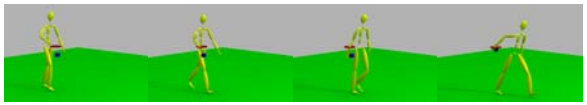
Motion Planning for Virtual Humans



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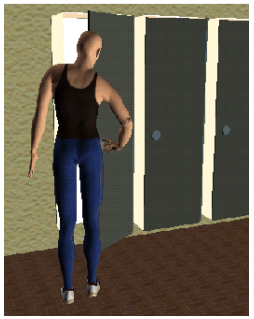
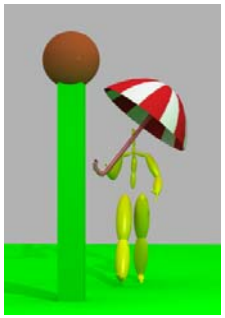
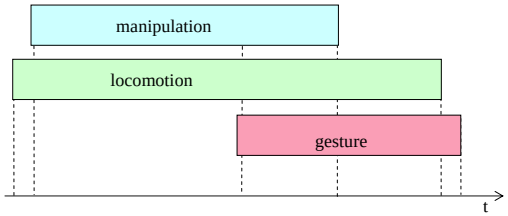
UCMERCED

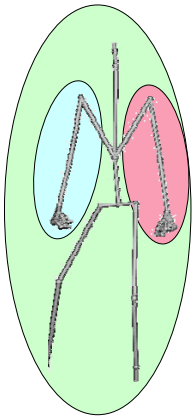
How to Plan Coordinated Motions ?



