Navigating with the Pilot

15-494 Cognitive Robotics
David S. Touretzky &
Ethan Tira-Thompson

Carnegie Mellon
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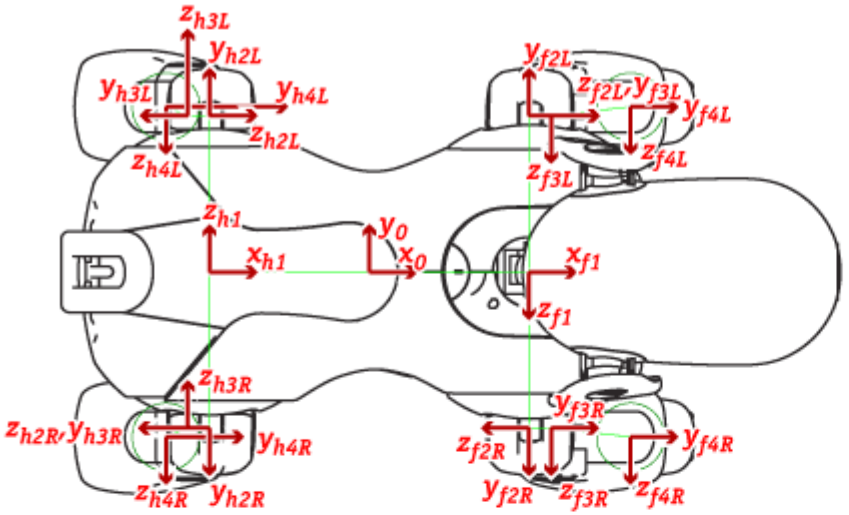
How Does the Robot Walk?

- Multiple walk engines incorporated into Tekkotsu:
  - CMPack '02 AIBO walk engine from Veloso et al. (CMU), with modifications by Ethan Tira-Thompson
  - UPennalizers AIBO walk engine from Lee et al. (U. Penn)
  - XWalk engine by Ethan Tira-Thompson for the Chiara
- Basic idea is the same:
  - Cyclic pattern of leg motions
  - Parameters control leg trajectory, body angle, etc.
  - Many different gaits are possible by varying phases of the legs
  - “Open loop” control: no force feedback
  - Can't adapt to rough terrain
  - Can move quickly, but not very accurately

