

Innovation Science

Frameworks and Practices

Andrew Kusiak
 Mechanical and Industrial Engineering
 3131 Seamans Center
 The University of Iowa
 Iowa City, IA 52242-1527
 Tel. (319) 335-5934
andrew-kusiak@uiowa.edu
<http://www.icaen.uiowa.edu/~ankusiak>

Intelligent Systems
 Laboratory

Outline

- Innovation definition
 - Examples of innovation rules
 - Innovation science
 - Data in innovation
 - Innovation case studies
 - Conclusion
-

Background

- NSF Engineering Design Workshop
 - Growing interest in Innovation as a main differentiator of US economy
 - 9/11 Commission Report "Failure of Imagination"
 - US President "Innovation in Manufacturing" Executive Order
-

Basic Research Questions

- To what degree is Innovation an art or a science?
 - Can the science base of innovation be established?
 - What elements of innovation can be taught?
 - What methodologies/computational tools can be developed in support of innovation?
 - What type of work environments foster innovation?
-

Why Innovation Science?

Main Drivers

- 50% of economic growth attributed to innovation
 - Strong differentiator of US economy in the 21st century
 - Innovation may easily override almost any other improvement that we could possibly make
 - Success of entrepreneurship programs
-

Innovation Approach Example: Boeing Co.

Large Scale Problem

- Why do we fly the way we do?
 - Passenger processing
 - Handbags processing
 - Main luggage processing
 - Plane loading and unloading
 - Can we do better?
 - Systems of systems solution
-

Innovation Approach Example: HP Co.

Small Scale Problem

- What should a printer do besides printing (e.g., faxing)?
 - What functionality should it have?
-

Innovation Tools

Example

- Brainstorming can be done WELL and POORLY
 - What about more serious tools supporting innovation?
 - Who knows about these tools?
 - Who will develop them?
-

Why Innovation Science?

Gaps

- Research
 - Innovation is not well understood
 - Teaching
 - Lack of courses and curricula
 - Lack of textbooks
 - Practice
 - Tools in use are limited, e.g., TRIZ – software based on Soviet era patents yet it has been used by numerous industries
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Innovation Science Perspectives (1)

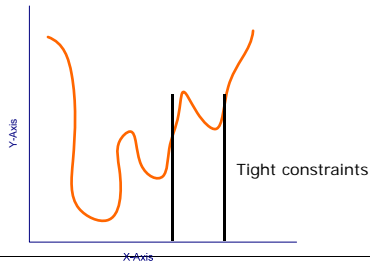
“Borrowing” from

- Mathematical programming
 - Evolutionary computation
 - Data mining
-

Innovation Science Perspectives (2)

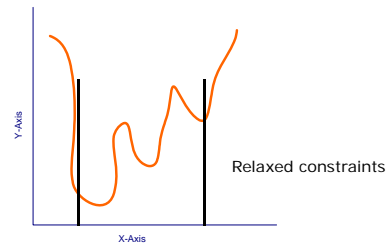
Find the minimum!

