Developing World Prosthetics

SP.713  Lecture 1  2/3/10
Original Project

Vac-cast winner of IDEAS competition 2006
History of the class

Vac-Cast -> IDEAS -> India -> SP.714->SP.718
Class Overview

SP.714 718 Developing World Prosthetics
W 3:00-5:00  4-402
9 Units (U) P/F A/B/C/D
http://stellar.mit.edu/S/course/SP/sp10/SP.7148
Team meetings TBD
Course Description

DWP is a collaboration between MIT and Jaipur Foot Organization (JFO) to improve the design, manufacture, and distribution of rehabilitation devices in the developing world.

In addition, we have tried to reach other countries collaborating with Community in Nicaragua, Fablab, and Northwestern Univ. this year.
Goal

Course Goals

• Gain awareness of communities in the developing world and the technical challenges they face.

• Learn about useful and appropriate prosthesis technologies for developing communities, their impact, and how they can be conceived, designed and implemented.

• Learn the hands-on skills.
Grading

Project work and class participation 15%
Homework assignments 15%
Mid-term Presentation 30%
Final Presentation/Report 40%
People

Lectures

• Ken Endo
• Robert Emerson, Lifestyle P&O

TAs

• A lots
<table>
<thead>
<tr>
<th>Date</th>
<th>Topic</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>February 3</td>
<td>Class overview/Introduction</td>
<td>Ken Endo</td>
</tr>
<tr>
<td>February 10</td>
<td>Developing World Prosthetics/Projects</td>
<td>Ken Endo and TAs</td>
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<td>February 17</td>
<td>TBA</td>
<td>Guest Lecturer</td>
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<tr>
<td>February 24</td>
<td>Anatomy &amp; Biomechanics</td>
<td>Prof. Hugh Herr</td>
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<td>March 3</td>
<td>Invited Talk</td>
<td>Dr. Pooja Sandeepan</td>
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<td>March 10</td>
<td>TBA</td>
<td>Guest Lecturer</td>
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<td>March 17</td>
<td>Mid-term Presentation</td>
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<tr>
<td>March 24</td>
<td>– no class – SPRING BREAK</td>
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Syllabus

March 31  Overview of Prosthetic Device  Bob Emerson
April 7   Foot/Ankle  Bob Emerson
April 14  Knee/Socket  Bob Emerson
April 21  Below Knee Amputee  Bob Emerson
April 28  Above Knee Amputee  Bob Emerson
May 5     Upper Extremity  Bob Emerson
May 8     MIT museum event
May 12    Final presentation
Projects Overview

• Teams of 3-5 students
• TAs meet for at least an hour a week
• Meet outside of class
• Lab space (TBD)
Contents for today

• Why international development at MIT?
• Jaipur Foot Organization
• Biomechanics of Human Walking
• Past Projects
Why international development at MIT?
Prosthetic/Orthotic Technology

- Material Science
- Dynamics
- Mechanical Engineering
- Biomechanics
- Neuroscience
- Biology
- Physiology
- Pathology
- Rehabilitation Engineering
- Anatomy
- Orthopedics
- Electrical Engineering
- Computer Science
- Control
R&D Focus

• Researchers in universities and companies tend to emphasize state-of-art technologies
  – Publication
  – Funding/grant
  – Tenure
  – Market (not needs)
Millennium Development Goals

1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria, and other diseases
7. Ensure environmental sustainability
8. Develop a global partnership for development
Base of Pyramid

Limitation of current strategies

poverty

4 billion people
Base of Pyramid: BoP

$3,000 per year
In the Future....

Huge market with more than 6 billion

New market emerges by pushing up the base of pyramid
For Solving Problems

- Religion
- Gender Issue
- Culture
- Environment
- Economy
Twelve Steps to Practical Problem Solving

1. Go to where the action is.
2. Talk to the people who have the problem and listening to what they say.
3. Learn everything you can about the problem’s specific context.
4. Think big and act big.
5. Think like a child.
6. See and do the obvious.
7. If somebody has already invented it, you don’t need to do so again.
8. Make sure your approach has positive measureable impacts that can be brought to scale. Make sure it can reach at least a million people and make their lives measurably better.
9. Design to specific cost and price targets.
10. Follow practical three-year plans
11. Continue to learn from your customers.
12. Stay positive: don’t be distracted by what other people think.

[Out of Poverty, Paul Polak]
What’s D-lab?