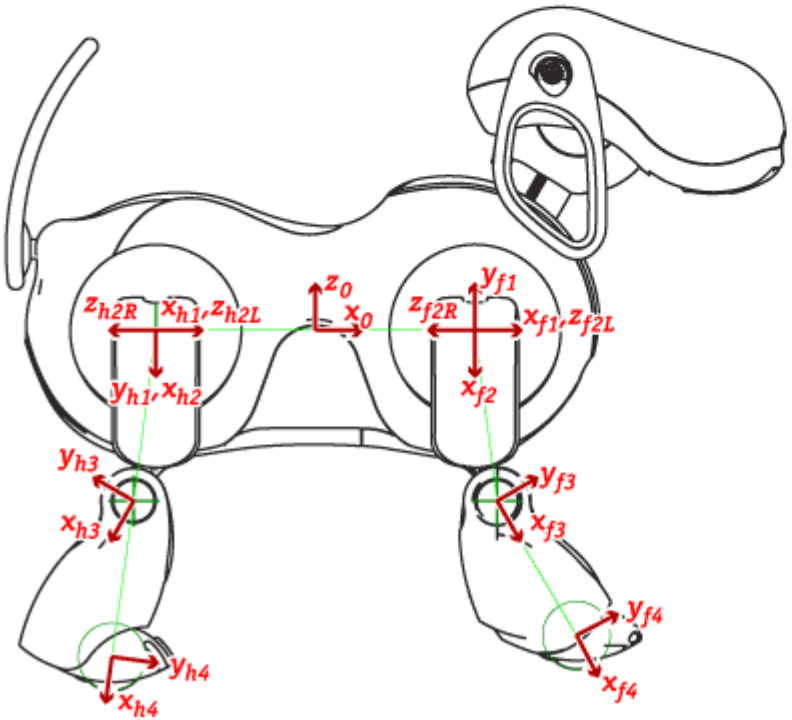


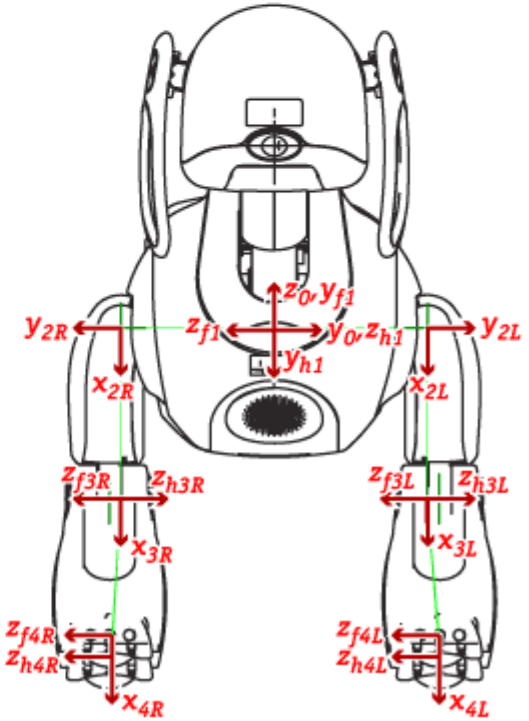
ERS-7 Legs

	Δx	Δy	Δz
1. - shoulder	65	0	0
2. - elevator	0	0	62.5
3. - knee	69.5	0	9
f4. - ball	*69.987*	*-4.993*	4.7
h4. - ball	*67.681*	*-18.503*	4.7

Diameter of ball of foot is *23.433*mm
Each link offset is relative to previous link

The shins shown in this diagram appear to be slightly distorted compared to a real robot. Corresponding measurements have been taken from actual models.





Modified CMPack Walk Engine

46 Leg Parameters:

- Neutral kinematic position (3x4)
- Lift velocity (3x4)
- Lift time (1x4)
- Down velocity (3x4)
- Down time (1x4)
- Sag distance (1)
- Differential drive (1)

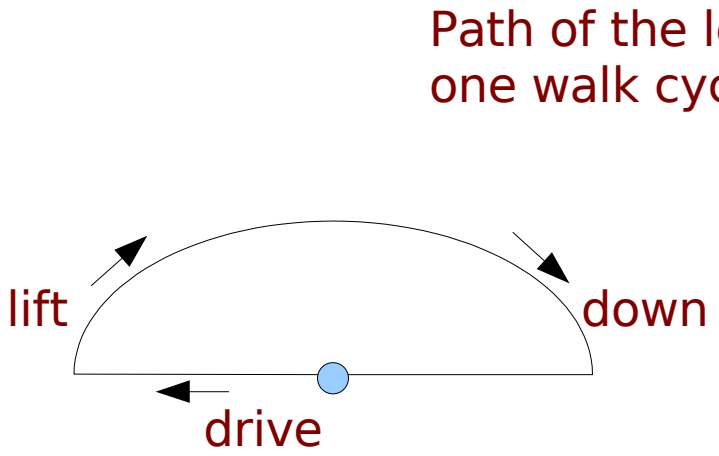
5 Body Parameters:

- Height of body (1)
- Angle of body (1)
- Hop amplitude (1)
- Sway amplitude (1)
- Walk period (1)

Modified fom Sonia Chernova's lecture notes

Neutral Kinematic Position

- Position (x,y,z) of the leg on the ground at some fixed point during the walk cycle.
- Where the legs would hit the ground if the robot were pacing in place (traveling with zero velocity).



From Sonia Chernova's lecture notes

Leg Lift and Leg Plant

- Lift velocity vector (mm/sec) determines how leg is lifted off the ground
- Down velocity vector (mm/sec) determines how leg is placed back on the ground.

- Lift time and down time (1 value each per leg) control the order of leg motions.
  - Expressed as a percentage of time through the walk cycle that the leg is raised and lowered.
  - Governs which legs move together and which move at opposite times: pace vs. trot vs. gallop.