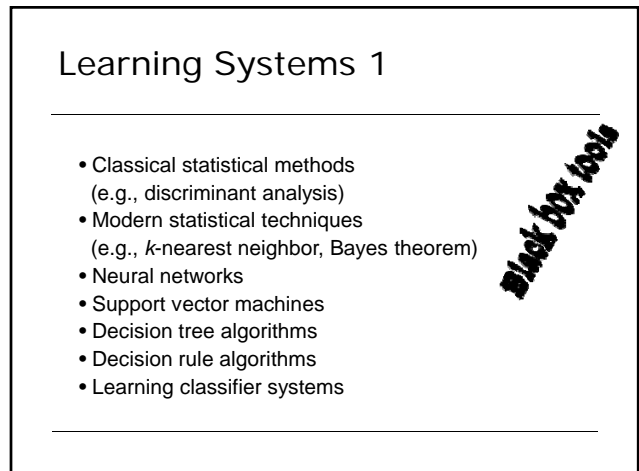
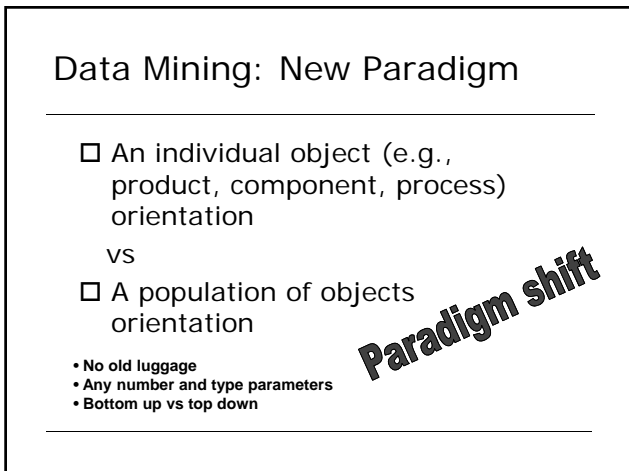
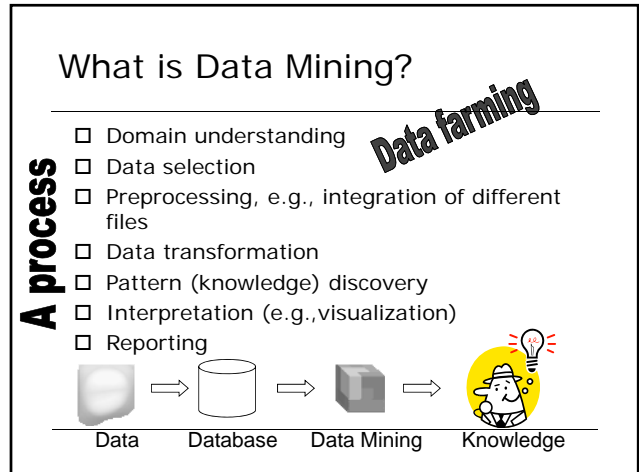
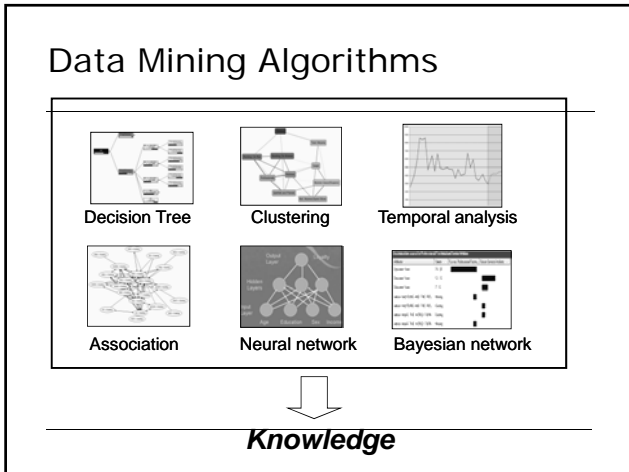
Example



Innovation Science Perspectives (3)

Constraint relaxation





Learning Systems 2

- Association rule algorithms
 - Text mining algorithms
 - Meta-learning algorithms
 - Inductive learning programming
 - Sequence learning
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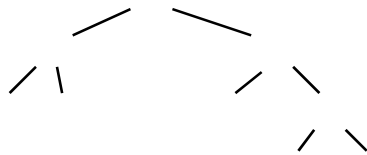
Innovation Science Perspectives (4)

- Evolutionary computation, e.g., genetic programming
 - Based on natural systems
 - "Smart" exploration of alternatives

