Control of biped locomotion inspired from walking in monkeys

Charles-Henry Houdemer

Biorob
Ecole polytechnique fédérale de Lausanne

LSRO
École polytechnique fédérale de Lausanne

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Supervisors : Sarah Dégallier, Jesse Van den Kieboom, Solaiman Shokur, Auke Jan Ijspeert

Outline

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   - Results
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Insights on BMIs

- Three different forms :
  - Invasive
  - Partially-invasive
  - Non-invasive
- Two types :
  - Motor BMI
  - Sensory BMI
- Transform data either from or to the brain by predicting and interpreting correct behaviour

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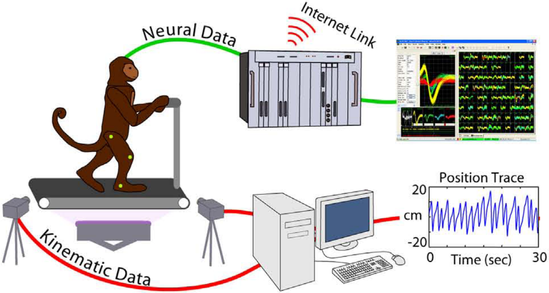
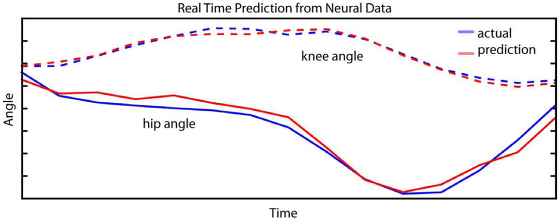
Previous work

- Fitzsimmons' work on monkeys[1] :
  - Model try to predict the position of each joint
  - Quality of predictions is good for one direction but degrades for two directions
  - Must switch between two models for forward and backward

Experimental setup



Achievements



Goal of the project

- Build a CPG with the data from Nicolelis Lab in Duke University
- Data consists in Cartesian positions of hip, knee and ankle positions, speed of walking and indication if the foot is on the ground
- Reproduce the walking gait of a rhesus monkey with this CPG recieving basic inputs from a BMI
- Generalize it if possible to :
    - Different sessions;
    - Different speeds;
    - Different monkeys;
    - Both directions.

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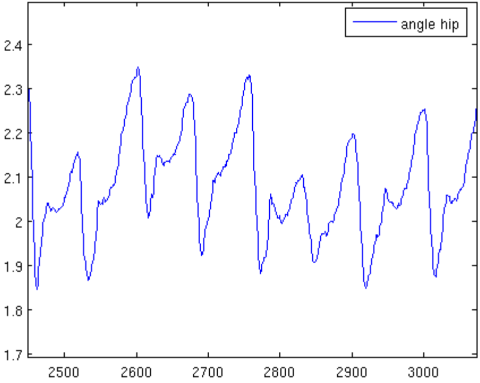
Challenges

- Monkeys are not naturally bipedal
- Monkeys' behaviour is not always predictable
  - Play with holding bar
  - Make feet slide on the ground
  - Video
  - Causes variability in measurements

Typical variations in the hip angles



Long term goals

- Allow paraplegics to regain the control of their legs
- Allow for more robust predictions
  - Less informations are needed
  - Less neurons are needed
  - May lose more neurons before losing efficency

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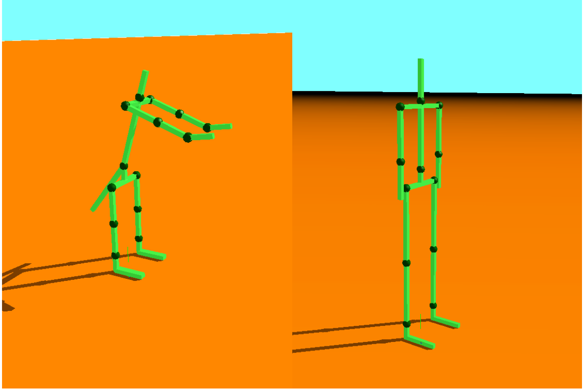
Creation

Built from the webots human model of Jesse van den Kieboom

- Only hand size and total weight were known
- Size and masse extrapolated with data from Hamada[2]
- Main differences :
  - Tail added;
  - Head lighter than with normal division to reflect that a monkey head is lighter than a human one.
- Uses a grannywalker to prevent it from falling on its side

Monkey and human models



- Curves were normalized for testing
    - CPGs can be easily scaled but not change shape
- For each cycle :
    - Amplitude was normalized
    - $\hat{y} = (y - \bar{y})/(y_{max} - y_{min})$
    - Frequency was normalized by scaling each time interval to a reference one

Duty factor

- Duty factor
  - Decreases with speed
  - Right leg different than left one
  - Variance lower with high speeds
- Equation of the form (for one cycle) :
  - $\frac{stancetime}{totaltime}$

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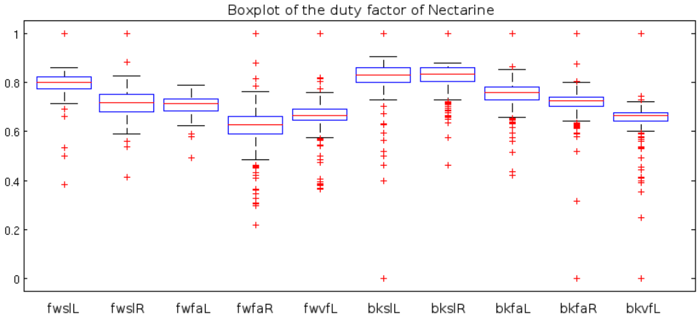
Boxplot of the duty factor of Nectarine
1
0.8
0.6
0.4
0.2
0
fwslL
fwslR
fwfaL
fwfaR
fwvfL
bkslL
bkslR
bkfaL
bkfaR
bkvfL