From Sonia Chernova's lecture notes

Body Angle/Height; Hop & Sway

- Body angle (radians) relative to the ground, measured at the origin of the motion coordinate frame.
  - Controls whether the robot is pitched up or down.
- Body height (mm) relative to the ground, measured at the origin of the motion coordinate frame.
- Hop and sway amplitudes (mm) constrain the body's vertical and horizontal oscillations during walking. (Usually set to 0.)

From Sonia Chernova's lecture notes

Walk Period

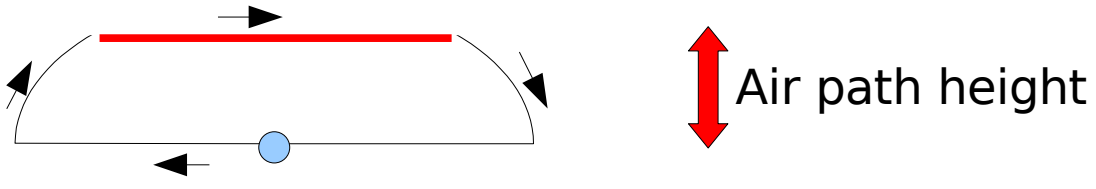
- The walk period (msec) specifies the time of one walk cycle.
- Note that this is independent of speed.
- To walk faster, the AIBO takes larger steps; it does not change the period of the walk cycle the way a person would do.

From Sonia Chernova's lecture notes

- Chiara walks are statically stable, and period does vary with speed.

New CMPack Parameter: Front & Back Leg Height Limits

- Height of the air path of the front and back legs.
- Upper bound: may not be reached, depending on other leg motion parameters.



