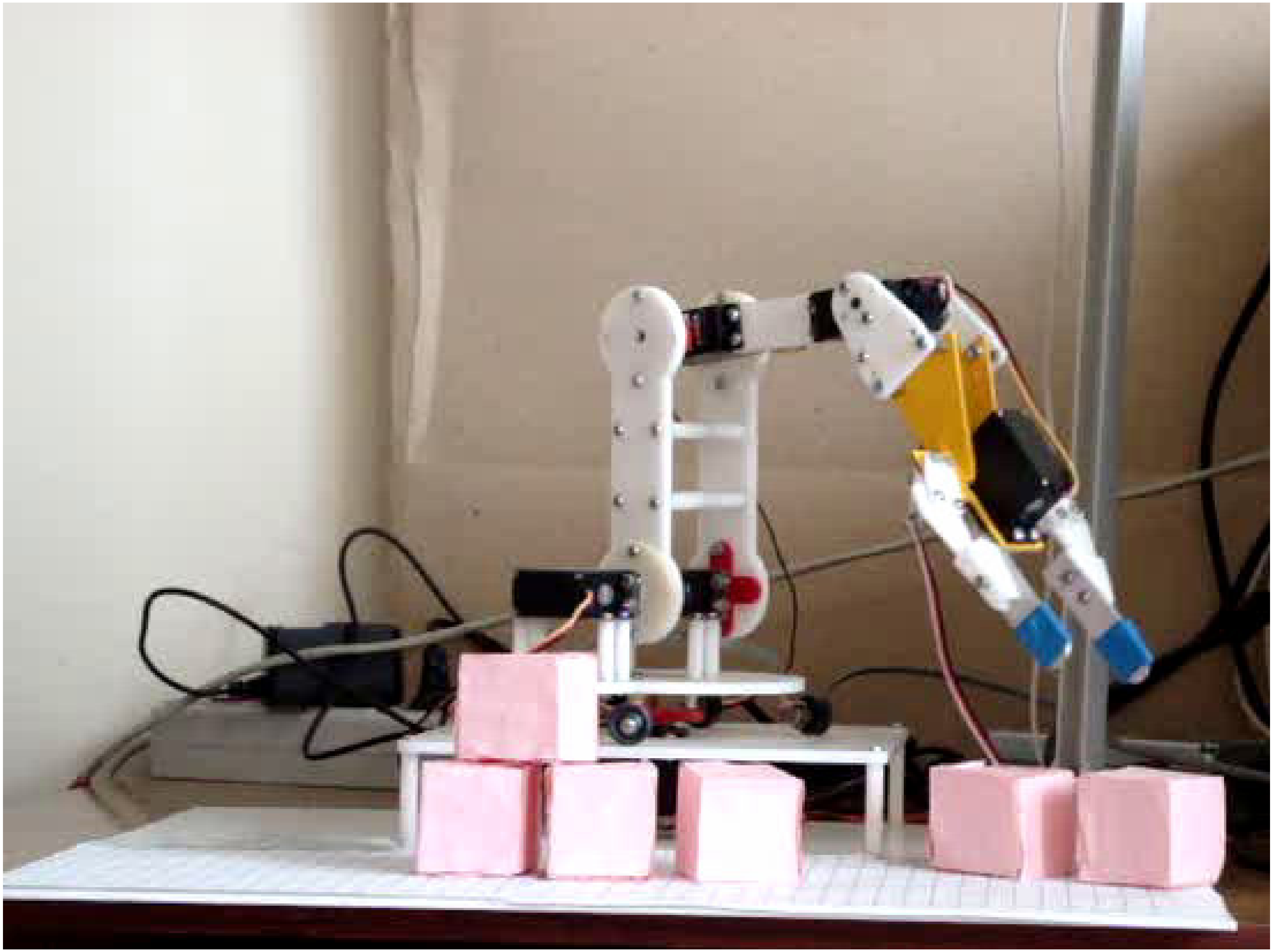
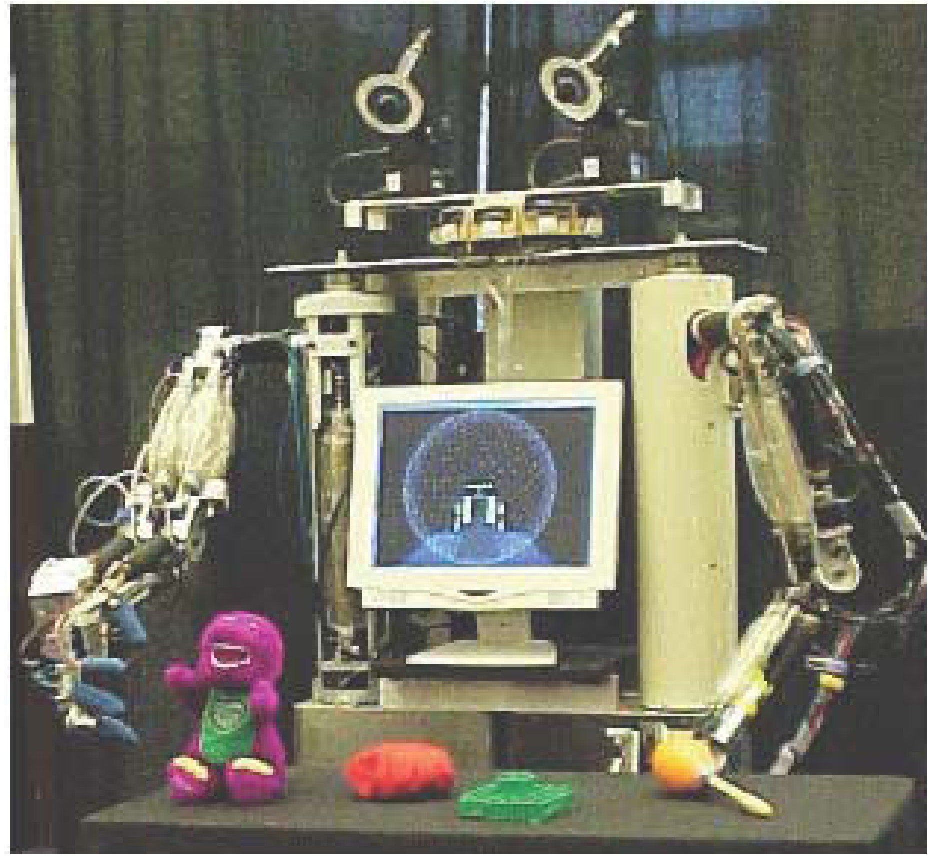
Theory of actions, robot control and semigroups



