Future Technology Evolution
Robotics and Beyond

Nathalie Gosset, MS, MBA
Alfred E. Mann Institute for Biomedical Engineering
at the University of Southern California
gosset@ieee.org
RELEVANCE

MEANINGFUL IMPACT
Technologies of The Future, The Secret to Remaining Relevant

3/21/2014

Nathalie Gosset, gosset@usc.edu
Technologies of The Future, The Secret to Remaining Relevant

S curve

Looking for the S curves

PREDICTING GLOBAL TRENDS

Inspired from Everett Rogers’ Diffusion of Innovations
Technologies of The Future, The Secret to Remaining Relevant

3/21/2014

Nathalie Gosset, gosset@usc.edu

PROFESSIONAL ADVANCEMENT

Find S curves
And stay at the knee of S curve

Obsolete
No Differentiation
Unique Value To Industry

THE EASY SPOT
NEW TRENDS
JOBS
FUNDING
Technologies of The Future, The Secret to Remaining Relevant

Getting Involved in Novel Fields

Learning something new on an S curve
2014 AND BEYOND

MANAGING ALONG THE S CURVES

S #1
CONTINUOUS
MINI-REPOSITIONING

S #2
S #7

UNIQUE IDENTITY AND THE BUSINESS OPPORTUNITIES ARE FOUND AT THE CONVERGENCE OF THE S CURVES

Nathalie Gosset, gosset@usc.edu
MANAGE YOUR CYBER BRAND

‘S’ CURVES

APPLICATIONS
- Brain – Machine – Human Interface
- Personalized Medicine
- Individual - Self Creation

FORCES
- World Of the Small
- “Flat” World
- Digital World

Technologies of The Future, The Secret to Remaining Relevant
Nathalie Gossett, gosset@usc.edu
In this presentation a robot is ...

“... any automatically operated machine that replaces human effort, though it may not resemble human beings in appearance or perform functions in a humanlike manner.”

Encyclopedia Britannica
GOALS OF USING ROBOTS

1. OUTPUT
2. QUALITY
3. COST

PROTECT
AUGMENT
FREE TIME

INDUSTRIAL
SERVICE

The LEADERS in Advancing Robot Technology

1. JAPAN
2. USA
3. EUROPE
4. SOUTH KOREA
4.5. INDIA
5. CHINA

Source: SRI Consulting Business Intelligence: Disruptive Global Trends, Appendix E
86% Industrial Robots
Units Sold

- Repetitive
- High speed
- High precision
- Pre-planned trajectories
- No humans

Reference – IFR World Robotics 2010

Industrial Robots

2012
$26 billion in revenues
175,000 units sold

- Challenges
  - Uncertainty
  - Synchronization
  - New Tasks Added
  - Glitch = Disaster

Technologies of The Future, The Secret to Remaining Relevant

### Industrial Robots

- **Automotive**: 40%
- **Electronics**: 38%
- **Rubber & Plastics**: 11%
- **Metal**: 6%
- **Food & Beverage**: 5%

### Service Robots

- **Units Sold**: 14%
- **Defense**: 31%
- **Field Robots**: 45%
- **Medical**: 6%
- **Logistic Systems**: 7%
- **Personal and Domestic**: 11%
- **Rehab**: 3%