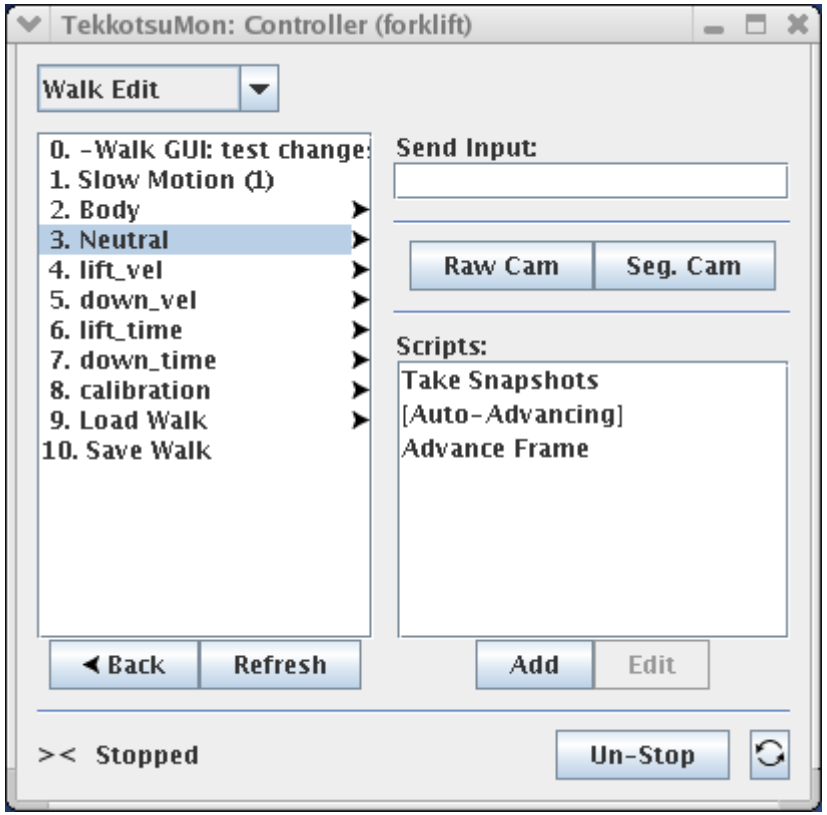
From Sonia Chernova's lecture notes

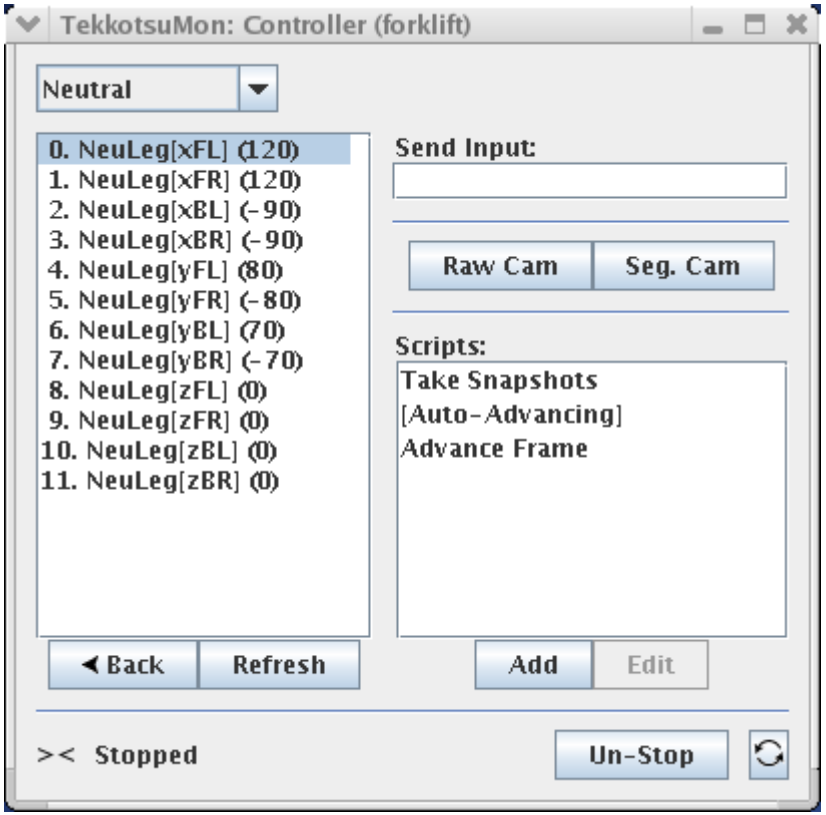
Walk Parameter Optimization

- Many RoboCup groups use machine learning techniques to optimize walk parameters.
- CMPack uses a genetic algorithm.
- Candidates are evaluated by having the robot walk and measuring the results.
- CMPack got 20% speedup over previous hand-tuned gaits.

Tekkotsu Walk Editor

- Root Control > File Access > XWalk Edit
- Values are stored in a walk parameter file
  - Default parameter file is walk.plist