Stanford

MIT



Vanderbilt

Theory of actions

- Aristotle. Nicomachean Ethics (Third Book).
- A.Mele, editor. The Philosophy of Action. Oxford University Press, Oxford, 1997.
- F.Brown, editor. Proceedings of the 1987 workshop on The Frame Problem in AI.
- M.Georgeff, editor. Journal of Logic and Computation, Special issue on Action and Processes, 1994.
- Working notes of AAAI Spring Symposium, 1995.

“What is left over if I subtract the fact that my arm goes up from the fact that I raise my arm?”

Ludwig Wittgenstein,

Philosophical Investigations §621.

Following a common approach in reasoning about actions, dynamic systems are modeled in terms of state evolutions caused by actions.

A state is a complete description of a situation the system can be in.

Actions cause state transitions, making the system evolve from the current state to the next one.

In principle we could represent the behavior of a system (i.e. all its possible evolutions) as a transition graph where:

each node represents a state, and is labeled with the properties that characterize the state;

each arc represents a state transition, and is labeled by the action that causes the transition.

Honda Humanoid Robot

Honda Corporation

30 degrees-of-freedom

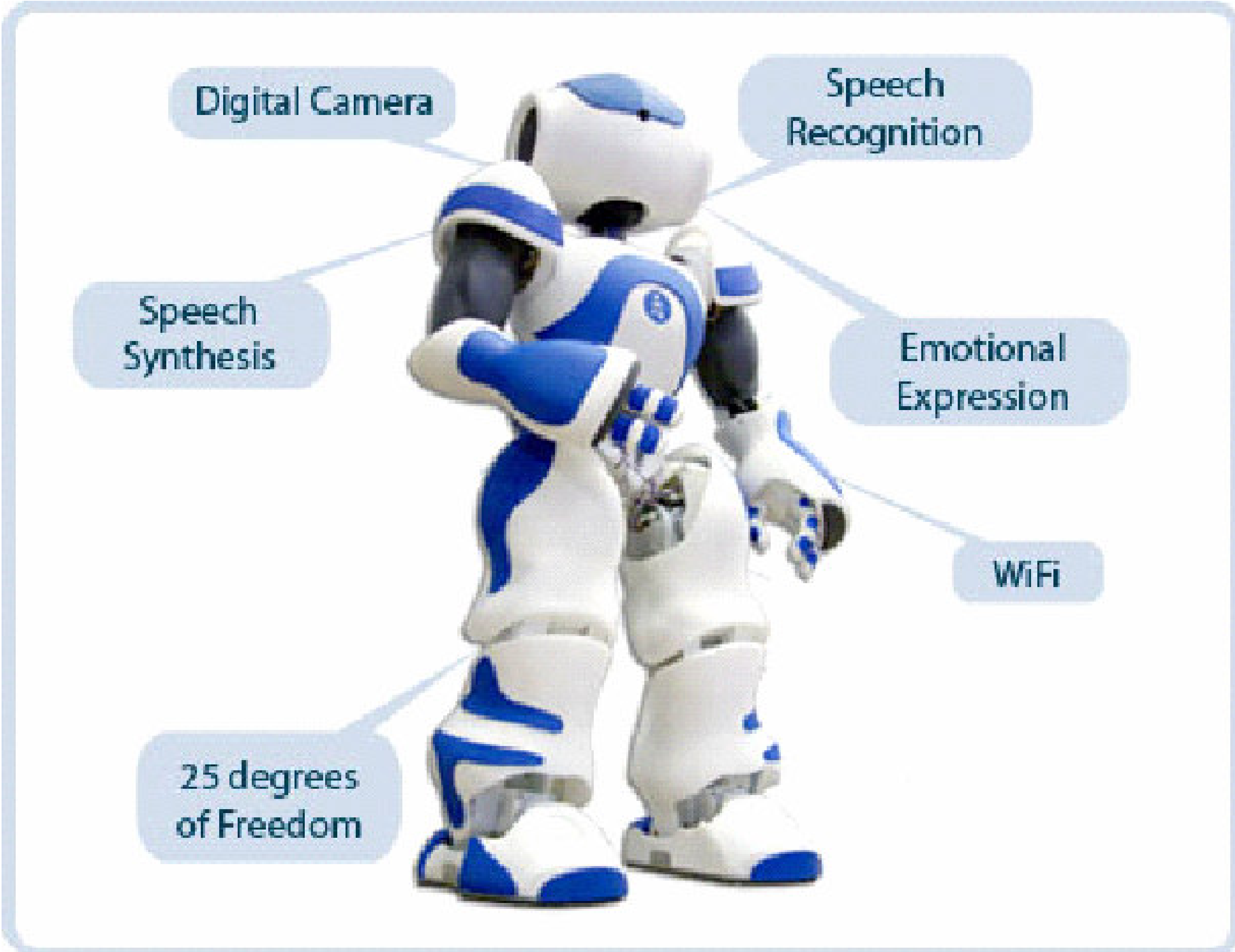
As it is impossible to search such huge spaces for what constitutes a good action, it is necessary to either find more compact state-action representations, or to focus learning on those parts of the state-action space that are actually relevant for the movement task at hand.

Schaal S.
Is imitation learning the route to humanoid robots?
Trends in Cognitive Sciences.
1999. **3**:233-242.