Example: Design without patent infringement

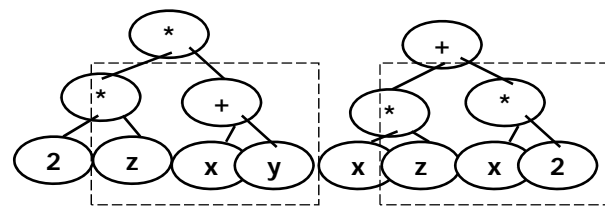
GP Representation

- Designs are represented as trees



$$F(x,y,z) = (* (* (+ 2)))$$

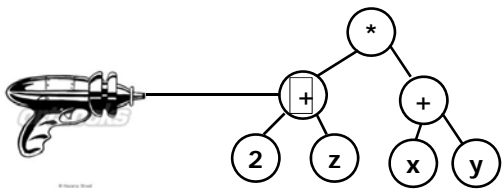
Crossover



Design 1

Design 2

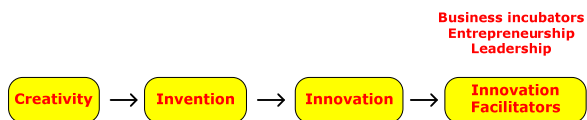
Mutation



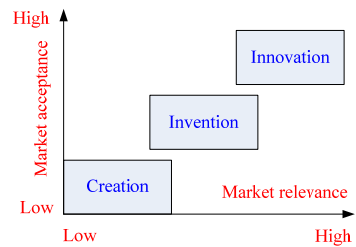
Reproduction

- Fittest designs are selected
 - Tournament selection
 - Fitness function?
-

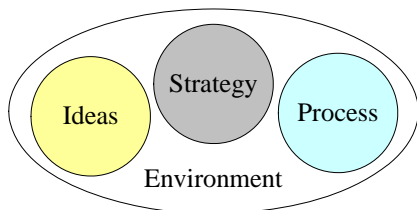
Innovation Environment: Definitions



Relationship between Creation, Invention, and Innovation



Innovation: What is Needed? (1)



<http://www.getfuturethink.com>

Innovation: What is Needed? (2)

- Ideas: Consider many alternatives
 - Strategy: Setting goals and ways of achieving them
 - Process: Establish basic innovation steps
 - Environment: Making innovation a natural activity
-

Product Innovation: The Necessary Conditions

- Basic Elements:
 - Market needs
 - Knowledge of the market
 - Product/process knowledge
 - Innovation management
 - Right level and mix of innovation at any given corporation
 - Customers adapt slowly to change

If you don't innovate fast in today's world, you will go away very, very quickly [Curtis Carlson, CEO, SRI International]

Innovation: A Question

- Where to focus:
 - Generating new inventions?
 - Transformations of existing solutions into innovations?
 - Integrating existing inventions into innovations?
-

**Radical
innovation**
**Continuous
innovation**
**Integrative
innovation**

Innovation in the Literature

- Creativity
 - Book *The Creating Brain: The Neuroscience of Genius* by Nancy Andreasen, U of Iowa Professor of Psychiatry
 - Andreasen's Theory (Hypothesis): "Creative ideas appear spontaneously when people are not trying to be creative"
 - Example 1
 - Mozart who composed his music after a good meal and a walk, that would occasionally trigger a complete symphony
-

Innovation in the Literature

- Creativity
 - Example 2
 - Friedrich Kekule – German chemist who determined the structure of benzene - entered a dreamlike state in which the form of benzene came to him in a brilliant flash
-

Innovation in the Literature

- Creativity
 - Terrence Ketter – Professor of Psychiatry, Stanford U
 - Ketter's Theory (Hypothesis): "Creativity is directly related to mental instabilities, because the brain uses its negative emotion to initiate a real or fictional solution to the problem"
 - What comes first creativity or the mood disorder?
 - Where does creativity comes from? [It is not known, Peggy Nopoulos, UI Professor of Psychiatry]
-

Innovation in Industry: SRI

- Innovativeness
 - Book *Innovation: The Five Disciplines for Creating what Customers Want* by Curtis Carlson, CEO, SRI International, Menlo Park, CA and William Wilmot, Director, Collaboration Institute
 - Hypothesis: "Rapid, consistent innovation comes from highly disciplined processes" [which may surprise many]
-

Innovation in Industry: SRI

□ Innovativeness

■ Five disciplines:

1. "Select important, not merely interesting problem"

E.g., Douglas Engelbart, the SRI engineer who invented the computer mouse and hypertext, asked his team "to make the world a better place by augmenting and extending the human intellect"

Innovation in Industry: SRI

□ Innovativeness

■ Five disciplines:

2. "Assess each innovation for its value to the customers"

Look beyond cost and quality, e.g., into convenience and conscience

3. "Appoint a champion who is insanely committed to the project"

No champion, no project, no exception

Innovation in Industry: SRI

□ Innovativeness

■ Five disciplines:

- 4 & 5. "Building teams and doing so across the organizations"

Engelbart's iterative approach was also applied on a larger scale by Google, which publishes beta versions of its products and feeds customer responses into development of these products

Innovation in Industry: Xerox

□ Combine Ideas

Xerox Corporation looks for intersection between ideas and combining them into next offering of products

Pentilla, C., Big Ideas, *Entrepreneur*, March 2007, pp. 62.

Innovation in Industry: Xerox

- Create an Internal Incubation Fund
Xerox sets aside funds that encourages employees to network and develop ideas that are different from the currently funded ones

Pentilla, C., Big Ideas, *Entrepreneur*, March 2007, pp. 62.

Innovation in Industry: McDonald's

- McDonald's innovation team thinks it terms of "back-casting" – starting with an end-product and working backward towards the basic idea that is cost and technology feasible

Pentilla, C., Big Ideas, *Entrepreneur*, March 2007, pp. 62.

Innovation in Industry: McDonald's

- Do Rapid Prototyping
McDonald's transforms quickly ideas from a blackboard to 3-D models

Pentilla, C., Big Ideas, *Entrepreneur*, March 2007, pp. 62.

Innovation in Industry

- Take it On-Line
Idea management software automates the innovation process by allowing multiple partners to contribute to the idea being worked on

Pentilla, C., Big Ideas, *Entrepreneur*, March 2007, pp. 62.

Networking ... Networking

	Society of Collaborative Networks DEE-FCT - Campus of the New University of Lisbon 2829-516 Monte da Caparica - Portugal http://www.socolnet.org
	Member N ^o : 156 Andrew Kusiak MEMBER
	

<http://www.socolnet.org>

<http://web.mit.edu/innovation/>

Innovation in Industry

Take advantage of "gift economy"

Examples

- Wikipedia
- Linux operating system
- Firefox web browser
- Media sites: YouTube, Digg, and Flickr

Y. Benkler, *The Wealth of Networks*, Yale University Press, New Haven, CT, 2006.

http://www.benkler.org/Benkler_Wealth_Of_Networks.pdf

Innovation in Industry

Allan Morally – Ford's CEO

- Innovation rule at Boeing
 - Encouraging managers to speak up about problems (not prize him and themselves for the job well done as commonly recommended, e.g., D. Trump – a business person has to be always positive)

Innovation in Industry

Carlos Ghosn

- Renault and Nissan
- Has become
 - A two suitcase man
 - 7 Eleven man
 - Rock star of a company

Innovation in Industry

- Carlos Ghosn's Innovation Ideas
 - Sell-off Nissan shares to the suppliers
 - Forming world-wide alliances
 - Pursuing the concept of common platform across continents
 - Micro managing, as needed.
-

Innovation in Insurance Industry

- Pay As You Drive™ insurance is a new type of car insurance providing comprehensive individual cover
 - Using the latest GPS (Global Positioning System) technology monthly insurance premium is calculated based on driving pattern of an individual driver
-

<http://www.payasyoudriveinsurance.co.uk/index.htm>

Different Thinking

- All businesses require innovation driven by new ideas. Some degree of unconventional thinking is essential for businesses to succeed.
 - Experience points to many companies trapped by conventional thinking.
-

Garvin, D. A. and Levesque, L.C., Meeting the Challenge of Corporate Entrepreneurship, *Harvard Business Review*, October 2006, pp. 102-112.