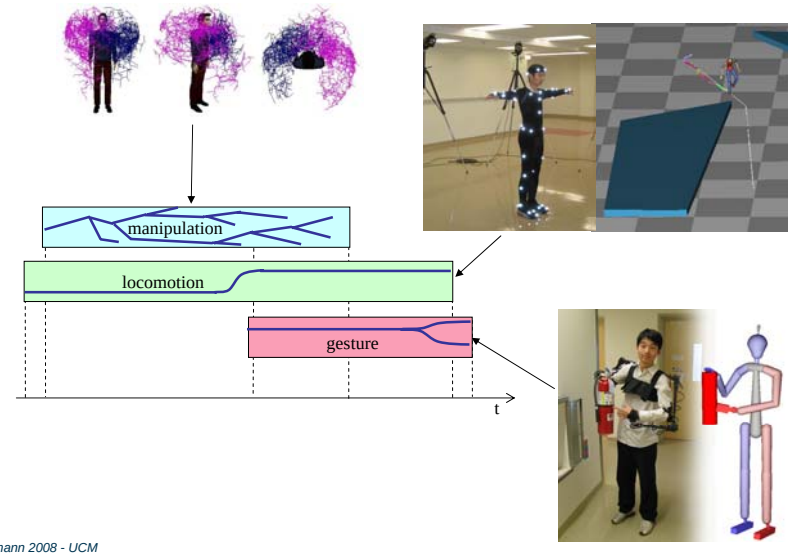


Approach

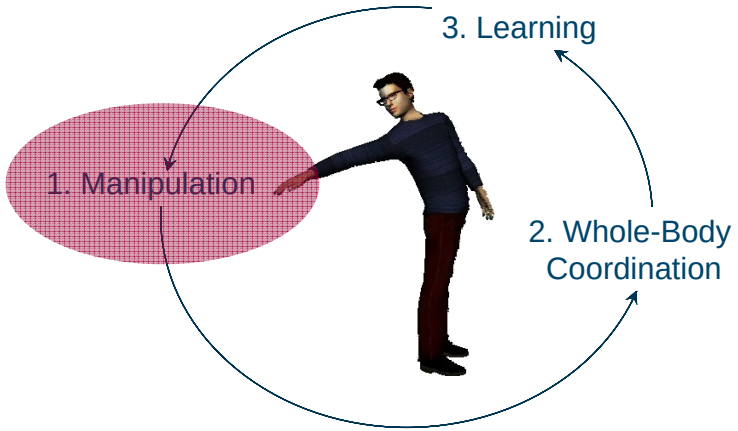




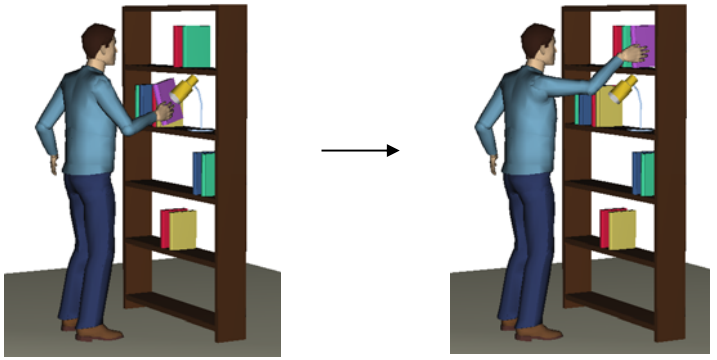
Approach



Topics



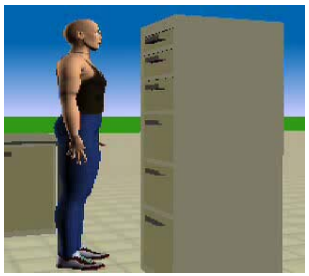
The Basic Problem

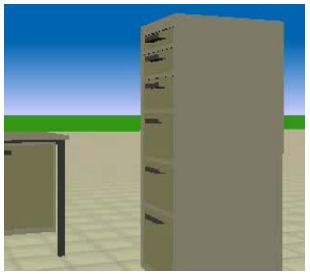


The Inverse Kinematics Approach

- IK solves joint rotations such that the end-effector reaches a given target

Examples: Jacobian-Based IK



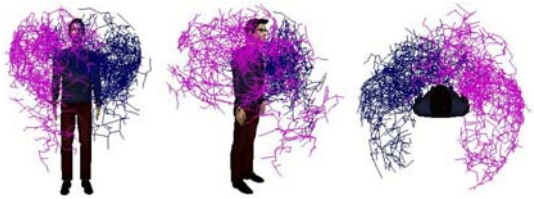


M. Kallmann, **Interaction with 3-D Objects**, In Handbook of Virtual Humans, John Wiley & Sons, UK, 2004, 303-322.

Examples: Jacobian-Based IK

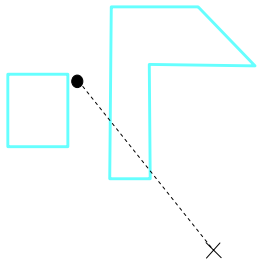
The Motion Planning Approach

- Sampling-based planners explore the free space around obstacles

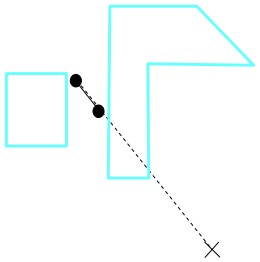


RRT Review

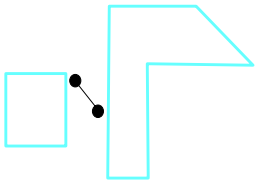
RRT Review



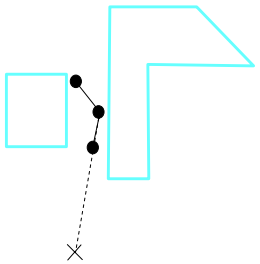
RRT Review



RRT Review



RRT Review



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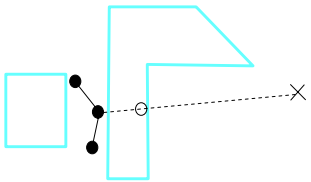
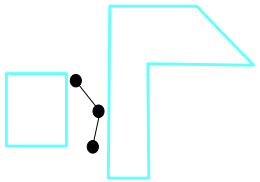


RRT Review



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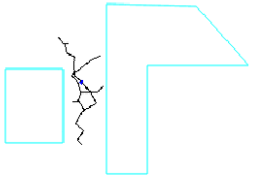
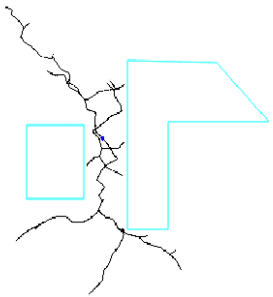
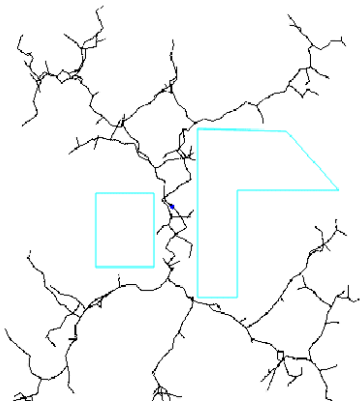