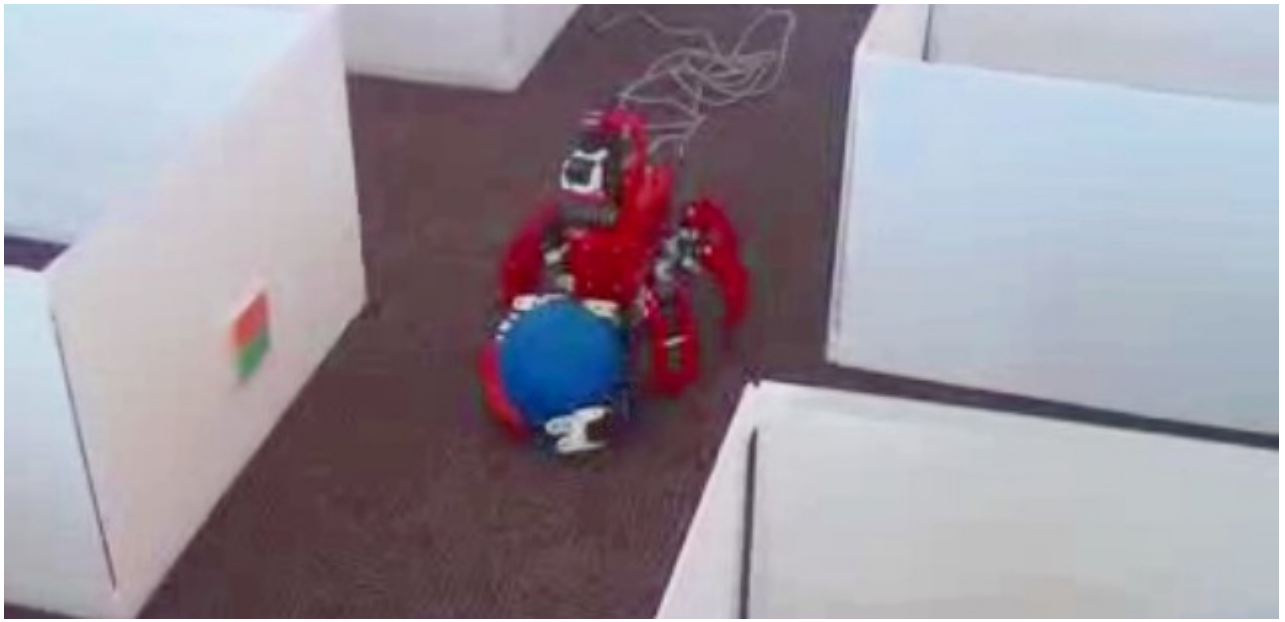


Chiara Gaits

- One leg at a time (default). walk.plist
  - Requires the least power.
  - Slow: 6 beats/cycle.
- Two legs at a time. walk2.plist
  - Intermediate speed and power.
  - 3 beats/cycle.
- Three legs at a time: tripod gait. walk3.plist
  - Fastest gait that is still statically stable.
  - Requires lots of power.
  - 2 beats/cycle.

A Five-Legged Gait

- Sherene Campbell of Florida A&M University got the Chiara to walk on five legs so it could use its right front leg as a pincer. (See video on YouTube.)

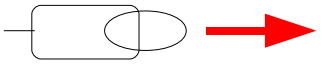


XWalkMC

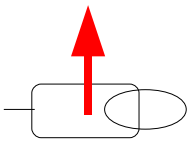
- XWalkMC is a motion command that uses the Chiara walk engine to calculate leg trajectories.

- Walking is controlled by three parameters:

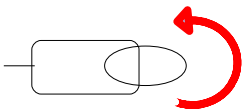
  - x velocity (forward motion)



  - y velocity (lateral motion: strafing)



  - angular velocity (rotation)

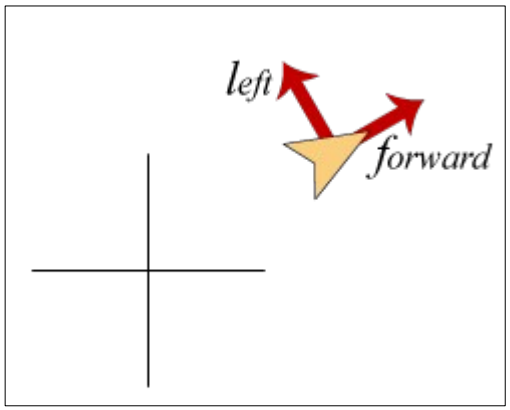


WalkNode

- Subclass of StateNode
- Activates a WalkMC on start()
- Deactivates it on stop()
- Provides functions to set (x,y,a) velocities
- WalkNode($, xdisp, ydisp, adisp, time, WalkNode::DISP)
  - Displacements in mm and radians; time in sec.
  - Use a time of 0 to request maximum velocity.
- WalkNode($, xvel, yvel, avel, time, WalkNode::VEL)
  - Velocities xvel, yvel in mm/sec; avel in rad/sec; time in sec

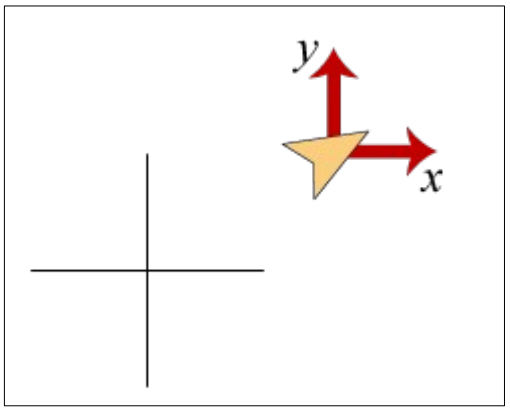
Waypoint Engine

- Takes the robot through a path defined by a series of waypoints.
- Each waypoint specifies a position (x,y) and orientation.
- Three waypoint types:



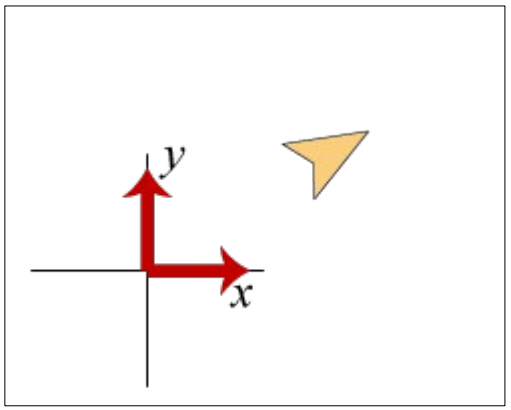
Egocentric

"Three steps forward"



Offset

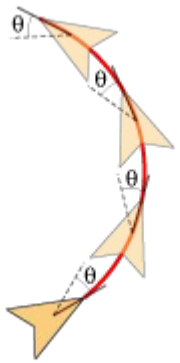
"Three steps north"

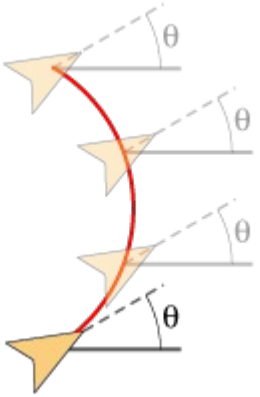


Absolute

"To (30,12)"

Controlling Body Orientation





`angleIsRelative == true`

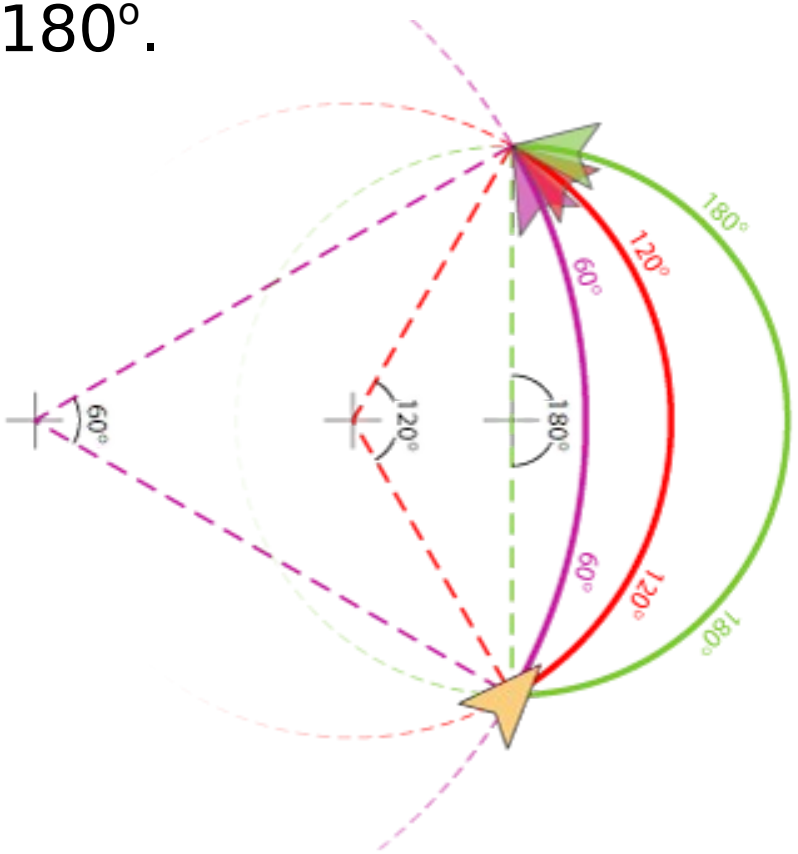
The angle is relative to the path, so an angle of 0 means the robot's body will **follow** the direction of travel.

`angleIsRelative == false`

The angle is relative to the world coordinate system, so the body will **hold** a constant heading while walking.