Different Thinking – Counter Examples

- Microsoft's using too much energy on limiting open-source software.
 - Polaroid's grudging move into digital cameras.
 - GM's and Ford's reluctance to embrace hybrid cars, improve fuel economy, and embracing the common platform idea.
 - Distaste of media companies for blogs.
-

Innovation and Globalization (1)

- At present (2007) emerging markets make 21% of the global economy
- 25 years from now emerging markets will make up at least 50% of the global economy
- In the past 20 years US exports to emerging markets have increased 338% (much faster than domestic demand)

USA Today, March 7, 2007, p. 11A

Innovation and Globalization (2)

Industrial Examples

- GE plans to double sales in emerging markets from 15% to 30% between 2007 and 2010
- Goldman Sachs builds a franchise in China
- Dell and GM increasingly produce in India and China for local markets

USA Today, March 7, 2007, p. 11A

Innovation and Globalization (3)

Culture Change

- P&G
 - Places young managers with local families
 - Establishes international focus groups to tailor products to local markets
 - Forms business alliances with new breed of companies

USA Today, March 7, 2007, p. 11A

Innovation and Globalization (4)

Culture Change

- Universities
 - Emphasize teaching creative problem solving skills
 - Introduce programs of study and work abroad
 - Promote learning foreign languages

USA Today, March 7, 2007, p. 11A

Innovation at Different Countries

- Australia
 - National Innovation Awareness Strategy
 - Innovation for business
 - Innovation for youth

<http://www.innovation.gov.au/>

Imitation vs Innovation

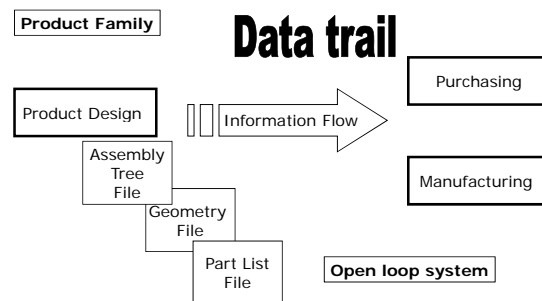
Imitative Design	Innovative Design
Market demand is relatively predictable	Potentially large and unknown demand; The risk of failure is large
Rapid market recognition and acceptance	Market acceptance may be initially slow; however, the imitative competition response may be also slow
Readily adaptable to existing market, sales, and distribution networks	May require unique, tailored market distribution and sale policies aimed at educating customers
Fits existing market segmentation and product policies	Demand may cut across traditional marketing segments, disrupting divisional responsibilities