RRT Review



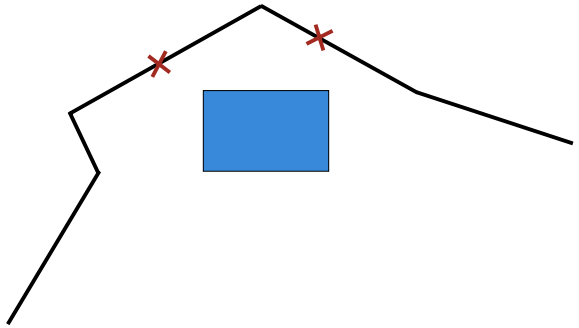
RRT Review



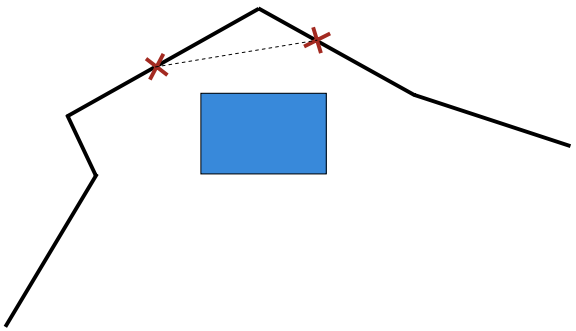
Bidirectional RRT

Trees rooted at c_i and c_g grow simultaneously

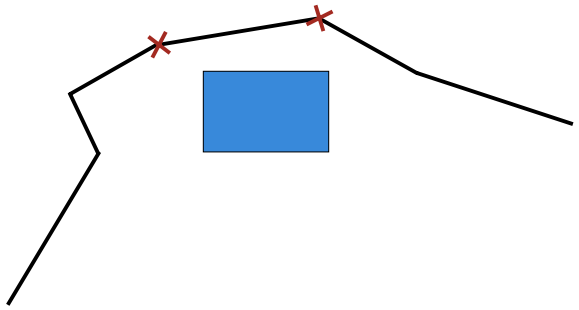
Smoothing Review



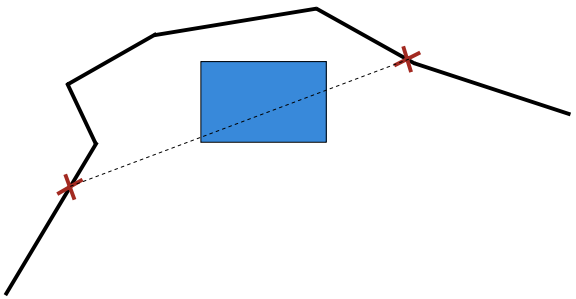
Smoothing Review



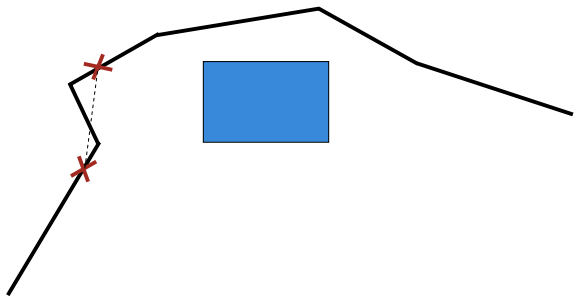
Smoothing Review



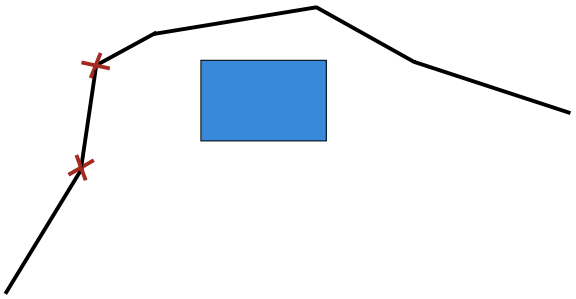
Smoothing Review



Smoothing Review



Smoothing Review

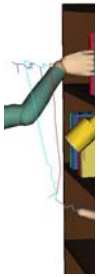


Example

RRTs used to animate characters

tree expansion

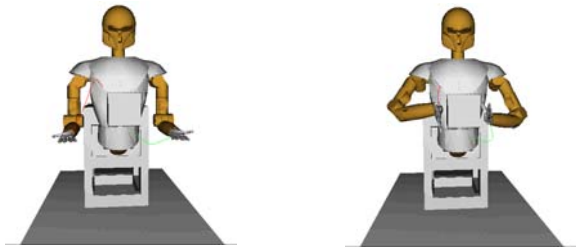
connection found



solution optimized

Example

RRTs used for both arms



Example

RRTs for Object Relocation

M. Kallmann, **Scalable Solutions for Interactive Virtual Humans that can Manipulate Objects**, AIIDE 2005.

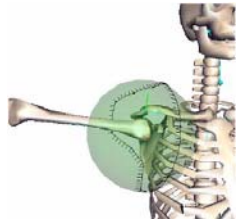
Motion Planners for Characters

- What is needed?
  - Configuration sampling routine
  - Distance function between postures
  - Posture interpolation method
  - Validity check routine

Sampling Whole Body Reaching Postures

- 22 DOFs control layer
  - 7 in each arm, 2 in each clavicle
  - 3 in the torso (distributed in spine)
  - 1 knee flexion (translational DOF)

- Specific per-articulation parameterization and range limits
  - Ex: swing-and-twist decomposition for the shoulder:
    $R = R^{twist}\ R^{swing}$
    $R^{twist}=R_z(\theta)$, $R^{swing} = [S_x\ S_y\ 0]$



M. Kallmann, A. Aubel, T. Abaci, and D. Thalmann, **Planning Collision-Free Reaching Motions for Interactive Object Manipulation and Grasping**, Eurographics, 2003.