Images of Talon Robots and various service robots.
SERVICE ROBOTS

2012
$4.1 billion in revenues
13,600 units sold

Most Revenues (2010)
within each Service Robot Group

DEFENSE
Drones

FIELD
Milking Robot

MEDICAL
Surgery

LOGISTICS
Guided Vehicles

DOMESTIC
Vacuum Cleaner

PERSONAL
Most Famous Robots

The Mars Exploration Curiosity

<table>
<thead>
<tr>
<th>Large application</th>
<th>Unit sold (2010)</th>
<th>Revenues (in $M)</th>
<th>% sold</th>
<th>% revenues</th>
<th>Average unit price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spirit</td>
<td>6,125</td>
<td>$696</td>
<td>45%</td>
<td>22%</td>
<td>$113,633</td>
</tr>
<tr>
<td>Curiosity</td>
<td>4,200</td>
<td>$744</td>
<td>30%</td>
<td>18%</td>
<td>$177,143</td>
</tr>
<tr>
<td>Assisted surgery and therapy</td>
<td>907</td>
<td>$1,987</td>
<td>7%</td>
<td>33%</td>
<td>$1,500,000</td>
</tr>
<tr>
<td>Automated guided vehicles</td>
<td>900</td>
<td>$730</td>
<td>7%</td>
<td>13%</td>
<td>$811,111</td>
</tr>
<tr>
<td>Vacuum cleaning, toys, hobby, research and education</td>
<td>1,445</td>
<td>$538</td>
<td>11%</td>
<td>13%</td>
<td></td>
</tr>
</tbody>
</table>

Robots Sales Volume and Revenues (2010)

<table>
<thead>
<tr>
<th>Industry Segment</th>
<th>Unit sold (2010)</th>
<th>Revenues (in $M)</th>
<th>% sold</th>
<th>% revenues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automotive</td>
<td>32,700</td>
<td>$1,235</td>
<td>40%</td>
<td></td>
</tr>
<tr>
<td>Electronics</td>
<td>30,745</td>
<td>$1,200</td>
<td>38%</td>
<td></td>
</tr>
<tr>
<td>Rubber &amp; Plastics</td>
<td>8,940</td>
<td>$350</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>Food and Beverage</td>
<td>4,350</td>
<td>$150</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Metal Product</td>
<td>4,500</td>
<td>$180</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>81,235</td>
<td>$5,800</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

Reference - IFR World Robotics 2010
Technologies of The Future, The Secret to Remaining Relevant

Service Robots
Bring more Revenues/Unit

Units Sold
Industrial Robots: 86%
Service Robots: 14%

Revenues
Industrial Robots: 59%
Service Robots: 41%

Robots on the S Curve
INDUSTRIAL
LOGISTIC
FIELD
DEFENSE
DOMESTIC
PERSONAL
MEDICAL
REHAB
Technologies of The Future, The Secret to Remaining Relevant

2010

INDUSTRIAL

LOGISTICS/DEFENSE

FIELD

MEDICAL

PERSONAL DOMESTIC

AUGMENTATION OF HUMAN POWER

2025

X2

X3

X3

X3

X33

new

CHALLENGES AND FUTURE DIRECTIONS

ADAPTATION TO THE ENVIRONMENT

SHAPE SHIFTING SELF ASSEMBLE

NAVIGATION

VISUAL RECOGNITION

OBJECT GRASPING

MACHINE LEARNING
SHAPE SHIFTING TOPOLOGIES

LATTICE
moves to a neighboring position on a 2D or 3D grid

CHAIN or TREE
Connected together in a string

HYBRID
Combination of both

contain electronics, sensors, computer processors, memory, and power supplies and actuators

Cornell

Carnegie Mellon

USC

ROOMBOTS (SWITZERLAND)

Chair from 12 RB modules. Typical office chair for size comparison included.

Table from RB modules and L-shaped passive pieces.

RB stool from 8 RB modules.

Miniature-table from 8 RB modules.

Coffee table from 8 RB modules and...

Stool from 12 RB modules and...

Ecole Polytechnique Federale de Lauzanne

Description of M-Tran http://unit.aist.go.jp/is/frgg/dsysd/mtran3/what.htm
Several robotic fields have identified “Grand Challenges”

- Demonstration of a system with >1000 units
- Self sustaining for one year with no human intervention
- Self replication
- Small enough to be injected into a mammal
- Able to monitor molecules in the blood stream and filter molecules
Target Applications for Grand Challenges

- Space exploration, Lunar colonization
- Construction of large architectural systems
- Deep sea exploration/mining
- Search and rescue in unstructured environments
- Rapid construction of arbitrary tools under space/weight constraints
- Disaster relief shelters for displaced peoples
- Shelters for impoverished areas which require little on-the-ground expertise to assemble

