fact that temporal logics, unlike other formalisms, have a close connection with natural language, allowing the expression of statements such as

"is it possible to extinguish the fire?"

"does the agent try to extinguish the fire with an empty water tank?".

Model Checking



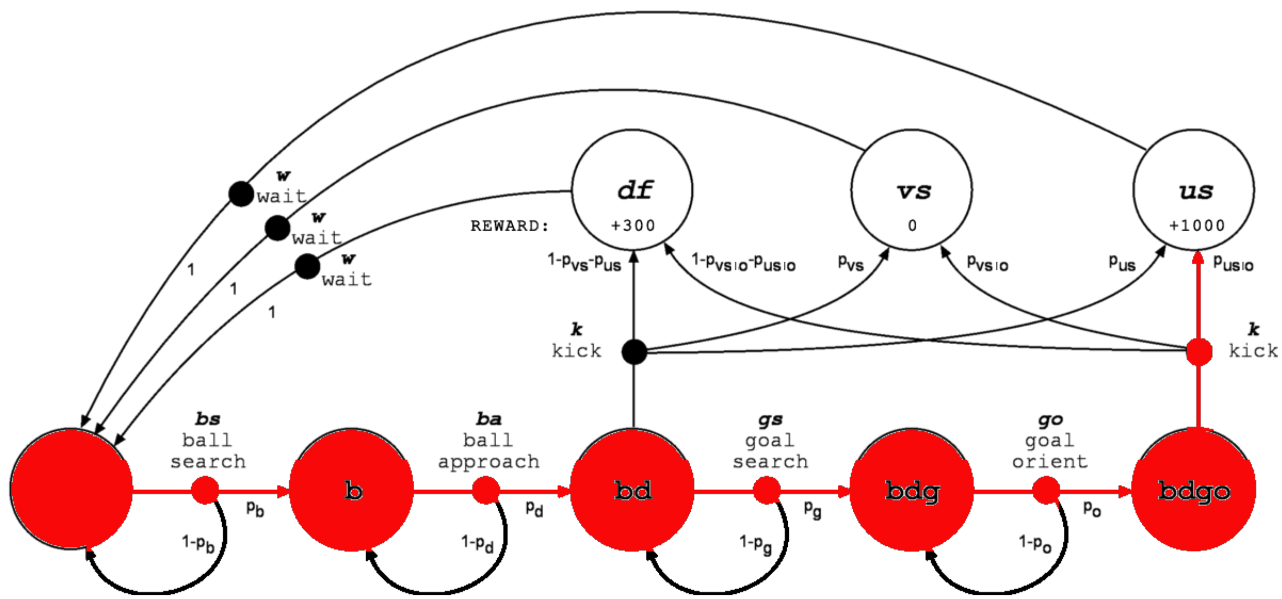
$$\mathbf{EF}\ ((!b)\&d)$$

modality	*meaning*
E	some path (i.e., there Exists a path)
A	All paths
X	neXt state (i.e., immediate future)
F	some state either in the present or in the Future
G	all states in the present and in the future (Global)

MDP Verification

$$P_{MAX=?}[!(b \ \& \ d \ \& \ !g \ \& \ !o \ \& \ a = 5)\mathbf{U}_{\leq 5} \ us]$$