Sampling Whole Body Reaching Postures

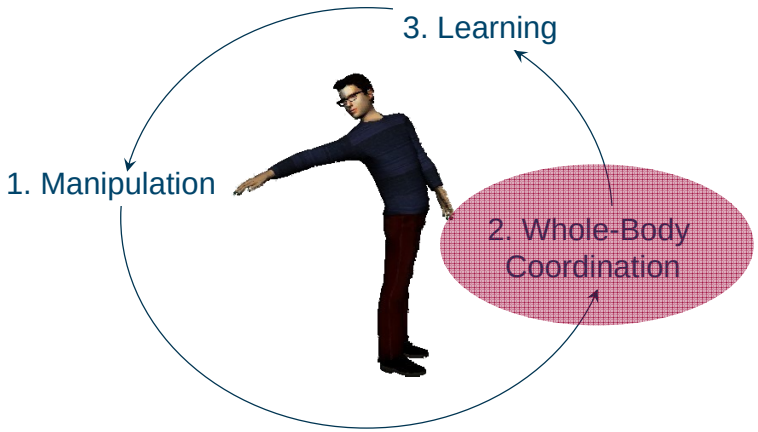
- 60% Regular
  - little spine and leg flexion
  - no clavicle motion
  - random arm poses
- 40% Distant
  - large spine and leg flexion
  - little elbow flexion
  - shoulder-clavicle coupling
  - arm-legs coupling
  - arm-torso coupling
- Balance, limits, collisions

Example

Play Video - http://graphics.ucmerced.edu/videos/2003_eg_reaching720x576.mpg

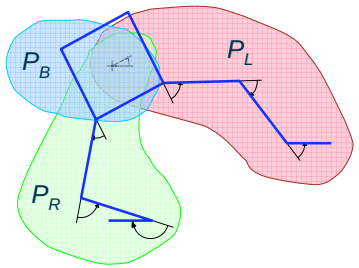
M. Kallmann, A. Aubel, T. Abaci, and D. Thalmann, **Planning Collision-Free Reaching Motions for Interactive Object Manipulation and Grasping**, Eurographics, 2003.

Topics



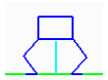
Coordination: Sequencing

- How to sequence primitive controllers?



M. Kallmann, R. Bargmann and M. Mataric´, **Planning the Sequencing of Movement Primitives**, SAB 2004, Los Angeles, CA,.

Coordination: Sequencing

Movement Primitive	Instantiation Condition	Primitive Motion	Parametric Space Dim.
 P_L	support in left foot	moves right leg articulations and body rotation	4
 P_B	support in both feet	moves body, feet fixed with IK	3
 P_R	support in right foot	moves left leg articulations and body rotation	4

Coordination: Sequencing

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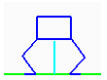
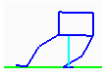
 P_B	support in both feet	moves body, feet fixed with IK	3
 P_R	support in right foot	moves left leg articulations and body rotation	4

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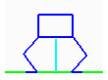 P_B	support in both feet	moves body, feet fixed with IK	3
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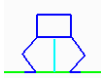
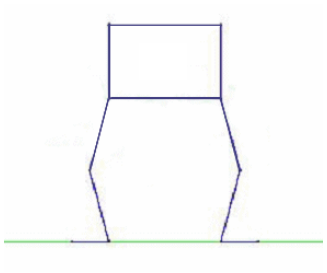
 P_B	support in both feet	moves body, feet fixed with IK	3
 P_R	support in right foot	moves left leg articulations and body rotation	4

Sequencing: Search Tree

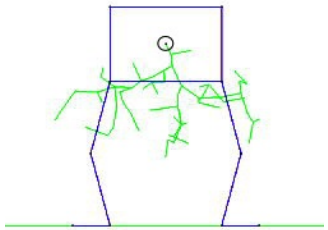
- Define a search tree (single component) having the root as the initial configuration c_i



search tree

Sequencing: Search Tree

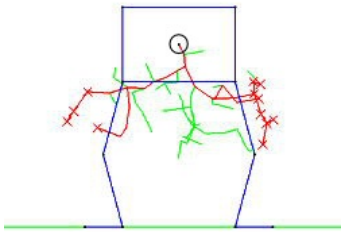
- Expand a roadmap in the parametric space of the motion primitive associated with c



search tree

Sequencing: Search Tree

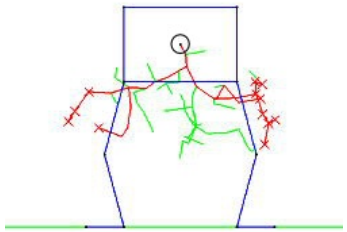
- Determine paths leading to configurations in a different support mode