Nao Project AI-05

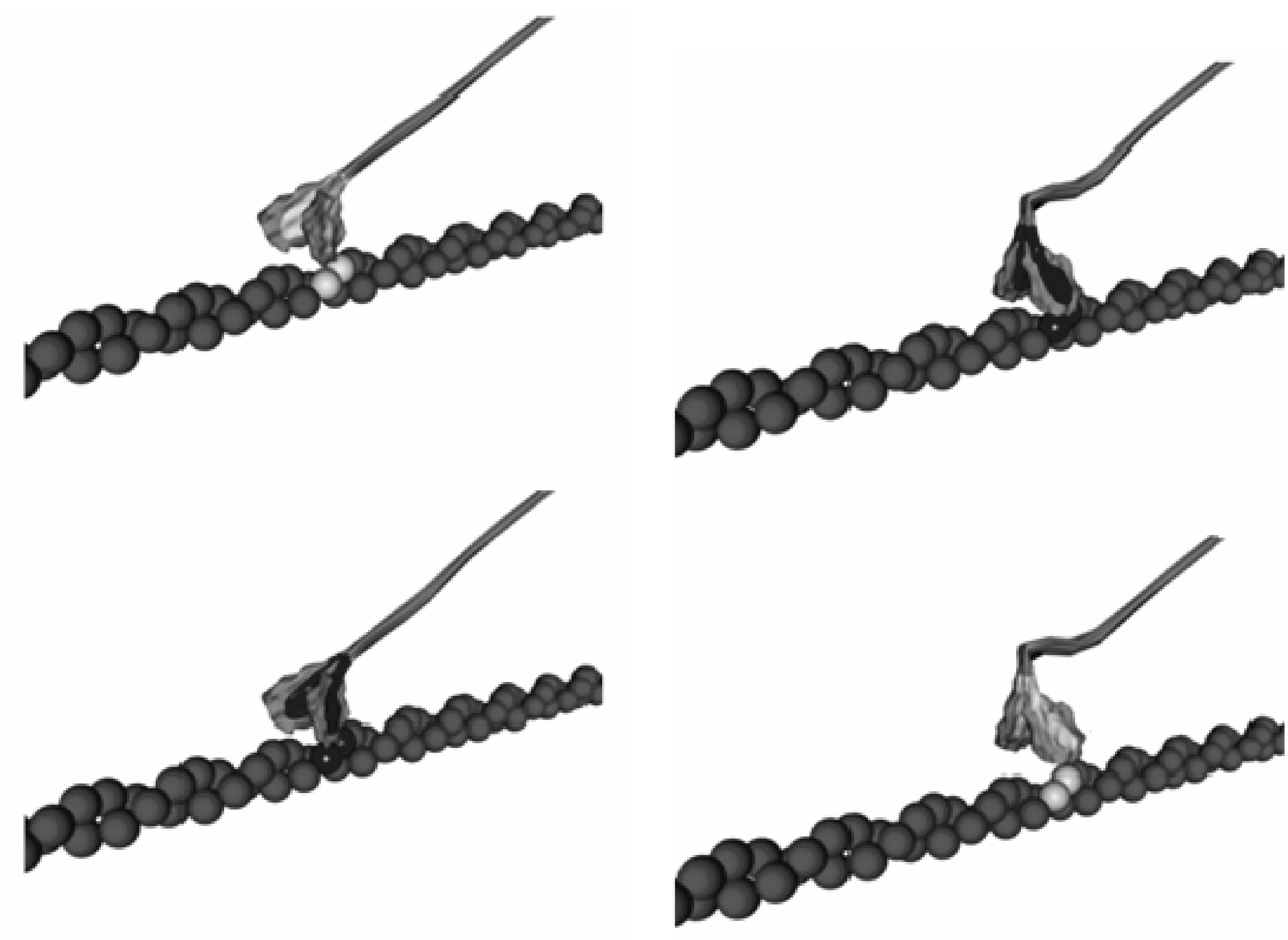
Aldebaran Robotics

25 degrees-of-freedom

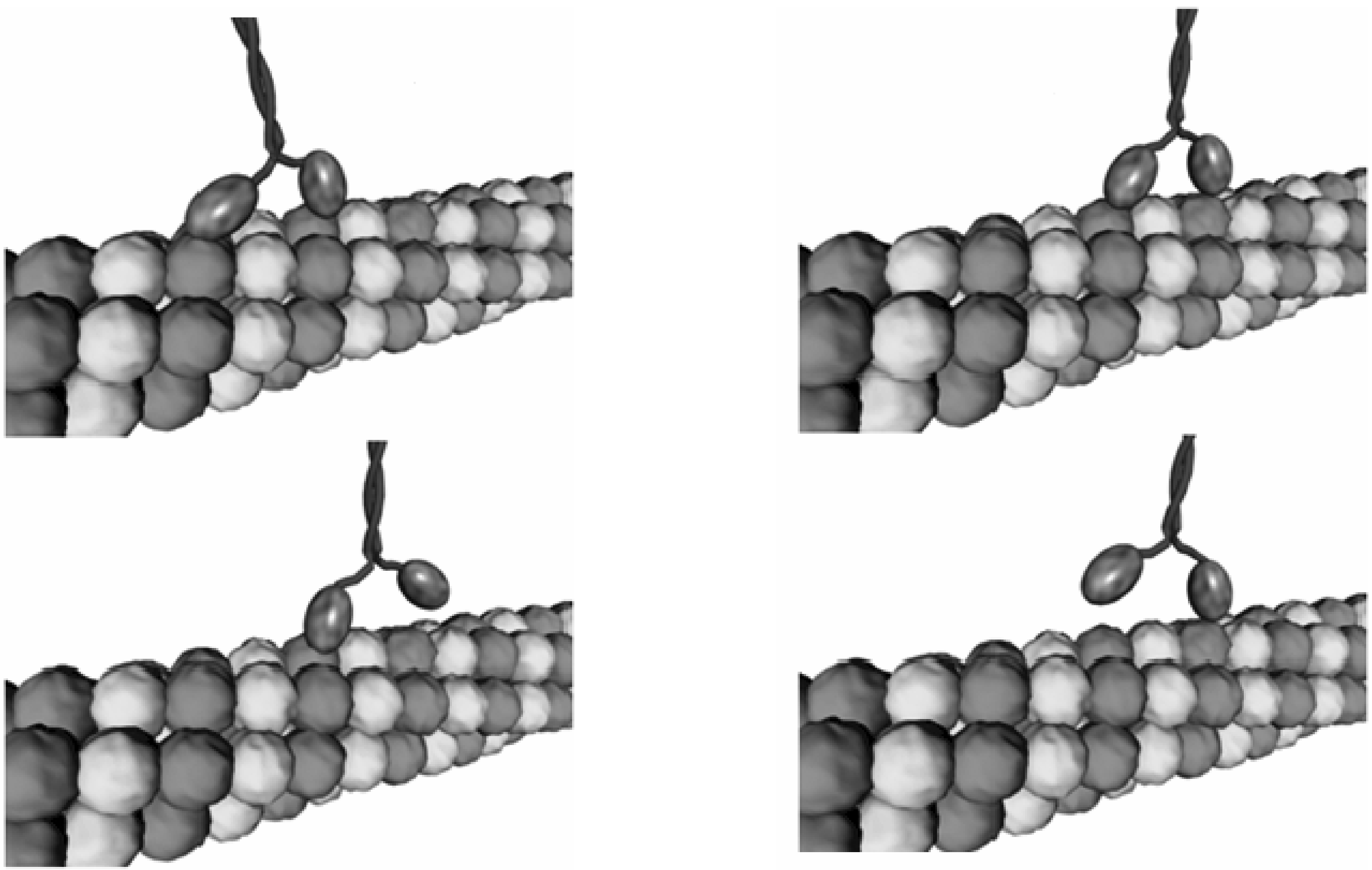

Digital Camera
Speech Recognition
Speech Synthesis
Emotional Expression
WiFi
25 degrees of Freedom

DNA nanomechanical devices

Myosin arm



Kinesin legs



A Synthetic DNA Walker for Molecular Transport

Jong-Shik Shin
Niles A. Pierce

> 200 degrees-of-freedom

> 1000000000000000000000

degrees-of-freedom for some DNA devices

In deductive planning complete knowledge of the behavior of the system is phrased in axioms of some logic.

Propositional Dynamic Logics.
Rosenschein [1981].
De Giacomo & Lenzerini [1995].

Situation calculus.
Reiter [1993].

In deductive planning one is typically interested in answering the following question:

“Is there a sequence of actions that, starting from an initial state leads to a state where a given property (the goal) holds?”

EXPTIME-complete (Kozen &Tiuryn [1990])

Humanoid robot at the Dynamic Brain Project at the ATR Labs in Japan

The apparently simple idea of imitation opened a Pandora's box of important computational questions in perceptual motor control.

There are no satisfying answers to questions of appropriate perceptual representations for imitation, motor representations, and the learning of these representations.