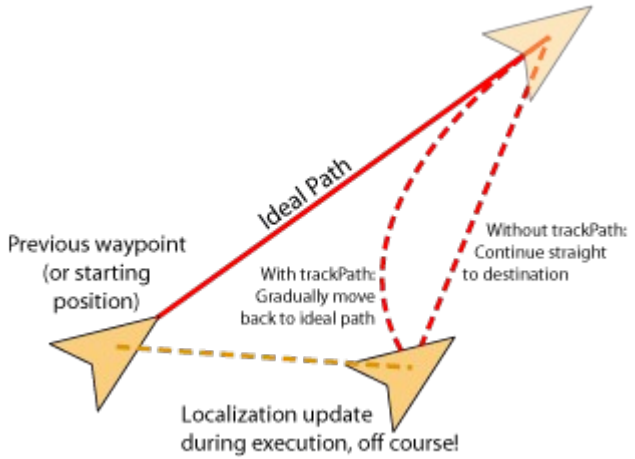
Arcing Trajectories

- Paths can be either straight lines or arcs.
- Arc parameter (in radians, not degrees) corresponds to the angle of the circle which is swept.
- Don't use values > 180º.



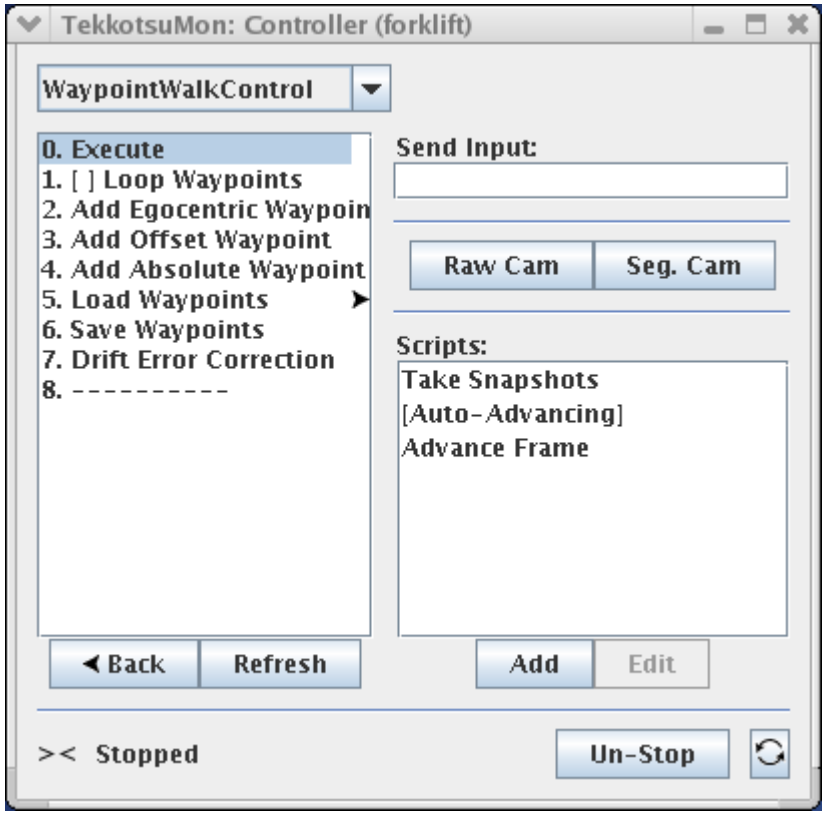
Track Path (Error Correction)

- setCurPos() function can be used to correct position if you have a localization module.
- When trackPath flag is true, the robot will attempt to return to its planned path after a perturbation.
- When false, it just goes straight to the destination.



