Abstract

Central Pattern Generators (CPGs) are a powerful bio-inspired method to generate motions. Usually the numerous parameters of the CPGs are set by learning algorithms like genetic algorithms or policy gradient. This gives the user little control over the resultant motions, which might look awkward. We propose a methodology to set the CPG parameters by user interaction, in detail by touch interaction. We describe the elements of the developed system and verify its feasibility by the realization from scratch of a crawling motion.

概要

CPGによってロボットの運動を生成する場合、CPGのパラメータ調整の困難さが問題となる。通常、パラメータ調整は遺伝的アルゴリズムや方策勾配法などの利用で行われるが、望みの動作を実現するための評価関数の決定は困難である。一方、ユーザが手動でパラメータ調節を行う場合、パラメータ空間が大きく、パラメータ間の関係が複雑であることから直感的に調節することができない。そこで本研究では、ユーザが全身触覚センサを持つロボットを直接触れることでCPGのパラメータを調節し、目的の動作を生成する手法を開発する。

Human intuition often employed for motion development

(Breaazeal 04), (Ikeura et al 90), ...

Several Oscillators available:

- Sinusoidal (Morimoto et al 06)
- Hopf/adaptive frequency Hopf (Righetti et al 06)
- Rayleigh (De Pina Filho et al 05)
- Van der Pol (Veskos et al 05)
- FitzHugh-Nagumo (Collins et al 94)
- Hopfield (Mathayomchan et al 02)
- Matsuoka (Inada et al 03, Inoue et al 04)
- ...

Five network structures usually employed in literature

- Chain
- Full connections
- Homologous joints
- Quadraped robot (Tsujiya et al 03)
- Quadraped robot (Kimura et al 00)

Legend

- Oscillator
- Actuator
- Connection
- Between oscillators
- Control of an actuator by an oscillator
- Body part

We chose the Hopf oscillator and the star topology for their generality and predictability.
Avoid useless computation:

- **direct mapped cache of postures** (useful for periodic motions):
  - address is a hash of the angles, discretized by $1°$
  - content = collision yes/no
  - list of parts that cannot collide
  - list of parts moved when a single joint is rotated

**Self collision prevention system**

- Some CPG parameter settings cause self collisions
- Real hardware can be damaged, online fast prevention of self collisions required
  - guarantee to detect collision postures
  - no need to detect collision-free postures with high precision
- Simplified model: links modeled as parallelepipeds

**Determinant of the oscillator whose parameters should be modified:**

- Most distal joint that generates a movement in the direction normal to the sensor surface

**Determination of the parameter change**

- Time reference: oscillator phase
- $\tau_{p}$, pushing time
- $\rho_{js}$, dot product between $\mathbf{n}$, normal to the pressed sensor surface
- $\Delta$, derivative of the position of the center of sensor $s$ when selected joint $j$ is rotated
- Constants $\Theta_{o}, \pi, \omega_{p}, \omega_{n}, \pi, \pi, \omega_{r}, \pi, \omega_{z}$

**Offset**

- Very long push $\tau > \Theta_{o}$
- Amplitude medium push $\Theta_{o} > \tau > 0$
- Phase single tap $\tau < \Theta_{o}$

**Frequency double tap**

- short-short = increase frequency
- short-long = decrease frequency

**Comparison**: optimization of the parameters by Genetic Algorithm

- (population size 20, 60 generations, real value encoding, roulette wheel selection, mutation probability 1)
- Task achieved but motion looks awkward
- Larger ranges for the pitch and roll

**Future works**

- Distinguish between user touches and floor contact
- Introduction of feedback to entrain to the environment
- Implementation on the real hardware

**References**