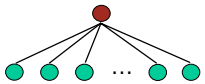
search tree

Sequencing: Search Tree

- Each path represents a new child of c

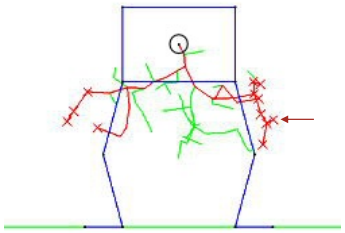


search tree



Sequencing: Search Tree

- Select lowest (A*) cost leaf *c*
  cost(*c*) = length(root,*c*) + dist(*c*,goal)



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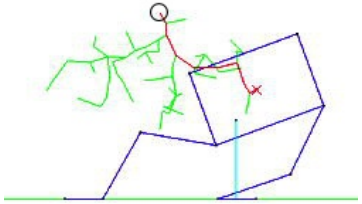
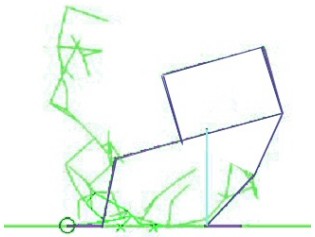


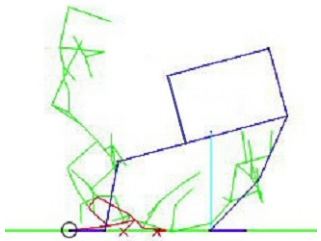
Sequencing: Search Tree

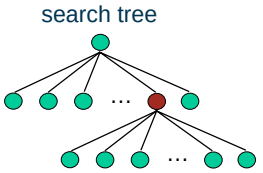
- Expand a roadmap in the parametric space of the new motion primitive associated with *c*



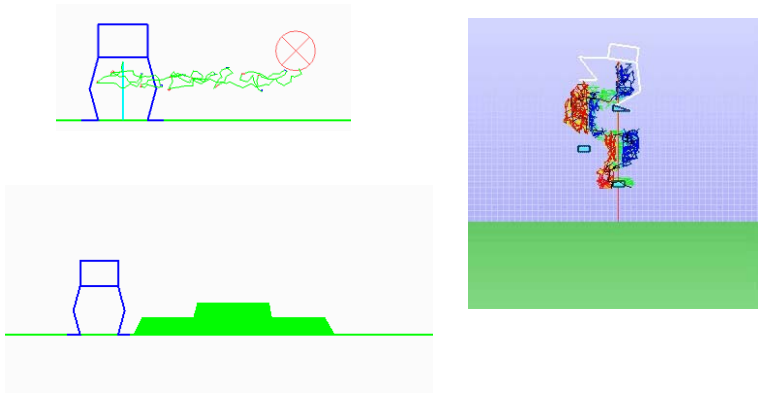
Sequencing: Search Tree

- Determine paths leading to configurations in a different support mode, and add new leafs





Sequencing Examples



M. Kallmann, R. Bargmann and M. Mataric´, **Planning the Sequencing of Movement Primitives**, SAB 2004, Los Angeles, CA,.

Extension to Characters

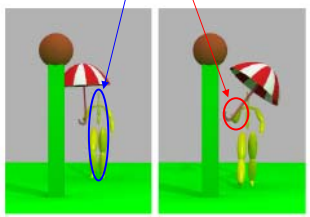
- Analytical IK needed

M. Kallmann, **Analytical Inverse Kinematics with Body Posture Control**, Computer Animation and Virtual Worlds, vol. 19, num.2, May 2008, pp. 79-91(13).

Coordination: Concurrency

- DOFs divided in two parts, for ex:
  - Rear part used by dominant motion skill: walking
  - The rest used by a controlled skill: arm motion

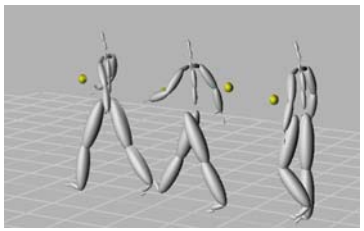
$(p, q^1,\ldots, q^{r-1}, q^r,\ldots, q^n) = (c^w, c^a)$ in $C^W \times C^A$



A. Shapiro, M. Kallmann, and P. Faloutsos, **Interactive Motion Correction and Object Manipulation**, ACM SIGGRAPH Symposium on Interactive 3D graphics and Games (I3D), 2007.