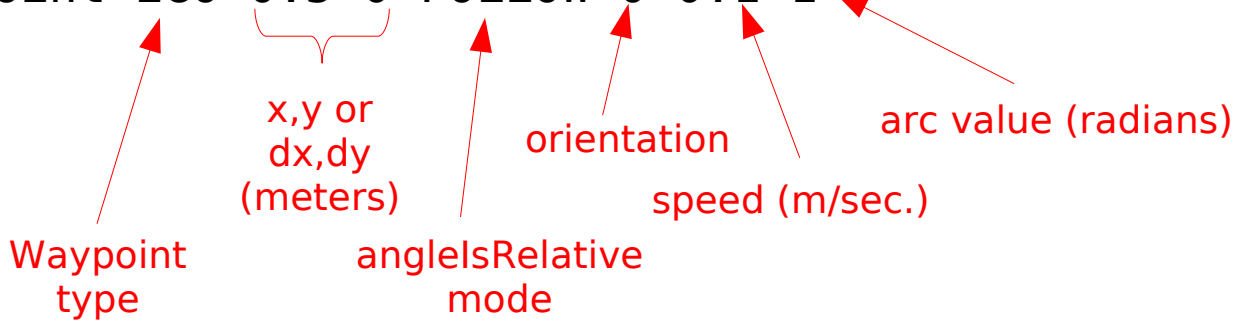
Waypoint Walk Editor

- Root Control > File Access > WaypointWalk Control
- Allows interactive creation, execution of waypoint file.



Sample Waypoint File

```
#WyP
#add_{point|arc} {ego|off|abs} x_val y_val {hold|follow} angle_val
#                                                        speed_val arc_val
max_turn_speed 0.65
track_path 0
add_point EGO 0.3 0 FOLLOW 0 0.1 0
add_point EGO 0.5 0 FOLLOW 0 0.1 1
#END
```



WaypointWalk

- WaypointWalk is a motion command.
- Can load waypoints from a waypoint file, or construct them dynamically with function calls.
- Uses a XWalkMC to do the actual walking.
- XWalkMC will post status events indicating the progress of the walk.

Manipulation by Walking

- Course project by Ethan Tira-Thompson

  http://ethan.tira-thompson.com/stuff/16-741/project.html

- Inspired by Matt Mason's “mobipulator” project.

The Pilot

- Higher level approach to locomotion.
- Specify effect to achieve, rather than mechanism:
  - Walk a certain distance.
  - Go to an object.
- Specify policies to use:
  - Cliff detection (IR sensor)
  - Obstacle avoidance (turn off to knock down soda cans)
  - Localization procedure
- Experimental code; changing rapidly.

Pilot Request Types

- walk – essentially a WalkMC request
- waypointWalk – provides Waypoint walk functionality
- setVelocity – set speed and go forever
- localize – look for landmarks and invoke the particle filter
- goToShape – path plan and travel to the location of a shape on the world map

- *More functions are planned...*

Trivial Pilot Example

```
$nodeclass MyPilotDemo : VisualRoutinesStateNode {

  $nodeclass Goer : PilotNode($, PilotTypes::walk) : doStart {
    pilotreq.dx = 500;   // forward half a meter

  }

  $setupmachine{
     Goer =PILOT=> SpeechNode($,”I have arrived”)
  }



}



REGISTER_BEHAVIOR(MyPilotDemo);
```

Collision Detection

```
$nodeclass PilotLab3 : VisualRoutinesStateNode {

  $nodeclass Forward500 : PilotNode($, PilotTypes::walk) : doStart {
    pilotreq.dx = 500;
    pilotreq.forwardSpeed = 100;    // speed 100 millimeters/second
  }

  $nodeclass Backup : PilotNode($, PilotTypes::walk) : doStart {
    pilotreq.dx = -100;             // negative displacement means back up
    pilotreq.forwardSpeed = 30;     // speeds are always non-negative
  }

  $setupmachine {
    forward: Forward500
    forward =PILOT=> SpeechNode($,"done")
    forward =PILOT(collisionDetected)=>
       SpeechNode($,"Ouch! I hit something.") =C=> Backup
  }

}
```

Path Planning

```
$nodeclass DoIt : PilotNode($, PilotTypes::goToShape) : doStart {

   NEW_SHAPE(avoidMe, EllipseData,
     new EllipseData(worldShS, Point(250, 500, 0, allocentric),
                                80, 50, 0.5));
   avoidMe->setColor(rgb(255,0,0));

   NEW_SHAPE(destination, PointData,
     new PointData(worldShS, Point(700, 700, 0, allocentric)));
   destination->setObstacle(false);

   pilotreq.targetShape = destination;
}
```