Navigating with the Pilot

15-494 Cognitive Robotics
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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

<table>
<thead>
<tr>
<th></th>
<th>Δx</th>
<th>Δy</th>
<th>Δz</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. - shoulder</td>
<td>65</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2. - elevator</td>
<td>0</td>
<td>0</td>
<td>62.5</td>
</tr>
<tr>
<td>3. - knee</td>
<td>69.5</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>f4. - ball</td>
<td>69.987</td>
<td>-4.993</td>
<td>4.7</td>
</tr>
<tr>
<td>h4. - ball</td>
<td>67.681</td>
<td>-18.503</td>
<td>4.7</td>
</tr>
</tbody>
</table>

Diameter of ball of foot is 23.433mm
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 from 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).
  - Requires the least power.
  - Slow: 6 beats/cycle.

- Two legs at a time.
  - Intermediate speed and power.
  - 3 beats/cycle.

- Three legs at a time: tripod gait.
  - Fastest gait that is still statically stable.
  - Requires lots of power.
  - 2 beats/cycle.
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)
XWalkNode

- Subclass of StateNode
- Activates an XWalkMC on start()
- Deactivates it on stop()
- Provides functions to set (x,y,a) velocities

XWalkNode($, xvel, yvel, avel)
- xvel, yvel in mm/sec; avel in rad/sec

XWalkNode($, xvel, xdisp, yvel, ydisp, avel, adisp)
- velocities in mm/sec and rad/sec; 0 means “max speed”
- displacements in mm and rad
WalkNode

- For the iRobot Create, “walking” means driving.

- `WalkNode($, xvel, yvel, avel)`
  - `xvel` = velocity in mm/sec
  - `yvel` must be zero
  - `avel` = angular velocity in radians/s

- `WalkNode($, xdist, ydist, adist, 1)`
  - `xdist` = distance in mm
  - `ydist` must be zero
  - `adist` = angle in radians
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 > 180°.
Track Path (Error Correction)

- The `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

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

Waypoint type
angleIsRelative mode
orientation
speed (m/sec.)
arc value (radians)
x,y or dx,dy (meters)
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.
The Pilot

- Higher level approach to locomotion.

- Specify effect to achieve, rather than mechanism:
  - Go to an object.
  - Maintain a bearing or distance relative 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 an XWalkMC request

- **WaypointWalk**
  - Waypoint walk functionality plus extras

- **visualSearch**
  - Use Lookout to search for an object; may rotate the body

- **gotoShape**
  - Travel to the location of a shape on the world map

- *More functions are planned...*
Trivial Pilot Example

#nodeclass MyDemo : VisualRoutinesStateNode

  #shortnodeclass Goer : PilotNode(PilotRequest::walk) : DoStart
  pilotreq.x = 500;  // forward half a meter

#nodemethod setup

  #statemachine
  startnode: Goer =PILOT=> SpeechNode($,"I have arrived")
  #endstatemachine

#endnodeclass
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.