Result: 0.0047634412



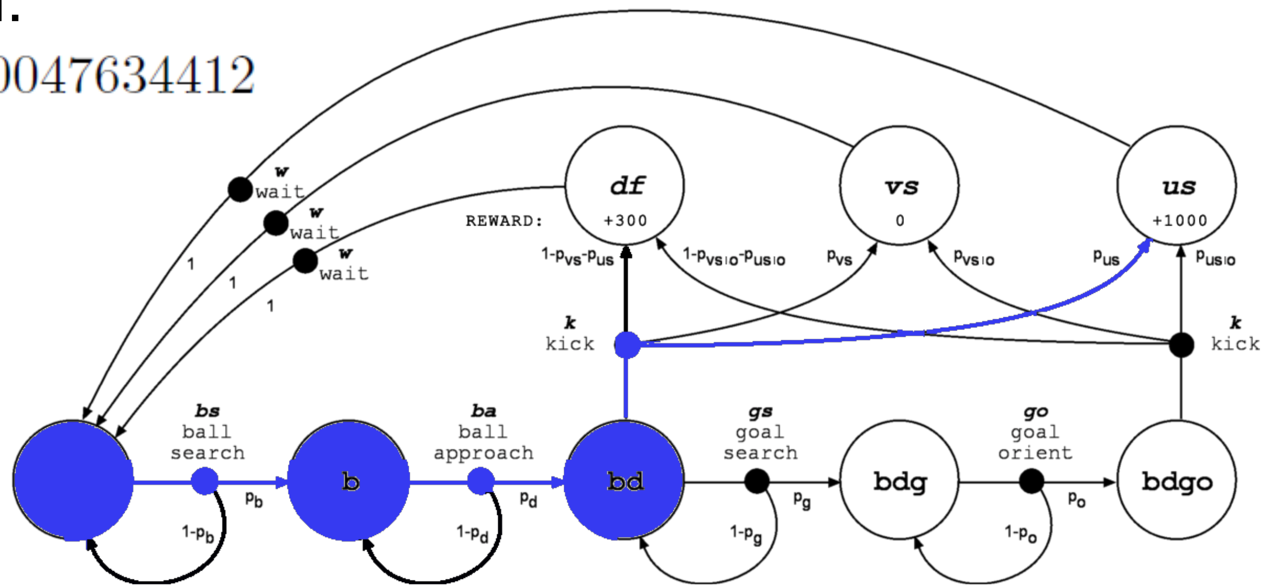
MDP Verification

$$P_{MAX=?}[\mathbf{F}_{\leq 3}\ us] = 0.0038810800$$

$$P_{MAX=?}[!(b\ \&\ d\ \&\ g\ \&\ o)\ \mathbf{U}_{\leq 3}\ us] = 0.0038810800$$

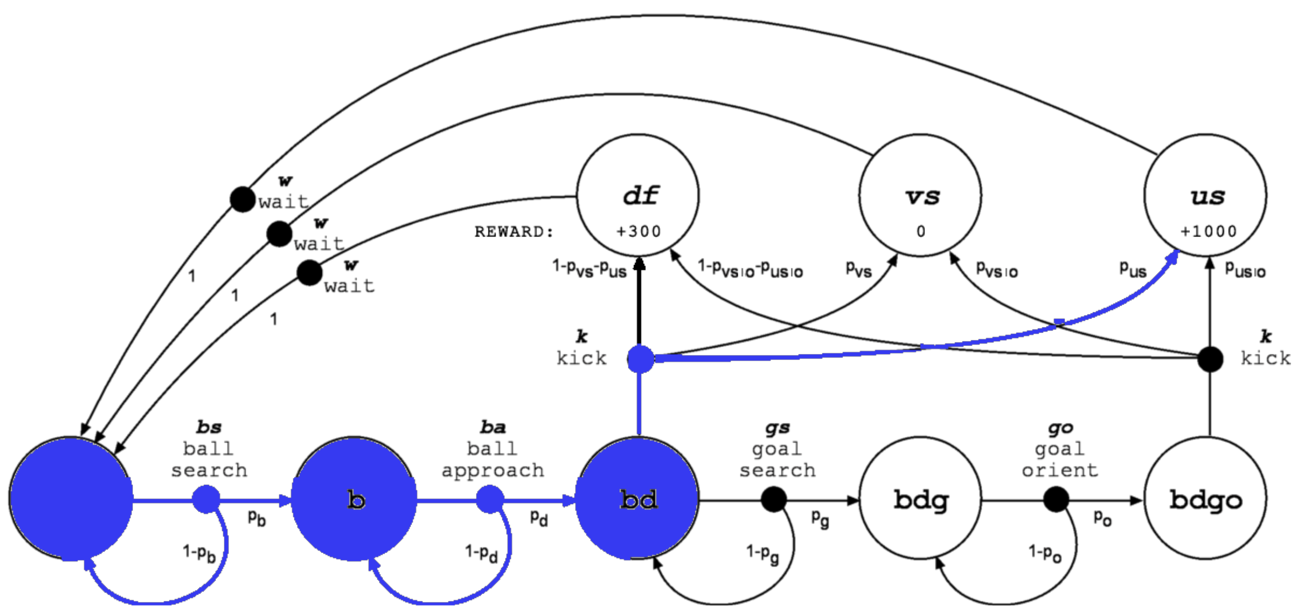
Oriented:

Result: 0.0047634412



MDP Non-Trivial Verification

$$P_{MAX=?}[!(b \ \& \ d \ \& \ g \ \& \ o)\mathbf{U}_{\leq 5} \ us] = 0.0169411043$$



MDP Non-Trivial Verification

$$\frac{0.0169}{0.0047} = 3.6$$

This is almost four times more probable scoring a goal in the opponent's frame with a fast kick than with an oriented kick (the main problem will be that the robot could actually score in its own goal).