Feb 2014 DARPA plans for modular flying drones, which can "transform" to meet various mission needs.
**Lattice Structures**

<table>
<thead>
<tr>
<th>Robot</th>
<th>Degrees of Freedom</th>
<th>Dimensions</th>
<th>PI (Organization)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metamorphic</td>
<td>6</td>
<td>2D</td>
<td>Chirikjian (Caltech)</td>
</tr>
<tr>
<td>Fracta</td>
<td>3</td>
<td>2D</td>
<td>Murata (Nagoya University, Mechanical Engineering Laboratory)</td>
</tr>
<tr>
<td>Fractal Robots</td>
<td>?</td>
<td>3D</td>
<td>Michael (UK)</td>
</tr>
<tr>
<td>3D Fracta</td>
<td>6</td>
<td>3D</td>
<td>Murata et al. (Nagoya University, Mechanical Engineering Laboratory)</td>
</tr>
<tr>
<td>Molecule</td>
<td>4</td>
<td>3D</td>
<td>Kotay &amp; Rus (Dartmouth)</td>
</tr>
<tr>
<td>TeleCube</td>
<td>1</td>
<td>3D</td>
<td>Suh et al., (PARC)</td>
</tr>
<tr>
<td>Vertical</td>
<td>7</td>
<td>2D</td>
<td>Hosakawa et al., (Riken)</td>
</tr>
<tr>
<td>Crystalline</td>
<td>4</td>
<td>2D</td>
<td>Vona &amp; Rus, (Dartmouth)</td>
</tr>
<tr>
<td>iCube</td>
<td>?</td>
<td>3D</td>
<td>Unsal, (Carnegie Mellon University)</td>
</tr>
<tr>
<td>Micro Unit</td>
<td>2</td>
<td>2D</td>
<td>Murata et al.(Advanced Industrial Science and Technology, Japan)</td>
</tr>
<tr>
<td>Pneumatic</td>
<td>7</td>
<td>2D</td>
<td>Inou et al., (Tokyo Institute, Japan)</td>
</tr>
<tr>
<td>Stochastic</td>
<td>0</td>
<td>3D</td>
<td>White, Kopanski, Lipson (Cornell)</td>
</tr>
<tr>
<td>Stochastic-3D</td>
<td>0</td>
<td>3D</td>
<td>White, Zykov, Lipson (Cornell)</td>
</tr>
<tr>
<td>Prog. parts</td>
<td>0</td>
<td>2D</td>
<td>Klavins, (U. Washington)</td>
</tr>
<tr>
<td>Miche</td>
<td>0</td>
<td>3D</td>
<td>Rus et al., (MIT)</td>
</tr>
<tr>
<td>Mikron</td>
<td>1</td>
<td>3D</td>
<td>Stoy et al., (U.S Denmark)</td>
</tr>
</tbody>
</table>

Tables constructed, edited, and updated from the educational site Razor Robotics: reconfigurable robots

**Chain Structures**

<table>
<thead>
<tr>
<th>Robot</th>
<th>Degrees of Freedom</th>
<th>Dimensions</th>
<th>PI (Organization)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polypod</td>
<td>2</td>
<td>3D</td>
<td>Yim (Stanford)</td>
</tr>
<tr>
<td>Tetrobot</td>
<td>1</td>
<td>3D</td>
<td>Hamline et al. (Rensselaer Polytechnic Institute, Center for Integrated Electronics)</td>
</tr>
<tr>
<td>ANAT Robot</td>
<td>8</td>
<td>3D</td>
<td>Charies Khairallah (CA)</td>
</tr>
<tr>
<td>CONRO</td>
<td>2</td>
<td>3D</td>
<td>Will &amp; Shen (USC/ISI)</td>
</tr>
<tr>
<td>PolyBet</td>
<td>1</td>
<td>3D</td>
<td>Yim et al. (Xerox, PARC)</td>
</tr>
<tr>
<td>Y1 Modules</td>
<td>1</td>
<td>3D</td>
<td>Gonzalez-Gomez et al., (U. Hamburg, UAM)</td>
</tr>
<tr>
<td>O2-I Modules</td>
<td>1</td>
<td>3D</td>
<td>Zhang &amp; Gonzalez-Gomez (U. Hamburg, UAM)</td>
</tr>
<tr>
<td>Evolve</td>
<td>2</td>
<td>3D</td>
<td>Chang Fanxi, Francis (National University of Singapore)</td>
</tr>
</tbody>
</table>

