Developing CPG based periodic motions using tactile interaction

Fabio DallaLibera*  * DEI, Padua University, Italy
Takashi Minato†  † JST ERATO, Osaka, Japan
Hiroshi Ishiguro†‡  ‡ Dept. of System Innovation, Osaka University, Japan
Emanuele Menegatti*  Osaka University, Japan

CPGs have numerous parameters

Manually set
- Control over the resultant motion
- Change-effect relationship
- Often unintuitive

Automatically set
- Little user effort
- Difficult to provide a good evaluation function

Development is time consuming

Tactile interaction

Tradeoff:
- Intuitive, limited effort
- Control over the result

Concept

Oscillator Model

Similar touches must lead to similar changes, CPG must be very predictable:

\[ z_j' = \gamma (\mu_j - |z_j|)^2 z_j + i \omega_j z_j + F_j(t) \]

\[ \omega_j = p_j \omega_0 \]

\[ m_j = \Re \{ z_j \} + o_j \]

\[ F_j(t) = w e^{i \phi_j} z_j^0 \]

\[ \omega_0 \in \mathbb{R} \] reference frequency parameter

\[ \mu_j \in \mathbb{R} \] oscillation amplitude parameter

\[ \gamma \in \mathbb{R} \] recovery speed after perturbation

\[ p_j \in \mathbb{N} \] frequency parameter

\[ \Re \{ \cdot \} \] real part

\[ \phi_j \in \mathbb{R} \] phase parameter

\[ o_j \in \mathbb{R} \] oscillation center parameter

\[ z_j^0 \in \mathbb{C} \] state variable of the reference oscillator

\[ F_j \in \mathbb{C} \] external perturbation

Experiment

Motion Development Time (min) Changes (offset, amplitude, frequency, phase)

<table>
<thead>
<tr>
<th>motion</th>
<th>Development Time (min)</th>
<th>Changes (offset, amplitude, frequency, phase)</th>
</tr>
</thead>
<tbody>
<tr>
<td>crawling</td>
<td>56</td>
<td>22, 57, 2, 39</td>
</tr>
<tr>
<td>sidestep</td>
<td>29</td>
<td>56, 31, 4, 18</td>
</tr>
<tr>
<td>walking</td>
<td>34</td>
<td>132, 60, 15, 28</td>
</tr>
</tbody>
</table>

Humans implicitly control many aspects: ex. in crawling pitch&roll range smaller than GA

Touch protocol

Determination of the oscillator:
Most distal joint generating movement in the direction normal to the sensor surface

Determination of the parameter:
- Offset variation → very long push
- Amplitude variation → long push
- Phase variation → single tap
- Frequency increase → double tap, both short
- Frequency decrease → double tap, second long

Touch protocol

Phase change time reference [radians] 0 \( \pi/3 \) \( 2\pi/3 \) \( \pi \) \( 4\pi/3 \) \( 5\pi/3 \) \( 2\pi \)