Integrating humanistic research in the development of training robots

Anders Stengaard Sørensen

University of Southern Denmark

Invited talk at: The full day workshop on bodily human robot interaction
IEEE Human Robot Interaction Conference, Daegu Korea, 2019

March 11. 2019
Anders Stengaard Sørensen

Ph.D. Associate Professor Head of Training Technology Lab

• Expert in computer control
  • Sensors
  • Electronics
  • Physics
  • Math
  • Embedded systems
  • Robots

• Taking an interest in
  • Training
  • Rehabilitation
  • Bodily HRI

$$\int e^x \, dx = e^x$$

$$e^{j\pi} + 1 = 0$$
Ambition: $\mu m$ precision — $\mu s$ timing
Genric controller platform
SDU Training Robots 2010 — today

- Rehab training
- Elite training
- Preventive & recreational training

<table>
<thead>
<tr>
<th>Tech</th>
<th>Health</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robotics</td>
<td>Training physiology</td>
</tr>
<tr>
<td>Platform</td>
<td>Process</td>
</tr>
</tbody>
</table>
SDU Training Robots 2010 — today

- Rehab training
- Elite training
- Preventive & recreational training

<table>
<thead>
<tr>
<th>Tech</th>
<th>Health</th>
<th>Hum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robotics</td>
<td>Training physiology</td>
<td>Social practices</td>
</tr>
<tr>
<td>Platform</td>
<td>Process</td>
<td>Meaning</td>
</tr>
</tbody>
</table>
Example: Maximum load eccentric training
Mechanistic view is not enough!

There is more to physical human interaction than physics!

Why science teachers should not be given playground duty.

Unknown author
First steps

- **Establishing the simplest possible framework**
  - Coordinated sequential interaction
  - Examples of actions
  - Examples of interaction sequences

- **Establishing common concepts and terminology**
  - Discussions and debate
  - Experiments and analysis
  - Teaching engineering students EMCA & Embodied interaction
  - Workshops

- **Describing, analyzing and learning from experiments**
  - Impedance states
  - Impedance transitions
  - Actions that are recognized (Cataphoric)
  - Actions that are not
  - Tools for integrated video-, state- and sensor- analysis

- **Conclusions, suggestions and improvements**
- **Repeat!**
RoboTrainer-Light

- Rope pulling “robot”
- “Impedance machine”
  \[ F = \psi \left( t, x, \frac{dx}{dt}, \frac{d^2x}{dt^2}, \ldots \right) \]
- High bandwidth dynamics FPGA control system
  (Much faster than humans)

Anders Stengaard Sørensen

Integrating HUM & TECH in training robots
Remember Gitte’s talk? Embodied actions... Simplest possible robot equivalent?

- Production
- Perception
- Typification
Remember Gitte’s talk?
Embodied actions... 
- Production  
- Perception 
- Typification

Simplest possible robot equivalent?
State machine (DFA)
- Set of states 
- Set of input ‘symbols’ 
- Transition function

It is far from a perfect equivalent!
Remember Gitte’s talk? 
Embodied actions... 

- Production
- Perception
- Typification

Simplest possible robot equivalent? 
State machine (DFA)

- Set of states
- Set of input ‘symbols’
- Transition function

It is far from a perfect equivalent!

Detailed:
Humans are oriented towards details when categorizing behavior as actions, and typifying these.
Remember Gitte’s talk?
Embodied actions... 

- Production
- Perception
- Typification

Simplest possible robot equivalent?
State machine (DFA)

- Set of states
- Set of input ‘symbols’
- Transition function

It is far from a perfect equivalent!

Detailed:
Humans are oriented towards details when categorizing behavior as actions, and typifying these.

Coarse:
The robot’s ability to differentiate human behavior onto a set of ‘input symbols’ is extremely limited compared to the humans.
• 2 end-stops: Ceiling and Floor.
• Constant load in the air between them.
Example state machine

![State Machine Diagram]

- **Floor**
  - \( l = 50 \text{ cm} \)
  - \( v = 0 \)
  - \( F = ? \)

- **Air**
  - \( l = ? \)
  - \( v = ? \)
  - \( F = 5 \text{ kg} \)

- **Ceiling**
  - \( l = ? \)
  - \( v = 0 \)
  - \( F = 5 \text{ kg} \)

- \( l = 50 \text{ cm} \), \( v = 0 \), \( F = ? \)

- \( F > 5 \text{ kg} \)
- \( F < 5 \text{ kg} \)
- \( l \leq 0 \)

**Kinetic actions**
- Increase force
- Decrease force
- Pull down
- Move up
- Release

**Visible actions**
- Hand closing
- Gaze on hand
- Arm muscles tensing
- Weight on left foot
- Abrupt stop
- Gaze on robot
- Half step forward
- Gaze on hand
- Weight on right foot
- Rope/Arm start moving down
- Gaze on robot
- Step backward
- Weight on left foot
- Abrupt stop
- Gaze on hand
- Hand opens

**Time lines**
- 0s
- 2s
- 4s
- 6s
- 8s
- 10s

**Human and Camera actions**

- **Human**
  - \( l = 50 \text{ cm} \)
  - \( v = 0 \)
  - \( F = ? \)

- **Robot**
  - \( l = 0 \)
  - \( v = 0 \)
  - \( F = ? \)

Integrating HUM & TECH in training robots

Anders Stengaard Sørensen
l=0
v=0
F=?