- D-lab (http://d-lab.mit.edu)
  - A series of academic offerings for undergrad students in MIT
  - ‘D’ for Development through Dialog, Design, and Dissemination

Dialog
Introduction to international development

Design
Hand-on experience under constraints

Dissemination
Explore possible idea of international development for business plan competitions and ventures

Courtesy of Alfinio Flores. Used with permission.
# D-lab Course list

<table>
<thead>
<tr>
<th>Dialog</th>
<th>Design</th>
<th>Dissemination</th>
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<td>• D-lab Development</td>
<td>• Cycle ventures</td>
<td>• D-lab Dissemination</td>
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<tr>
<td></td>
<td>• D-lab Design</td>
<td>• Development Venture</td>
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<tr>
<td></td>
<td>• Developing World Prosthetics (DWP)</td>
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</tr>
<tr>
<td></td>
<td>• Wheelchair Design</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• ICT</td>
<td></td>
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<tr>
<td></td>
<td>• Health</td>
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</tr>
<tr>
<td></td>
<td>• Energy</td>
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</table>

http://d-lab.mit.edu/courses
Jaipur Foot Organization (JFO)
Jaipur Foot Organization (JFO)

• Bhagwan Mahaveer Viklang Sahayata Samiti (BMVSS) is a non-governmental, Non-profit, Non-Political, Non-religious, Voluntary Society helping the Physically Challenged persons particularly the resource less.

• BMVSS is running 15 Centres and 3 Sub-centers in India other than Jaipur as head office. Reach-out to patients through Camps.

Greddy named them JFO.
About JFO

• World’s Largest Artificial Limb Fitting Society
  • 20,000 limbs & 50,000 other aids & appliances in a year have annual budget of appx. 10 Crore INR (US $ 2.5 Million)

• Special Consultative status with the Economic & Social Council of the United Nations Organization

• Cost is only US $ 35 per Limb, which is good for 3-5 years rather the patient gets it FREE, all subsequent repairs & replacements are also FREE.
Goal of JFO

- Physical & Social Rehabilitation of the Physically Challenged Persons.
- Enabling them to regain their self respect and human dignity.
- Become normal and useful member of the society.
Statistics

Pie charts showing high prevalence of locomotor-related morbidities in both rural and urban India removed due to copyright restrictions.
Products

Jaipur foot

Transfemoral Prosthesis

Courtesy of Dr. Pooja Mukul, Bhagwan Mahaveer ViklangSahayata Samiti - Jaipur Foot Organization, Jaipur, India. Used with permission.
<table>
<thead>
<tr>
<th>Country</th>
<th>Count</th>
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<tr>
<td>Afghanistan</td>
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<tr>
<td>Bangladesh</td>
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<td>Dominican Republic</td>
<td>500</td>
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<tr>
<td>Honduras</td>
<td>400</td>
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<td>Indonesia</td>
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<td>Kenya</td>
<td>500</td>
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<td>Lebanon</td>
<td>145</td>
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<td>Malawi</td>
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<td>Nigeria</td>
<td>500</td>
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<td>Nepal</td>
<td>200</td>
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<td>Pakistan</td>
<td>989</td>
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<td>Panama</td>
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<td>Philippines</td>
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<td>Papua New Guinea</td>
<td>170</td>
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<td>Rwanda</td>
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<td>Somalia</td>
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<td>Sudan</td>
<td>1,800</td>
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<td>Trinidad &amp; Tobago</td>
<td>200</td>
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<td>Uganda</td>
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<td>Vietnam</td>
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<td>Zimbabwe</td>
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<td>Zambia</td>
<td>121</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>16,445</strong></td>
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Courtesy of Dr. Pooja Mukul, Bhagwan Mahaveer Viklang Sahayata Samiti - Jaipur Foot Organization, Jaipur, India. Used with permission.
TOTAL ASSISTANCE PROVIDED IN INDIA AND ABROAD

In 1975, the society began with a very modest fitment of 59 artificial limbs but is now fitting about 20,000 artificial limbs and about 30,000 Polio Calipers, and other Aids and Appliances every year in our centres and through mobile camps in India and abroad. Till 31st March 2007, the BMVSS has provided assistance as follows:-

<table>
<thead>
<tr>
<th>Artificial Limbs</th>
<th>3,10,220</th>
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<tbody>
<tr>
<td>Calipers</td>
<td>2,63,150</td>
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<tr>
<td>Tricycles</td>
<td>58,971</td>
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<tr>
<td>Crutches &amp; Other Aids</td>
<td>3,18,217</td>
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<tr>
<td>Hearing Aids</td>
<td>11,963</td>
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<tr>
<td>Polio Corrective Surgery</td>
<td>6,366</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>9,68,887</strong></td>
</tr>
</tbody>
</table>