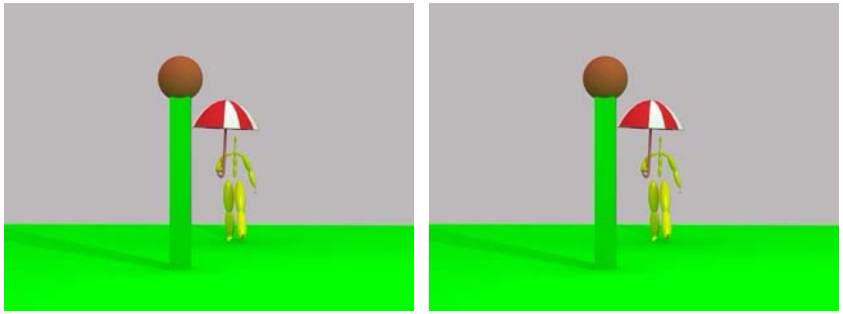
Search Space

- Sample in configuration-time space:
  - Each configuration (c^a,t) has 7 DOFs for arm or leg, plus time component in $[t_a,t_b]$
- For every sample (c^a,t)
  - Compose full body posture ($m^w(t)$, c^a) to test validity when dynamic world is w(t)



Example: Motion Correction

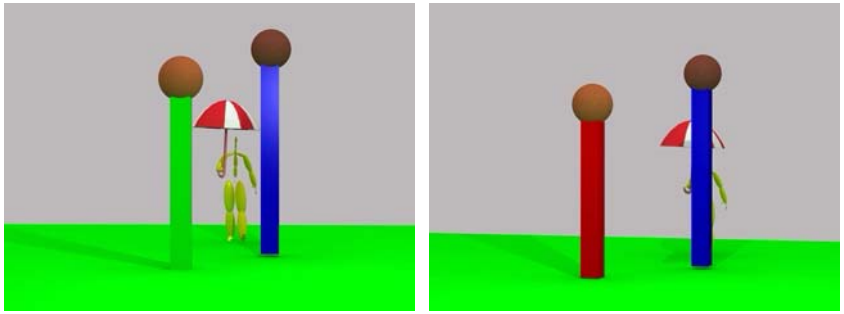
- Avoiding post with umbrella while walking