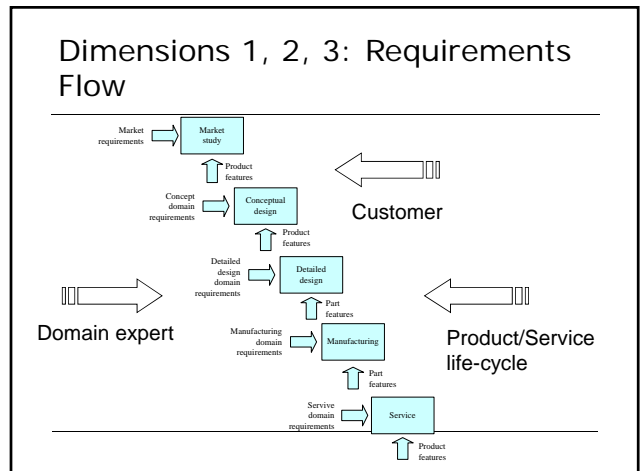
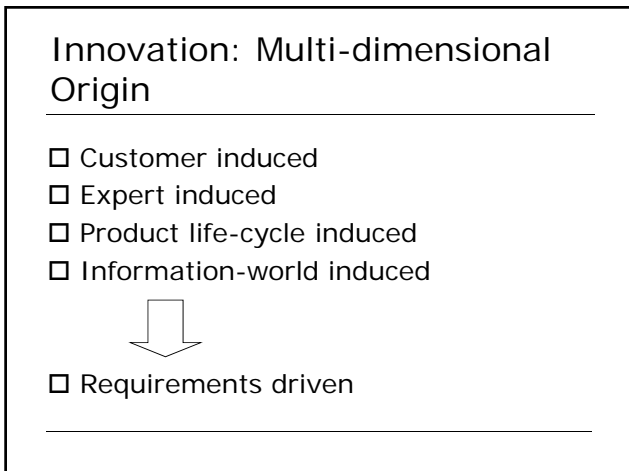
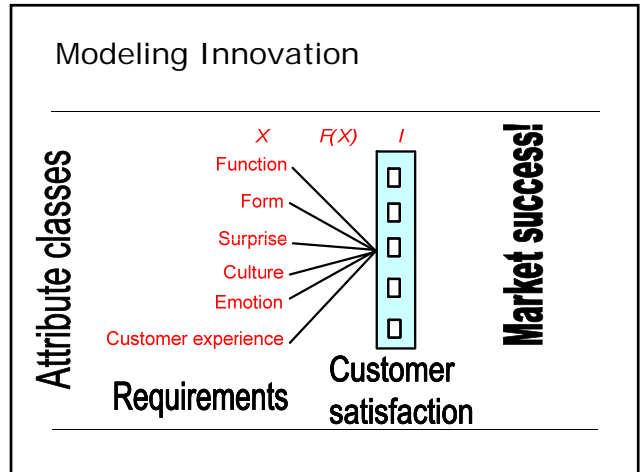
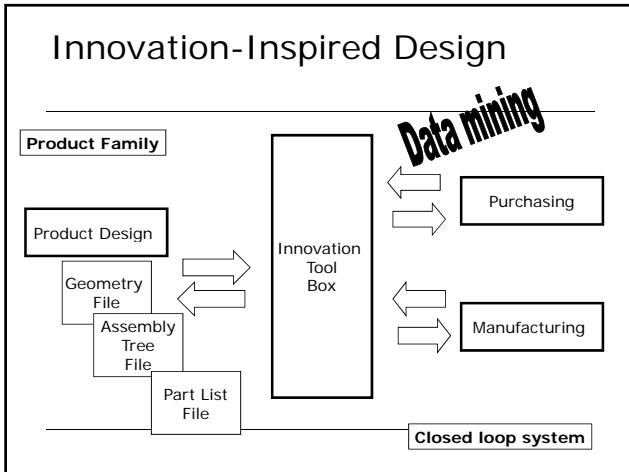
R.H. Hayes and W.J. Abernathy, *Managing Our Way to Economic Decline*, *Harvard Business Review*, Vol. 85, No. 7-8, 2007, pp. 138-149.

Data-driven Innovation

- Data reflect product/system behavior
- Data has been used to monitor, processes, improve efficiency, detect faults, and so on
- The use of data in data in innovation has not being pursued
- Innovative ideas may embedded in the data

Traditional Design





Customers Involvement

Example

- ❑ Procter & Gamble has opened its product development processes to key stakeholders
- ❑ Innovation success rate has doubled in two years
- ❑ R&D expenditure has decreased by 3.4%

Huston, L.; Sakkab, N., Connect and develop: Inside Procter & Gamble's new model for innovation, *Harvard Business Review*, 84(3), 2006, 58-66.

Domain Expert Involvement

Example

- ❑ Clinicians often administer drugs for cases that are not indicated on the label.
- ❑ In chemotherapy, the off-label use of drugs as much as 85% of the total prescriptions.
- ❑ 29 new approved drugs studied.
- ❑ In five year period after the drugs have been introduced to the market, 143 new applications were identified.
- ❑ Eighty-two (57%) of the 143 drug therapy innovations in the studied sample were discovered by practicing clinicians through field discovery.

DeMonaco, H.; Ayfer, A.; von Hippel, E, The major role of clinicians in the discovery of off-label drug therapies, *Pharmacotherapy*, 26(3), 2006, 323-332.