This is a more interesting result.

Videos

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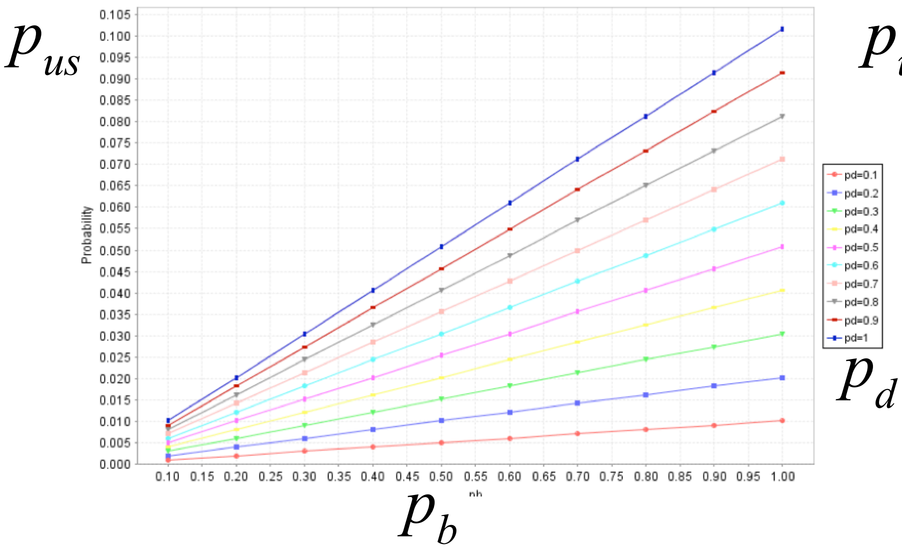
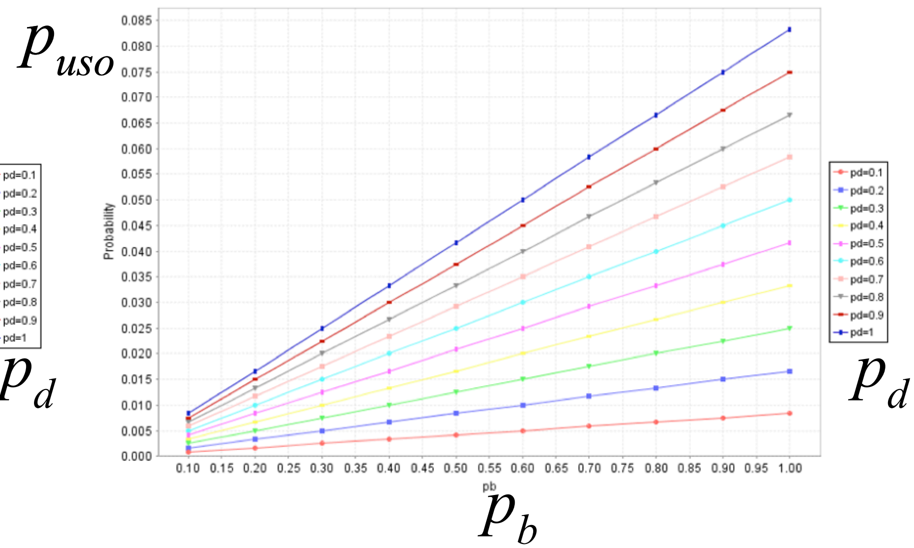
Experiments

(FK)



(GO)



When comparing p_{us} and p_{uso} in both graphs for an average turning speed of 50% less than the opponents', in all the cases the scoring probability for fast kicking (FK) was greater than that for goal oriented kicking (GO), no matter how good a vision detection system the robot could have.