Full video - http://graphics.ucmerced.edu/videos/2007_i3d_motioncorrection.mp4

Example: Motion Correction

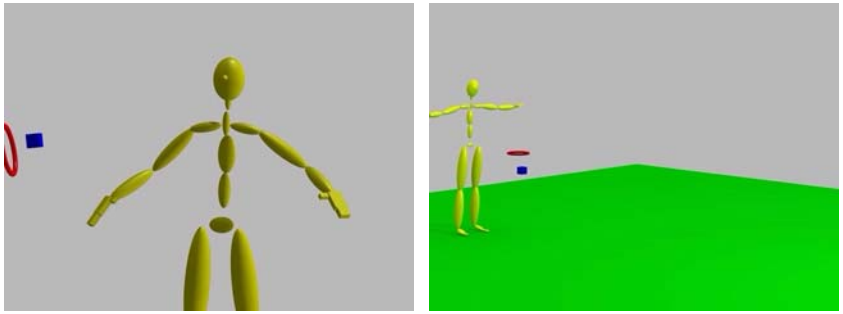
- Additional post added…



Full video - http://graphics.ucmerced.edu/videos/2007_i3d_motioncorrection.mp4

Example: Dynamic Environments

- Dynamic environment and dynamic targets

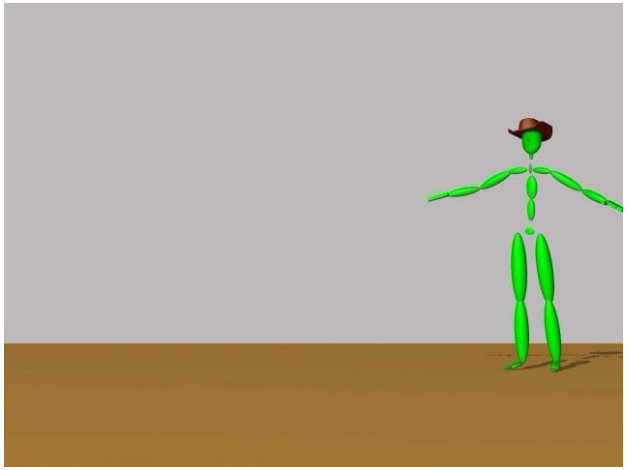


Moving obstacles and moving targets

Moving obstacles, moving targets, moving character

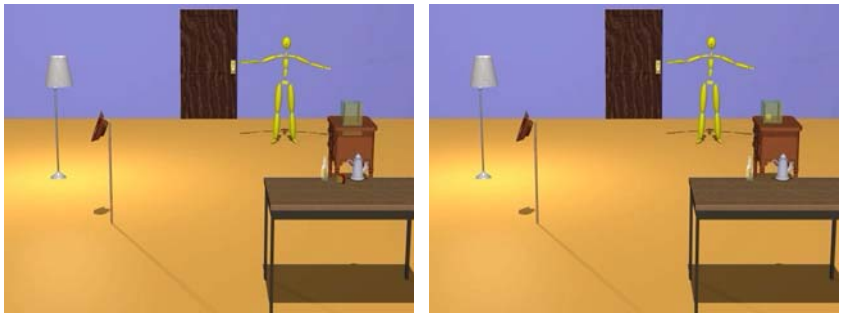
Full video - http://graphics.ucmerced.edu/videos/2007_i3d_motioncorrection.mp4

Example: Dynamic Environments



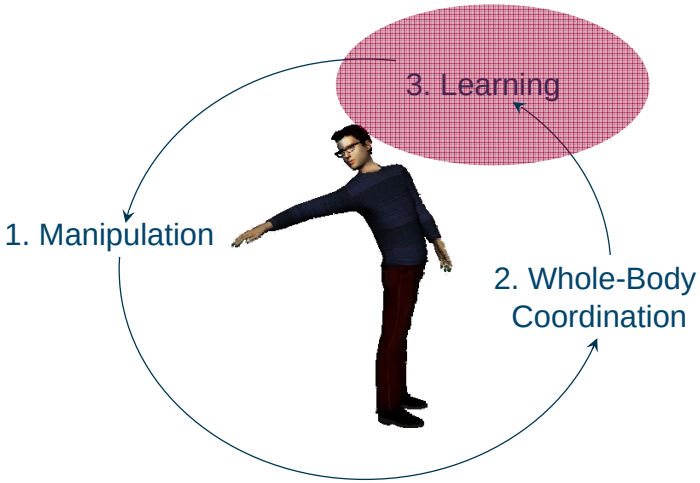
Full video - http://graphics.ucmerced.edu/videos/2007_i3d_motioncorrection.mp4

Example: Object Manipulation



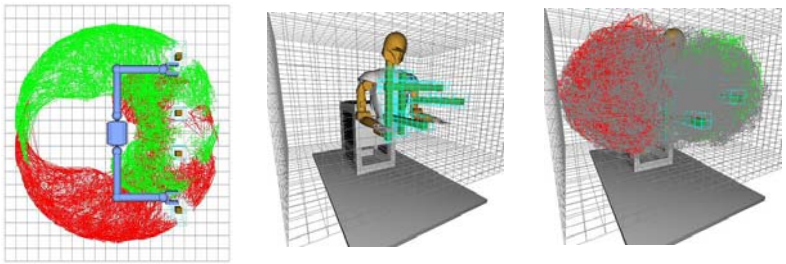
Full video - http://graphics.ucmercedu/videos/2007_i3d_motioncorrection.mp4

Approach



Dynamic Roadmaps

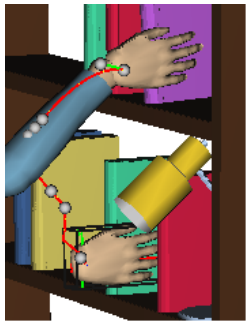
- Pre-compute roadmap only with static obstacles
- On-line roadmap updates with a grid mapping
  - Updates can be significant



M. Kallmann and M. Mataric´, **Motion Planning Using Dynamic Roadmaps**, Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), 2004.

Learning Attractor Points

- Attractor points are easier to maintain



X. Jiang and M. Kallmann, **Learning Humanoid Reaching Tasks in Dynamic Environments**, IROS, 2007.

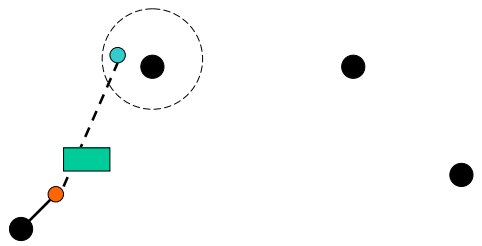
Attractor-Guided Planning

Attractor
Obstacle
Expanding Node
Sample Node

Attractor-Guided Planning

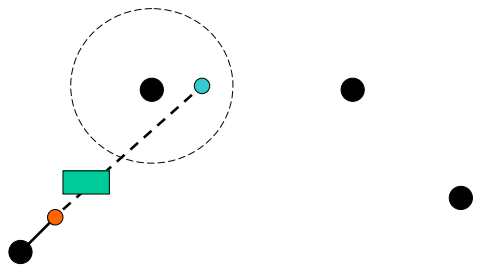
Attractor
Obstacle
Expanding Node
Sample Node