Courtesy of Dr. Pooja Mukul, BhagwanMahaveer Viklang Sahayata Samiti - JaipurFoot Organization, Jaipur, India. Used with permission.
Cost of Typical Jaipur Foot Below Knee Limb

Jaipur Foot 2002 Expense by Classification
(overhead costs of camps are included in Cost of Limbs and Services)

Cost of Limbs and Services 89%

Operating Costs 4%

Other Assistance 7%

Ossur 2002 Expense by Classification

- Operating Costs: 52%
- Cost of Limbs and Services: 48%

Biomechanics of Human Walking
Anatomical Terminology

• Sagittal Plane
• Coronal/Frontal Plane
• Transverse / Axial Plane

Image by MIT OpenCourseWare.
Flexion vs extension

• Flexion: decreases angle between body segments
• Extension: increases angle
Abduction vs Adduction

- Abduction: away from midline
- Adduction: toward the midline
Plantarflexion vs. Dorsiflexion

Image by MIT OpenCourseWare.
Walking: The phases of a stride

Stride: Complete cycle of locomotor movement

- **stride length**: total cycle length
- **stride time**: total cycle duration
- **stride frequency** = \( \frac{1}{\text{stride time}} \)
- **step length**: distance traveled from heel-strike to heel-strike of adjacent legs

![Diagram showing the phases of a stride](Image by MIT OpenCourseWare.)
Joint angles

Walking Speed vs Angles

Assignment 1

• Read winter’s paper and answer the questions.
Team Projects

• Needs background about human biomechanics, anatomy, physiology et al.
• Hands-on
Term Project Flow

• Specify Projects
• Research existing designs
• **Mid-term Presentation 3/17**
• CAD model proposed design
• Manufacture Prototype
• Basic Test
• **Final Presentation 5/8 and 5/12**
Past Projects

• EZ-Unock Knee
• Free-Swing Orthotic Knee
• Vac sock
• Exo knee
Vac-Sock

• Method for prosthetic fitment
• Accurate limb fit
• Reusable materials

Courtesy Goutam Reddy. Used with permission.
Exo-Knee

- Stance-lock prosthetic knee

Jared Sartee

Courtesy of Jared Sartee. Used with permission.
MIT Knee

• Mr. Sanjeev Kumar (JFO) offered this project.
• Transfemoral prosthetics with knee lock system.

Engineering drawing and photo of prosthetic knee
Removed due to copyright restrictions.
Summer Internship

Photo of young boy walking with prosthetic leg removed due to copyright restrictions.
Shape & Roll Redesign

Improved Prosthetic Foot for the Developing World
Project Goals

• New attachment for exoskeletal socket
• Redesign support structure with material available in developing world
• Redesign to allow extreme dorsiflexion for squatting
Solutions

• Attachment for exo similar to ICRC foot
• Rod cut longitudinally as nut for attachment

Engineering drawing of prosthetic foot removed due to copyright restrictions.
### LegoLeg Project

**Project by:** Giovanni Talei Franzesi, Jacquelyn Kunkel, Matthew Rodriguez  
**Advisor:** Ken Endo

- **Carbon fiber composites are ideal** for lower limb prosthesis
  - Light
  - Strong
  - Can store/return energy
    - Makes movement much less tiring, faster and more natural

- **High cost** (~1-5K) prevents wider adoption in other countries

- **Main cost is fabrication**, not the raw material

- **Goal:**
  - To design a **leg/foot** system that
    - Can **match performance** of existing prosthesis but with greater modularity
    - Can **easily manufactured** with the tools in the FabLab, resulting in **greatly decreased final cost**, crucial to more extensive adoption

**Design:**
- Intrinsically modular
- Easily fabricated
- Rationally designed for optimal biomimetic performance

Engineering drawings of LegoLeg courtesy of Giovanni Talei Franzesi, Jacquelyn Kunkel, and Matthew Rodriguez. Used with permission.
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To India and Beyond!

- IDEAS competition
- MIT Public Service Center Fellowships
- A few fellowships via. Class
- Refine prototypes
- Learn about O&P in developing world
Solidworks® (optional)
COSMOSXpress
Homework!

• Read Winter’s paper and answer the questions.
• Solidworks® (optional)
  – Follow the tutorial (model and analyze)