Degrees-of-freedom: $A[1], A[2], \ldots , A[n]$

States of $A[i]$: $a[i,1], a[i,2], \ldots , a[i,p[i]]$

Actions of $A[i]$: $b[i,1], b[i,2], \ldots , b[i,q[i]]$

$S(R) = < \Sigma \mid Q >$

$\Sigma = \Phi \cup \Psi$

$\Phi = \Phi[1] \cup \ldots \cup \Phi[n], \Phi[i] = \{ a[i,j] : 1 \leq j \leq p[i] \}$

$\Psi = \Psi[1] \cup \ldots \cup \Psi[n], \Psi[i] = \{ b[i,j] : 1 \leq j \leq q[i] \}$

$Q = Q[0] \cup Q[1] \cup Q[2] \cup Q[3] \cup Q[4]$

$$Q[0] = Q[0,1] \cup Q[0,2] \cup Q[0,3] \cup Q[0,4] \cup Q[0,5]$$

$$Q[0,1] = \{\ a[i,j]a[s,t] = a[s,t]a[i,j] : 1 \le i \le n,\ 1 \le s \le n,\ 1 \le j \le p[i],\ 1 \le t \le p[s]\ \},$$

$$Q[0,2] = \{\ b[i,j]b[s,t] = b[s,t]b[i,j] : 1 \le i \le n,\ 1 \le s \le n,\ i \ne s,\ 1 \le j \le q[i],\ 1 \le t \le q[s]\ \},$$

$$Q[0,3] = \{\ a[i,s]b[j,t] = b[j,t]a[i,s] : 1 \le i \le n,\ 1 \le j \le n,\ i \ne j,\ 1 \le s \le p[i],\ 1 \le t \le q[j]\ \},$$

$$Q[0,4] = \{\ a[i,s]a[i,t] = 0 : 1 \le i \le n,\ 1 \le s \le p[i],\ 1 \le t \le p[i]\ \},$$

$$Q[0,5] = \{\ b[i,t]a[i,s] = 0 : 1 \le i \le n,\ 1 \le s \le p[i],\ 1 \le t \le q[i]\ \}.$$

$$Q[1] \subseteq \{\ a[i,s]b[i,j] = a[i,t] :$$
$$1 \le i \le n,\ 1 \le s \le p[i],\ 1 \le t \le p[i],\ 1 \le j \le q[i]\ \}.$$

$$Q[2] \subseteq \{\ aa[i,s]b[i,j] = aa[i,t] :$$
$$1 \le i \le n,\ 1 \le s \le p[i],\ 1 \le t \le p[i],\ 1 \le j \le q[i],\ a \in \Phi+\ \}.$$

$$
\begin{aligned}
&Q[3] \subseteq \{ \\
&a[i[1],s[1]]b[i[1],j[1]]a[i[2],s[2]]b[i[2],j[2]]\ldots a[i[r],s[r]]b[i[r],j[r]] = \\
&a[i[1],t[1]]a[i[2],t[2]] \ldots a[i[r],t[r]] : \\
&1 \leq i[1] < i[2] < \ldots < i[r] \leq n, \\
&1 \leq s[1] \leq p[i[1]],\ 1 \leq s[2] \leq p[i[2]],\ \ldots ,\ 1 \leq s[r] \leq p[i[r]], \\
&1 \leq t[1] \leq p[i[1]],\ 1 \leq t[2] \leq p[i[2]],\ \ldots ,\ 1 \leq t[r] \leq p[i[r]], \\
&1 \leq j[1] \leq q[i[1]],\ 1 \leq j[2] \leq q[i[2]],\ \ldots ,\ 1 \leq j[r] \leq q[i[r]]\ \}.
\end{aligned}
$$

$$
\begin{aligned}
&Q[4] \subseteq \{ \\
&aa[i[1],s[1]]b[i[1],j[1]]a[i[2],s[2]]b[i[2],j[2]]\ldots a[i[r],s[r]]b[i[r],j[r]] = \\
&aa[i[1],t[1]]a[i[2],t[2]] \ldots a[i[r],t[r]] : \\
&1 \leq i[1] < i[2] < \ldots < i[r] \leq n, \\
&r < n, \\
&1 \leq s[1] \leq p[i[1]],\ 1 \leq s[2] \leq p[i[2]],\ \ldots ,\ 1 \leq s[r] \leq p[i[r]], \\
&1 \leq t[1] \leq p[i[1]],\ 1 \leq t[2] \leq p[i[2]],\ \ldots ,\ 1 \leq t[r] \leq p[i[r]], \\
&1 \leq j[1] \leq q[i[1]],\ 1 \leq j[2] \leq q[i[2]],\ \ldots ,\ 1 \leq j[r] \leq q[i[r]], \\
&a \in ((\Phi[1] \cup \ldots \cup \Phi[n]) \setminus (\Phi[i[1]] \cup \ldots \cup \Phi[i[r]]))+\ \}\ .
\end{aligned}
$$