Attractor-Guided Planning



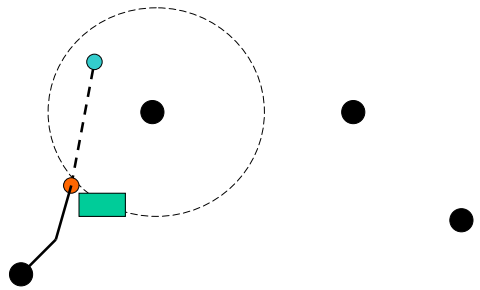
Attractor
Obstacle
Expanding Node
Sample Node

Attractor-Guided Planning



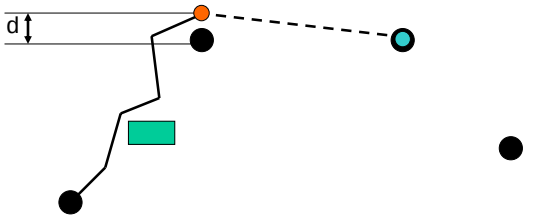
Attractor
Obstacle
Expanding Node
Sample Node

Attractor-Guided Planning



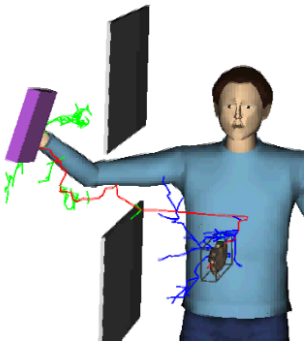
Attractor
Obstacle
Expanding Node
Sample Node

Attractor-Guided Planning

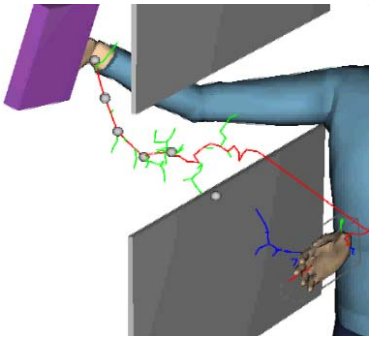


Attractor
Obstacle
Expanding Node
Sample Node

Attractor-Guided Planning

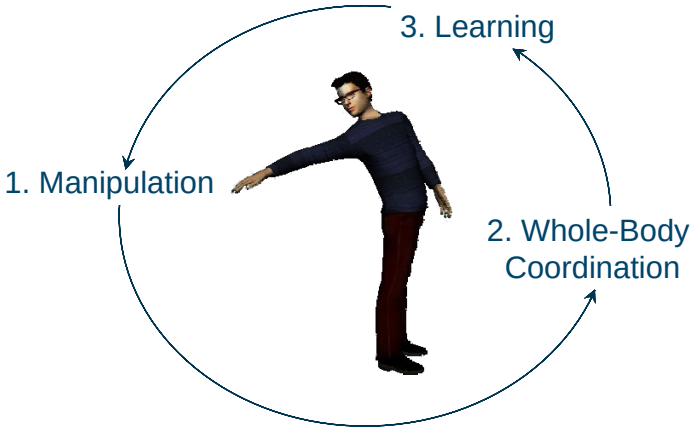


A standard RRT search tree



The AGP search tree

Topics



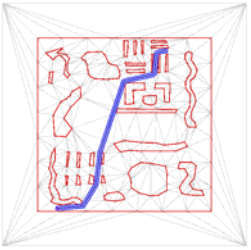
Final Notes

- SIGGRAPH Class 2008

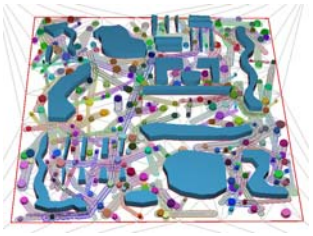
  Motion Planning and Autonomy for Virtual Humans

  - Julien Pettre – INRIA Rennes
  - Marcelo Kallmann – UC Merced
  - Ming Lin – UNC Chapel Hill
  - James Kuffner – CMU
  - Michael Gleicher – University of Wisconsin
  - Claudia Esteves – University of Guanajuato
  - Jean-Paul Laumond – LAAS Toulouse

Final Slide



Path Planning in Triangulations



Multi-Agent Navigation

Deformable Models

And thanks to students and collaborators:
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Mentar Mahmudi, Yazhou Huang,
Oktar Ozgen

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