Tables constructed, edited, and updated from the educational site Razor Robotics: reconfigurable robots
Hybrid Structures

<table>
<thead>
<tr>
<th>Robot</th>
<th>Degrees of Freedom</th>
<th>Dimensions</th>
<th>PI (Organization)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-TRAN I</td>
<td>2</td>
<td>3D</td>
<td>Murata et al., (Advanced Industrial Science and Technology, Japan)</td>
</tr>
<tr>
<td>M-TRAN II</td>
<td>2</td>
<td>3D</td>
<td>Murata et al., (Advanced Industrial Science and Technology, Japan)</td>
</tr>
<tr>
<td>Superbot</td>
<td>3</td>
<td>3D</td>
<td>Shen et al., (USC/ISI)</td>
</tr>
<tr>
<td>Molecules</td>
<td>1</td>
<td>3D</td>
<td>Zykov, Mytilinaios, Lipson (Cornell)</td>
</tr>
<tr>
<td>Odin</td>
<td>3</td>
<td>3D</td>
<td>Lyder et al., Modular Robotics Research Lab, (USD)</td>
</tr>
<tr>
<td>Roombots</td>
<td>3</td>
<td>3D</td>
<td>Sproewitz, Moecckel, Ijspeert, Biorobotics Laboratory, (Ecole Polytechnique Federale de Lausanne, Switzerland)</td>
</tr>
<tr>
<td>M-TRAN III</td>
<td>2</td>
<td>3D</td>
<td>Kurokawa et al., (Advanced Industrial Science and Technology, Japan)</td>
</tr>
</tbody>
</table>

Tables constructed, edited, and updated from the educational site: [Razor Robotics: reconfigurable robots](#).

Mobile Robots

<table>
<thead>
<tr>
<th>Robot</th>
<th>Degrees of Freedom</th>
<th>Dimensions</th>
<th>PI (Organization)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uni Rover</td>
<td>2</td>
<td>2D</td>
<td>Hirose et al., (Tokyo Technical Institute)</td>
</tr>
<tr>
<td>S-Bot</td>
<td>3</td>
<td>2D</td>
<td>Mondala et al., (Ecole Polytechnique Federale de Lausanne, Switzerland)</td>
</tr>
<tr>
<td>AMOEBA-I</td>
<td>7</td>
<td>3D</td>
<td>Liu JG et al., (Shenyang Institute of Automation, China)</td>
</tr>
</tbody>
</table>

Tables constructed, edited, and updated from the educational site: [Razor Robotics: reconfigurable robots](#).
# Self-Assembling Reconfigurable Endoluminal Surgical System

Scuola Superiore Sant'Anna, Italy (2011)

Gastrointestinal robot
Pieces swallowed one at a time
Assemble themselves inside the stomach

Ref: http://news.bbc.co.uk/2/hi/8238088.stm
Self Assemble and Reconfigurable Moteins (2011)

linear strings of beads fold into 2-D and 3-D shapes

Self-Assembling and Reconfiguring Managing Tight Entry Points

Origami Shape shifting (magnets and actuators) MIT 2011

Carried by the Flow

Robot Function At destination

UNDER A DOOR
Self-Assembling Micro Robots

U.S. Department of Energy's (DOE) and Argonne National Laboratory
Alexey Snezhko and Igor Aronson, physicists (2011)

Robot size: grains of rice that self-assemble themselves into “asters”
Environment: the particles are trapped between two layers of immiscible fluids.
Activation: alternating magnetic field applied perpendicular to the liquid surface

Gather and redirect free-floating particles by creating hydrodynamic flows
Capture a glass bead


Magnetically Actuated Micro-Robots (Mag-μBot)