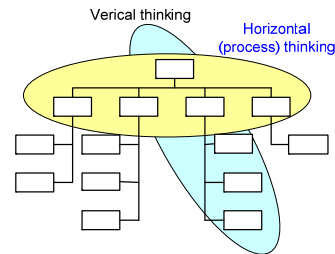
Dimension 4: Cyberspace

Example

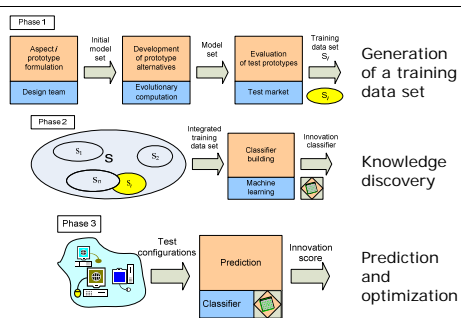
MySpace



Innovation: Process Thinking



Innovation: A Data Mining Solution



Challenges

- Data availability
- Industry struggle with embracing the concept of gift economy
 - Benefits from customers' input vs
 - Potential losses from revealing
- Lack of experience
- Computational experience with mass customization data

Summary

- Innovation handled at the business-rule level
- Data may change the innovation landscape
- Evaluation of products/services the most important gap
- Great promise of the innovation-driven economy
- Diverse products, systems, and services call for different innovation approaches

Intelligent Systems
Laboratory

Innovation

Case Studies

Case Study 1: Process Invention

Invention (possibly innovation) through integration of the existing technologies (Inventions)

Data Without Boundaries™

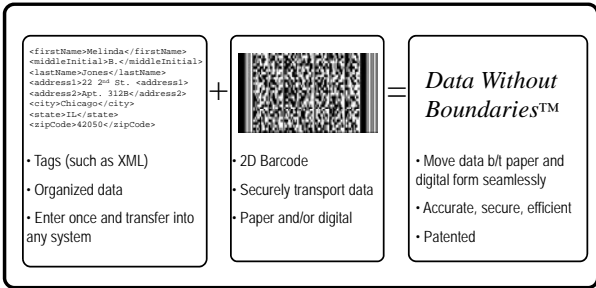
Video Barcode™



www.tripletailventures.com

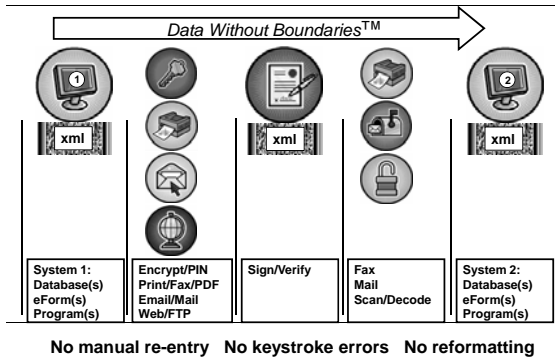


Technology Equation



United States Patent Nos. 6,764,009 and 7,070,103 and other pending patents

Moving Data Between Disparate Systems



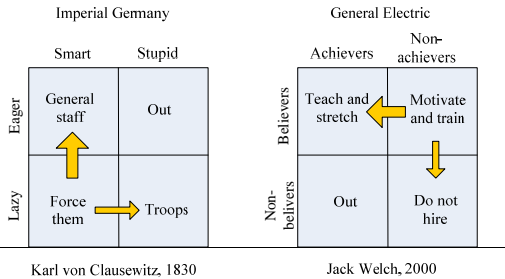
Case Study 2: General Electric (1)

Organization Innovation

- Jack Welch's 20 years
 - 1981 – First wave (Hard)
 - Create a new vision and strategy to drive reorganization, mass dismissals, divestments, and acquisitions
 - 1985 – Second wave (Soft)
 - Revolutionize GE to gain strengths of a large company with the leanness and agility of a small company
 - 1996 – Third wave (Soft and hard)
 - Develop an integrated, boundary-less, stretched, total quality company with A-players