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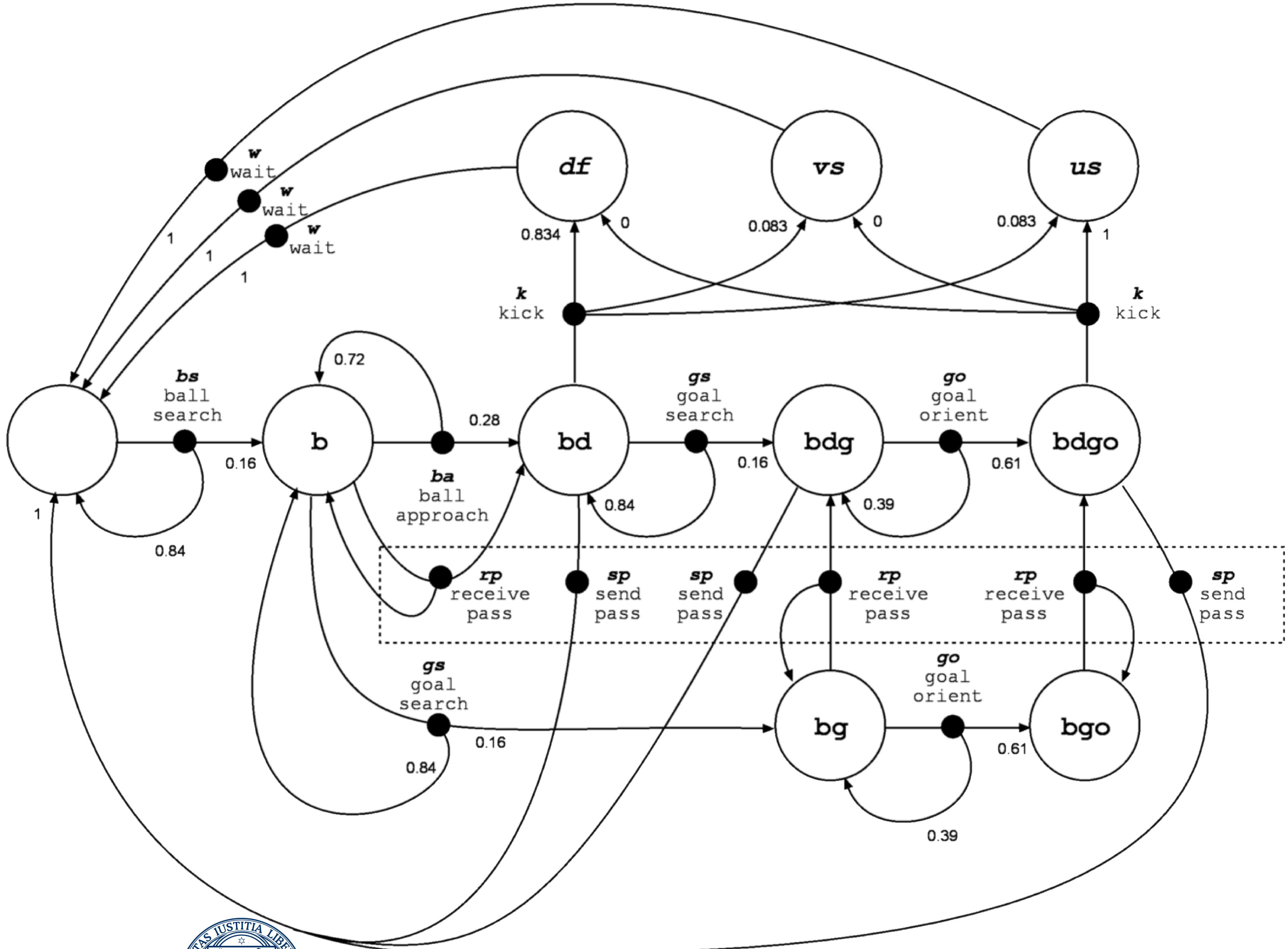
- The use of model checking strategies under MDPs allows designers and programmers to evaluate and predict the overall performance of a team by analyzing a set of playing skills.
- As each ability (probability) is evaluated considering the developed systems, it is feasible to find the strengths and weaknesses of these systems.

Future Work

- We are developing an on-board model checker for evaluating and activating specic strategies during the match (such as passing or having the goalie as attacker).


df
vs
us
w
wait
w
wait
w
wait
1
1
1
0.834
0
0.083
0
0.083
1
k
kick
k
kick
0.72
bs
ball
search
b
0.28
bd
gs
goal
search
bdg
go
goal
orient
bdgo
0.16
ba
ball
approach
0.16
0.61
1
0.84
0.84
0.39
rp
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pass
sp
send
pass
sp
send
pass
rp
receive
pass
rp
receive
pass
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pass
gs
goal
search
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0.16
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