Carnegie Mellon
Nano Robotics Lab, Mettin Siti (2010)

Robot size: 200 x 100 x 50-micron
Environment: running on a dime placed under water
Activation: magnetic

200x100 x 50 μ robot running on a time
500 um Star-shaped micro-robot inserting a peg

http://nanolab.me.cmu.edu/projects/MagneticMicroRobot/

Nathalie Gosset, gosset@usc.edu
Microbot Swimming in Arteries

Monarch University (Australia)
James Friend, MicroNanophysics Research Laboratory

Robot size: 250 µ diameter
Activation: Piezo Electricity

250 µ diameter microbot for insertion into blood vessels using a catheter

Ref: http://nanolab.me.cmu.edu/projects/MagneticMicroRobot/

ExampleS of Sizes of Modular Blocks in Research

10 cm 1.2 cm 500 um 250 um

USC MIT CMU Monarch U.
USA USA USA Australia

POWER and ACTUATOR CHALLENGES INCREASE
World Records of Self Assemble & Reconfigurable Robots

Most Active Modules
56
Polybot (Xerox PARC)

Smallest Actuated block
12 mm side
Smart Pebble (MIT)

Largest Actuated block
8 m ide
Giant Helium Filled Catoms (CMU)

Strongest Actuator
Can lift
5 stringed blocks
from horizontal

Fastest
23 unit-sizes/sec
Ckbot (Modlab)

CHALLENGES AND FUTURE DIRECTIONS

ADAPTATION TO THE ENVIRONMENT

NAVIGATION

VISUAL RECOGNITION

OBJECT GRASPING

MACHINE LEARNING

DESTINATION
TRAJECTORY
SENSE OF OWN VOLUME
Navigation

Big Dog
GOOGLE
(BOSTON DYNAMICS)

Path Planning is Hard to Compute

GPS work with maps in 2D

Obstacles exist in the vertical dimension and can be unpredictable

Surface quality may change
Adaptability - Challenges to Address

• 3D navigation: acquisition of 3D world models in support of navigation with clues for object recognition (Visual SLAM algorithm)

• Lighting changes causing variability in the performance of sensors

• Navigation in crowds

Case University – Bug Like Robots
Swarm Bots (Rice University)

VISUAL RECOGNITION ADVANCEMENT IN OTHER FIELDS READY FOR INTEGRATION

Visual Processing Algorithms

Facial Recognition Software

Eye Tracking Studies

Gesture / Finger pointing detection algorithms
SOFT TOUCH and TACTILE RECOGNITION

Robotic Air-Powered Hand with Elastic Ligaments
- Compressed air passes through actuators to control each finger separately.
- Cleveland-based Compressed Air and Gas Institute

Syntouch BioTack Sensors
- Identifies 100+ textures

TakkTile
- Harvard
- Air pressure-sensitive digital barometer

MACHINE LEARNING
A LARGE GAP TO DEVELOP

MAKING COOKIES
- MIT

FLIPPING PANCAKES
- Italian Institute of Technology
- WAM arm from Barrett Technology
CROSSING OF 2 S CURVES

ROBOTS

and

GREEN ENERGY

July 2013
first fleet of marine drones
Use acoustic signals among them
3D maps of underwater terrain
pollution monitors
Mine detections

2014
Precision Agriculture available to
Ventura County farmers

Humidity
Acidity
Growth

Nathalie Gosset, gosset@usc.edu
CROSSING OF 2 S CURVES

ROBOTS

And the

AGING of the
POPULATION

Assistive Robots

Graphics: http://www.dailygalaxy.com/photos/uncategorized/2008/01/10/robots_4_2.jpg
Technologies of The Future, The Secret to Remaining Relevant

Nathalie Gosset, gosset@usc.edu
Technologies of The Future, The Secret to Remaining Relevant

Androids

Androids Laboratory at Osaka University
Home Assistant Robot (Tokyo U.)