Case Study 2: General Electric (2)

1996 – Third wave: Selecting Leaders



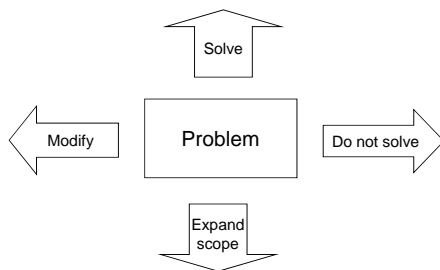
Case Study 3: Problem Innovation

Incremental innovation through requirements modification

Process Efficiency Optimization

*Boeing
Geometry design*

Innovative Problem Solving



Case Study 4: Different Types of Innovation

Organization Innovation

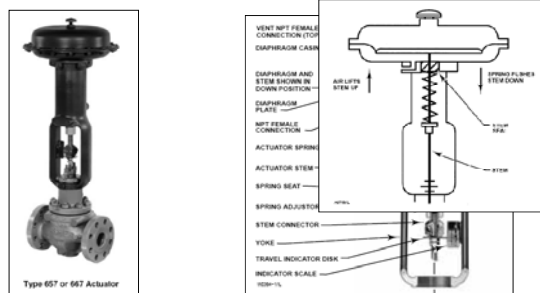
- Dell Corporation
 - Driver: Process innovation (e.g., manufacturing, supply chain, warranty service)
 - Success: Largest computer producer
- Apple Corporation
 - Driver: Product innovation (+ lately process innovation)
 - Success: Survived fierce competition despite strategic business errors
- Gateway Corporation
 - Drivers: Product and process innovation
 - Success: Limited market share

Case Study 5: Starbuck's Coffee

Product and Process Innovation

- Why customers are paying high price for low cost ingredients (material)?
 - Highly customized product (size and taste)
 - Unusual locations
 - Easily recognizable

Case Study 6: Product Innovation (Undergraduate Student Project)



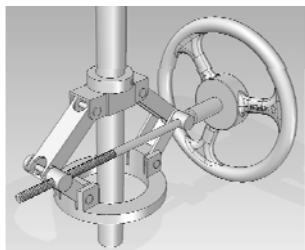
Valve

Actuator

Redesigned actuator

Primary design objective: Reduce cost of the actuator

Jack design – mirrors that of an automotive scissor jack



Conclusion

- Innovation handled at the business-rule level
- Data may change the innovation landscape
- Evaluation of products/services the most important gap
- Great promise of the innovation-driven economy
- Diverse products, systems, and services call for different innovation approaches

References (1)

- Carlson, C. and Wilmot, W., *Innovation: The Five Disciplines for Creating what Customers Want*, 2006, Crown Business, New York.
 - Benkler, Y., *The Wealth of Networks*, Yale University Press, New Heaven, CT, 2006.
 - Pentilla, C., Big Ideas, *Entrepreneur*, March 2007, p. 62.
 - Garvin, D. A. and Levesque, L.C., Meeting the Challenge of Corporate Entrepreneurship, *Harvard Business Review*, October 2006, pp. 102-112.
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 - A. Kusiak, Innovation Science, *Proceedings of the 11th IEEE Conference on Emerging Technologies and the Factories of the Future, ETFA 2006*, Prague, Czech Republic, September 2006, pp. 507-514.
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 - A. Kusiak and C.-Y. Tang, Innovation in a Requirement Life-Cycle Framework, *Proceedings of the 5th International Symposium on Intelligent Manufacturing Systems, IMS'2006*, Sakarya University, Sakarya, Turkey, 2006, pp. 61-67.
 - A. Kusiak and C.-Y. Tang, Data-Inspired Innovation Model, *Proceedings of the 36th International Computers and Industrial Engineering Conference, C&IE 2006*, June 2006, Taipei, Taiwan, pp. 1-8.
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<http://www.icaen.uiowa.edu/%7Eankusiak/recent-paper.html>