F>5kg
l<=0
l<20cm or l>22cm
l>20cm and l<22cm

High strip

F=5kg
F>1kg
l<20cm and l<22cm
l>20cm and l<22cm

Air

l=0
v=0
F=?

F>5kg
l<=0

Ceiling

l=?
v=?
F=5kg

l<100cm
l>=100cm

Low strip

l=?
v=?
F=5kg
Friction
F>1kg
l<100cm
l>=100cm

Floor

l=sinusoid

Fishing

l=0
v=0
F=?

F=5kg
l=?
v=?
F=5kg

F=8kg
l=?
v=?
Film:
Much can be learned about Bodily Human Robot Interaction from this.

Very obvious was:

- Subjects engage differently, highly influenced by initial visual cues.
- Subjects react differently to the slow range change.
- All subjects reacted identically to the floor. 60% force increase convinced everyone to change direction.
Always yield to the hands-on imperative!

1. Patiently developing and testing the system together teach us the essentials of each other's areas.
2. Humanists quickly learn the possibilities and restrictions of the technology, and enjoy projecting their knowledge onto this.
3. Engineers eventually learn the limitations of math when working with human behavior, and change focus from controlling it to exploring and synchronizing with it.

The RoBody method is mutual empowerment:

1. The partnership changes the way we think, by infusing our core fields into each other.
2. As engineers, we do not merely consult humanists and interpret their knowledge in terms of math and technology.
3. With RoBody, we empower humanists to transform their expertise into technology — using the hands of the engineer.
4. And we empower the engineers to understand and analyze human behavior as it is, not as math models can cope with.
1 Always yield to the hands-on imperative!

- Patiently developing and testing the system together teach us the essentials of each other's areas.
Always yield to the hands-on imperative!

- Patiently developing and testing the system together teach us the essentials of each other's areas.
- Humanists quickly learn the possibilities and restrictions of the technology, and enjoy projecting their knowledge onto this.
Always yield to the hands-on imperative!

- Patiently developing and testing the system together teach us the essentials of each others areas.

- Humanists quickly learn the possibilities and restrictions of the technology, and enjoy projecting their knowledge onto this.

- Engineers eventually learn the limitations of math when working with human behavior, and change focus from controlling it to exploring and synchronizing with it.
Lessons on integrating HUM

1. **Always yield to the hands-on imperative!**
   - Patiently developing and testing the system together teach us the essentials of each others areas.
   - Humanists quickly learn the possibilities and restrictions of the technology, and enjoy projecting their knowledge onto this.
   - Engineers eventually learn the limitations of math when working with human behavior, and change focus from controlling it to exploring and synchronizing with it.

2. **The RoBody method is mutual empowerment**
Lessons on integrating HUM

1. **Always yield to the hands-on imperative!**
   - Patiently developing and testing the system together teach us the essentials of each others areas.
   - Humanists quickly learn the possibilities and restrictions of the technology, and enjoy projecting their knowledge onto this.
   - Engineers eventually learn the limitations of math when working with human behavior, and change focus from controlling it to exploring and synchronizing with it.

2. **The RoBody method is mutual empowerment**
   - The partnership changes the way we think, by infusing our core fields into each other.
1. Always yield to the hands-on imperative!
   - Patiently developing and testing the system together teach us the essentials of each others areas.
   - Humanists quickly learn the possibilities and restrictions of the technology, and enjoy projecting their knowledge onto this.
   - Engineers eventually learn the limitations of math when working with human behavior, and change focus from controlling it to exploring and synchronizing with it.

2. The RoBody method is mutual empowerment
   - The partnership changes the way we think, by infusing our core fields into each other.
   - As engineers, we do not merely consult humanists and interpret their knowledge in terms of math and technology.
Lessons on integrating HUM

1. **Always yield to the hands-on imperative!**
   - Patiently developing and testing the system together teach us the essentials of each others areas.
   - Humanists quickly learn the possibilities and restrictions of the technology, and enjoy projecting their knowledge onto this.
   - Engineers eventually learn the limitations of math when working with human behavior, and change focus from controlling it to exploring and synchronizing with it.

2. **The RoBody method is mutual empowerment**
   - The partnership changes the way we think, by infusing our core fields into each other.
   - As engineers, we do not merely consult humanists and interpret their knowledge in terms of math and technology.
   - With RoBody, we empower humanists to transform their expertise into technology — using the hands of the engineer.
1. **Always yield to the hands-on imperative!**
   - Patiently developing and testing the system together teach us the essentials of each others areas.
   - Humanists quickly learn the possibilities and restrictions of the technology, and enjoy projecting their knowledge onto this.
   - Engineers eventually learn the limitations of math when working with human behavior, and change focus from controlling it to exploring and synchronizing with it.

2. **The RoBody method is mutual empowerment**
   - The partnership changes the way we think, by infusing our core fields into each other.
   - As engineers, we do not merely consult humanists and interpret their knowledge in terms of math and technology.
   - With RoBody, we empower humanists to transform their expertise into technology — using the hands of the engineer.
   - And we empower the engineers to understand and analyze human behavior as it is, not as math models.

Anders Stengaard Sørensen
Integrating HUM & TECH in training robots
Thank you

Anders Stengaard Sørensen

Integrating HUM & TECH in training robots