Carries out simple domestic chores (wiping floors, washing, cleaning dishes)

Can move furniture

equipped with 5 cameras and laser sensors, and 6 hands with three joints each.
Robovie II
Retail Assistant (Kyoto, Japan)

Reference:
http://phys.org/news180261433.html#jCp

RIBAII (RIKEN and Tokai Rubber Industries)

Can lift individuals of up to 176 pounds off the floor and place them in wheelchair

Smart Rubber sensors provide accurate tactile guidance

Targets Japanese elderly population

Reference:
TAIZOU, PHYSICAL THERAPY ROBOT FROM AIST (JAPAN)

Autom – Weight Loss Coach

http://intuitiveautomata.com/products.html
Bandit Rehab Coach (USC)

2 arms with 6 degrees of freedom
2 hands with 1 degree of freedom
1 pan/tilt neck with 2 degrees of freedom

CROSSING OF 2 S CURVES

ROBOTS

and

AUTISM AWARENESS
Kaspar Robot
(U. of Hertfordshire, UK)
Kinesics and Synchronization in
Personal Assistant Robotics

Nao
(U. of Connecticut)

teaches social interactions and physical contacts to autistic children teaches social interactions and physical contacts to autistic children


CROSSING OF 2 S CURVES

ROBOTS

and

ENGAGEMENT FROM FAR
**TELEPRESENCE**

- **ServiBoy**
  - Korea
  - 2010
  - Guidance to the public in public places

- **FURO**
  - Future Robots
  - Korea, 2010
  - Guidance and Education

- **LUNA**
  - RoboDynamics
  - USA, 2011
  - “new computer” $1,000 (soon for sale)

- **AVA**
  - iROBOT
  - USA, 2011
  - Healthcare Robot
  - To help people live independently (elderly population)
  - Bring experts (MD) to the home <$5,000 (not available yet)

- **RP-7 Robot**
  - InTouch Health
  - USA
  - Rent for $100K/year
  - Two-way, audio-video communications
  - Self-direct to required location

- **Robina**
  - From Toyota

---

**Image:**

iRobot, InTouch Health unveil RP-VITA telepresence robot, let doctors phone in bedside manner

*By Sean Buckley posted Jul 24th 2012 12:00AM*
CROSSING OF 2 S CURVES

ROBOTS

and

AUGMENTED HUMAN CAPABILITIES

AUGMENTING HUMAN PHYSICAL CAPABILITIES
EXOSKELETON ROBOTS

Raytheon XOX2 can lift 50 pounds per arm

Lockheed Martin HULC
AUGMENTING HUMAN PHYSICAL CAPABILITIES
EXOSKELETON ROBOTS

Bionics eLEGS

Huazhong University of Science and Technology, Wuhan, China

CROSSING OF 2 S CURVES

ROBOTS

and

BRAIN ACCESS FOR NEURO CONTROL
Technologies of The Future, The Secret to Remaining Relevant

Emotiv (Games Controlled by Thoughts)

Robotic Arm Controlled by the Thoughts of a Monkey (2009)

Work from the lab of Dr. Miguel Nicolelis at Duke University.

Implants were positioned in the primary motor cortex, about 2 to 3 millimeters deep into the brain, tapping 75 to 100 neurons.

Food is put in front of the monkey and as he thinks about moving his arm the sensor picks up electrical signals from nerve cells. These are sent to a computer controlling a prosthetic arm.

Computer decodes these signals, causing the prosthetic arm to reach out and pick up the food and place it in the monkey’s mouth.
It took ~ 1,000 attempts to pick up the food over a period of 1-2 weeks before the monkey could achieve high accuracy (80-100%).

**BrainGate Neural System (2012)**

Human thought controls reach-and-grasp movements performed by a robotic arm.
CIRCLING BACK TO OUR MISSION
OPPORTUNITIES ARE FOUND AT THE CONVERGENCE OF THE S CURVES

Use S Curves to Augment Your Own Professional Relevance And Impact
2014 AND BEYOND

MANAGING ALONG THE S CURVES

CONTINUOUSLY
DO MINI-REPOSITIONING

Cyberbrand Yourself
With an S Curve

What about a Robot S curve?
You can contact me at gosset@ieee.org