A Bio-Inspired Approach to Innovation

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FLL RMS Ninjineers

- 2012 1st Place Grand Champions Award, Tennessee FLL Championship
- 2012 1st Place Alliance Challenge Champion, FLL World Invitational
- 2012 1st Place Strategy & Innovation Award, FLL World Invitational
- 2011 2nd Place Champions Award, Tennessee FLL Championship
- 2011 2nd Place Robot Performance Award, Tennessee FLL Championship
- 2011 3rd Place Programming Award, FLL World Festival
- 2010 1st Place Grand Champions Award, Tennessee FLL Championship
- 2010 1st Place Robot Performance, Tennessee FLL Championship
- 2009 1st Place Robot Performance, Tennessee FLL Championship
- 2009 1st Place Robot Design, Tennessee FLL Championship
- 2008 2nd Place Champions Award, Tennessee FLL Championship
- 2008 2nd Place Robot Performance, Tennessee FLL Championship
- 2007 4th Place Robot Design, Tennessee FLL Championship

FIRST: For Inspiration and Recognition of Science and Technology

FRC Team 4265 Secret City Wildbots

- 2013 Champion, Quality Award, Woodie Flowers Award, Dean’s List Award, Smoky Mountains Regional
- 2013 FIRST World Championships
- 2013 IRI Semi-Finalist
- 2012 Rookie All-Star Award Smoky Mountains Regional
- 2012 FIRST World Championships
Oak Ridge National Laboratory

- 25 years
- 7 different careers
- RF Communications and Intelligent Systems Group
- Director, Cognitive Radio Program

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What is Innovation?
“Creativity is thinking up new things. Innovation is doing new things.”

Theodore Levitt
We're all copying and transforming and combining... you can't get something from nothing, you can't just summon it out of the air.
Why is innovation so hard?
What if we think of research as a startup?
“A startup is a human institution designed to create a new product or service under conditions of extreme uncertainty.”

Eric Ries
Customer Discovery

Pivot the business model until you can prove it works.

(customer discovery) -> (customer validation) -> (customer creation) -> (company building)

(repeat * until proven)

Problem/Solution Fit
Real Innovation in nature!

Problem/Solution Fit

Product/Market Fit
Why am I curious about bio-inspired systems?
“Communication, signal-processing and computation observed in biological systems far exceeds man-made engineered attempts at similar functions in efficiency, effectiveness and robustness and it’s accomplished with “inferior components”

- Vision
- Locomotion/navigation – *proprioception*
- Computation
- Hearing
- Sensemaking

Let’s try a thought experiment together. Let’s design a human auditory subsystem...
## Frequency Range of Hearing for Humans and Selected Animals

<table>
<thead>
<tr>
<th>Animal</th>
<th>Frequency (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>low</td>
</tr>
<tr>
<td>Humans</td>
<td>20</td>
</tr>
<tr>
<td>Cats</td>
<td>100</td>
</tr>
<tr>
<td>Dogs</td>
<td>40</td>
</tr>
<tr>
<td>Horses</td>
<td>31</td>
</tr>
<tr>
<td>Elephants</td>
<td>16</td>
</tr>
<tr>
<td>Cattle</td>
<td>16</td>
</tr>
<tr>
<td>Bats</td>
<td>1,000</td>
</tr>
<tr>
<td>Grasshoppers &amp; locusts</td>
<td>100</td>
</tr>
<tr>
<td>Rodents</td>
<td>1,000</td>
</tr>
<tr>
<td>Whales &amp; dolphins</td>
<td>70</td>
</tr>
<tr>
<td>Seals &amp; sea lions</td>
<td>200</td>
</tr>
</tbody>
</table>

Examples of Bio-Inspired Innovation

- Organisms
- Systems
- Patterns
- Principles
- Strategies

Photo: jurvetson/Flickr
What is Biomimicry?

- Conscious emulation of ________ found in nature
  - Form
  - Processes
  - Systems
- When faced with a problem we ask ...
- Has this been solved in nature?
- If so, how?
- Attempt to understand and functionalize it
- How might we...
Examples
Dynamic Spectrum Access...

A colony of bats leaving their cave...
Passive Cooling of Buildings

Velcro
Tires Can’t Go Flat

image via: world car fans
Highly Efficient Water Mixer

Image of impeller via PAX Scientific; Image of calla lily via the equinest
Reduce Drag/Friction in Water

Photo: Phelps and shark: ZUMA Press
Improved in Aerodynamics

Photos via Daimler
Reduce Noise of a High Speed Train

Source: treehugger.com
Superefficient "Wing/Blade"

Photo: Whale: Natura Paparazzo / Flickr; turbine: Envira-North Systems
Collect Water from the Air

Photo: Bug: [WikiCommons](https://commons.wikimedia.org); material: mit.edu; image: [grimshaw architects](https://www.grimshaw.com);
Hydrophobic/Self-Cleaning Paint

Photo: Lotus: [Jensen Chua](https://www.flickr.com/photos/jensenchua/); house: [Laertes](https://www.flickr.com/photos/laertes/).
“Stickybot”
Tidal Power Generation

Photo of turbines via BioPower; photo of kelp and fish via Tim Parkinson
Environmentally Friendly Adhesive

Photo of wood via Columbia Forest Products; photo of mussels via fragpot
Mondo Spider Electric Vehicle

images via: mondospider.com
Nano Air Vehicle

http://leesbirdblog.files.wordpress.com/2009/01/dragonfly-by-quytran.jpg
A Very Agile Robotic Arm
Butterfly Wings Could Lead to Better Solar Panels
Photonic Beetles Inspire Faster Computers

image via: physorg

http://futurismic.com/2008/05/23/beetlepunkbiomimicry-and-the-photonic-weevil/
High Contrast Low-power Display

Photo of device via Qualcomm; photo of butterfly via Izzy LeCours
Growing Batteries
“Opportunities for Innovation at the Intersection”

- Biomimetic Transduction (Sensing and Actuation)
  - EM, audio, visual/optical
    - Mantis Shrimp (UV/IR/CP light)
    - Inner ear gyroscope
    - Bats/Dolphins/Owls
  - Self-powered sensors
  - Power-conversion
  - Chromatophors

- Biomimetic...
  - Signal Processing (implicit vs. explicit)
  - Computation (implicit vs. explicit)
  - Control (Inter/Intra)
  - Intelligence/Learning/Adaptation/Cognition
  - Communication
  - Materials
  - Functional nano-materials
Mantis Shrimp’s Extraordinary Eyes

**Homo sapiens**

**Neogonodactylus oesteri**
iNVT / LFS Integration

Bio-Inspired Features
- Bio-Inspired Features

Bottom-Up
- "Models"
- "Primitives"
- Constraints
- Objectives/Goals

Top-Down
- "Primitives"

Bottom-Up
- "Models"
- Constraints
- Objectives/Goals

Bio-Inspired Processing

iNVT: iLab Neuromorphic Vision Toolkit
LFS: Learning From Signals
Accelerating Interest in Biomimicry

• Enablers ...
  – Neuroscience/neuroplasticity
  – Learning/Intelligence
  – Modeling & Simulation
  – Functional nano-matertials

“Technology trajectories, innovation, and the growth of biomimetics” – Patent database search results for: Biomimetic Or bionic OR biologically inspired
Mapping the Human Brain
Understanding Human Cognition
“We cannot solve our problems with the same thinking we used when we created them.”

Albert Einstein
“The greatest advancements we will see in the twenty-first century will come from the intersection of biology and technology.”

Steve Jobs
Thank You!