Square errors

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  - Mean error low
  - Variance relatively low
- Equation of the form (for one cycle) :
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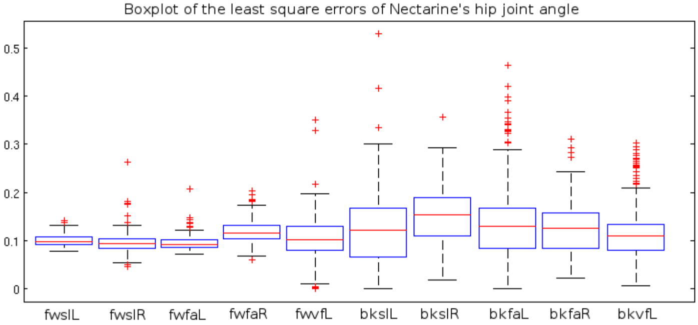
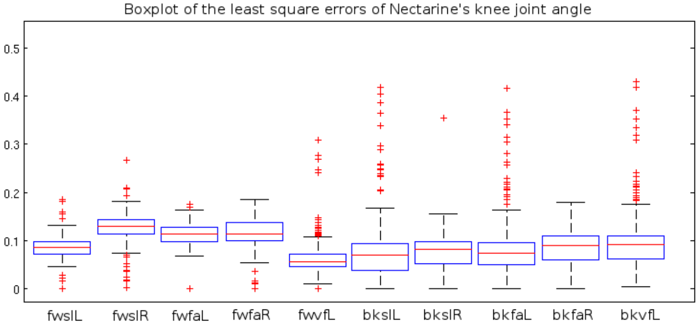
Square errors of Nectarine - Hip



Square errors of Nectarine - Knee



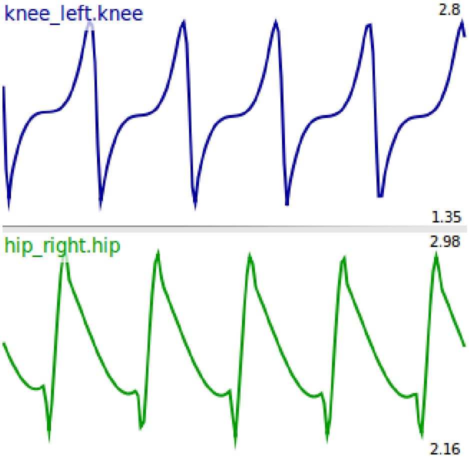
Design of the CPGs

- Data were in Cartesian form and contained the positions of the knee, hip and ankle
- CPG is of the form :
  - $\dot{x}_i = \gamma_i(f_i(\theta_i) - x_i) + \frac{df_i}{d\theta_i} \cdot \dot{\theta}_i + K_i$
- Phase coupling is of the form :
  - $p = sin(from.p * 2 * \pi - to.p * 2 * \pi - bias)$
- A cycle was arbitrarily chosen for the building of the CPG
  - Average
  - Starts and ends approximatively at the same height

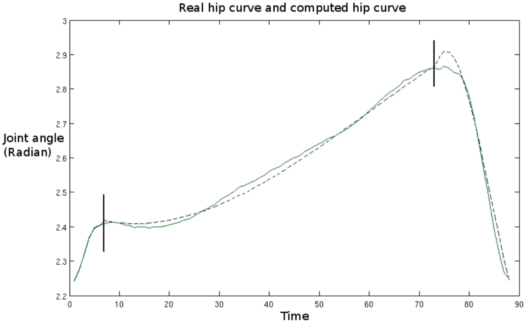
Design of the CPG

- Joint angle cycle was cut in three parts for interpolation
- Parts were interpolated with third degree polynomials
- Polynomials were used with cpgstudio
- Testing on webots was done with the cpg file obtained through cpgstudio and the libcpg, both from Jesse van den Kieboom
- The necessary data for building a CPG for the ankle and adapting the foot were obtained by tracking positions on a video with the help of Kostas Karakasiliotis. The implementation of the CPG was abandoned in order not to add more complexity to an already well performing model.

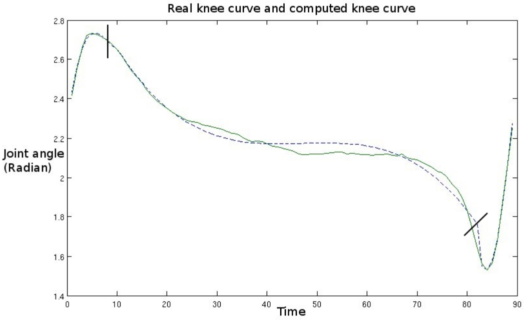
CPG output



Real and interpolated curves - Hip



Real and interpolated curves - Knee



Visual tests

- Can walk forward and backward
- Handles different speeds
  - Limited by ground adherence
- Video

Future improvements

- Implement flexible feet for more efficient foot contact
- Modify the polynomials to reduce the error in interpolation further in order to obtain a interpolated curve even more close to a real one

References

1. Nathan A. Fitzsimmons, Mikhail A. Lebedev, Ian D. Peikon,and Miguel A. L. Nicolelis. Extracting kinematic parameters for monkey bipedal walking from cortical neuronal ensemble activity.
2. Yuzuru Hamada, Nontakorn Urasopon, Islamul Hadi, and Suchinda Malaivijitnond. Body Size and Proportions and Pelage Color of Free-Ranging Macaca mulatta from a Zone of Hybridization in Northeastern Thailand.