The Process of Innovation in Computing: A Personal 30-Year Perspective

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http://www.ics.uci.edu/~wscacchi/Presentations/InnovationInComputing.pdf

Overview

- Preliminaries and definitions
- Early computing innovation studies (<1980)
- Developing computing innovation studies (1980-1990)
- Transforming organizations through computing innovation studies (1990-2000)
- Multi-modal computing innovation studies (>2000)

Preliminaries and definitions

- *Process of innovation in computing*
  - A trajectory of situated activities people perform to displace the status quo through a web of socio-technical resources, work situations, and interaction networks
- *Computing innovation*
  - Adds to or redistributes access to the available supply of computing resources, work situations, and interaction networks
- *Unit of analysis*
  - Life history of a computing innovation in a complex organizational setting

Preliminaries and definitions

- *Innovation life cycle stages*
  - Discovery or invention
  - Development
  - Diffusion
  - Adoption
  - Implementation
  - Routinization
  - Evolution (debugging, accretion, tuning, restructuring, merger, migration, retirement, reinvention)

Organizational field sites

- Andersen Consulting LLP
- AT&T and AT&T Bell Laboratories
- Bayfront Technologies, Inc.
- BellCore
- Computer Science Dept., USC
- Daegu Global R&D Collaboration Center
- Defense Acquisition University
- Discovery Science Center
- Eastman Kodak
- EDS
- Enabling Business Technologies LLC
- EON Reality
- Ernst and Young LLP
- Fujitsu
- GDE Systems Inc.
- Hewlett-Packard
- Holosofx Inc. (Active Management Inc.)
- Hughes Aircraft
- IBM
- Intel
- Intelligent Systems Technology Inc.
- Knowledge System Laboratory, Stanford University
- MCC
- McKesson
- Naval Air Warfare Center
- Naval Ocean Systems Center
- Naval Postgraduate School
- New Directions Technologies Inc.
- Northrop-Grumman
- Office of Naval Research
- Pacific Bell
- Pacific Life
- Perceptronics
- Physics Dept., UCI
- Software Engineering Institute, Carnegie-Mellon University
- SUN Microsystems
- TRW
- USC Advanced Biotechnology Center
- USC Entertainment Technology Center
- USC Information Sciences Institute
- *Virtual organizations* (about 20 Web-based projects developing free/open source software)
- WICOR (Wisconsin Gas)
- *Withheld* (another dozen in litigation support)

Early computing innovation studies (<1980)

Consumption of computing innovations

Case study: DoD production of a software innovation (Ada programming language)

- 1973, U.S. Department of Defense reports spending >$3B annually on software development, deployment, and support
  - Upwards of 90% of software costs go to "maintenance"
- 1975-1979 DoD invests $$$ in the invention and development of new programming language for embedded military applications
  - Language called Green, DoD-1, then Ada
- Was this a good idea/approach?

R. Kling and W. Scacchi, The DoD Common High Order Programming Language Effort (DoD-1): What Will the Impacts Be?, *SIGPLAN Notices*, 14(2), 29-41, 1979.

Predicting the future consumption of Ada as a software innovation

- Problematics:
  - Why does software cost so much to produce and consume?
  - How do DoD contractor business practices drive the cost of software?
- Observations:
  - Contractor financial operations treat software development as a liability, and software maintenance as a revenue
  - Financial conditions distort software production costs
  - Be careful for what you hope to realize through computing innovations

Other consequences that followed

- Kling and Scacchi subjected to criticism and career threats by DoD software researchers
- Senior military officials endorse KS79 observations
- Scacchi engaged by DoD Ada Office (1982) to design software production program focus for future Software Engineering Institute
  - Software production process
  - Software technology transfer process (innovation life cycle)
  - SEI-CMU launches in 1985 with these programs
  - MCC also adopts STT process program focus in 1986
- Be careful for what advice you offer for computing innovation processes and practices.

Process of Innovation in Computing (1977-1980)

Innovation / Organization	Hardware	Software	Organizational	Innovation Processes
UCI Physics	Computer graphics terminals	Operating system upgrade	CPU usage charge-back mechanism	Hassling and distracting
Pacific Life	Distributed computing systems (mini-computers)	Database management facilities	User-specialist liaisons	Structuring
Knowledge Systems Lab	Processor memory and disk storage upgrades	Text processing system	Computer-based work environment	Mirroring and pacing
Innovation Processes	Expanding and demanding	Tinkering and layering	Regulating and stabilizing	Fitting, packaging, and cycling

W. Scacchi, *The Process of Innovation in Computing: A Study in the Social Dynamics of Computing*, Unpublished Dissertation, Information and Computer Science Dept., UC Irvine, 1981.

Additional findings

- History of commitments constrains choice
- Narrow incentives and opportunities motivate choice
- Macrostructural patterns influence local computing
- Distribution of computing resources and system configurations is tied to the career contingencies of local participants
- Computing innovations enable new use, and use create demand for computing innovations
- Innovation in computing is a continuous process.

R. Kling and W. Scacchi, The Web of Computing: Computer Technology as Social Organization, in M. Yovits (Ed.), *Advances in Computers*, 21, 2-90, 1982.

Developing computing innovation studies (1980-1990)

Production of computing innovations

Case study: Understanding innovation development teamwork

- Comparative analysis of teamwork practices when formally specifying a software innovation to develop in complex setting.
  - USC System Factory Project (1981-1992)
  - Five graduate student teams, 5-7 members, two-week (part-time) process that incorporates planning, formal notation, automated tool use, reusable examples, documentation tasks, and team shared responsibility.

What to Understand

- Work *Structures* and *Shifts*: Resource arrangements, historical circumstances, division of labor and expertise, etc.
- Work *Processes*: Routine, habitual or emergent patterns of how work flows among people through/ onto work structures
- Work *Practices*: Behavioral discourse and social dynamics enacted through work processes

What to Understand

- Work structures are *domain independent constructs*
  - Prescriptive/descriptive abstractions
- Processes are *classes* of workflow
  - Descriptive and derived
  - Prescriptive and composed
- Practices are *instances*
  - Descriptive, historic and situated

Comparative analysis of software innovation production teamwork

- Six work structure types observed: **N**egotiated, **I**ntegrated, **R**eplicated, **D**elegated, **P**rediscriminated and **S**eparated
- Three types of structural shift observed:
  - anticipated **->**,
  - unanticipated **-->>**,
  - role shift within work structure +.

Work structures and shifts (data)

Team ID	T1	T2	T3	T4	T5
Team Size	6	7	7	7	5
Reusable Exemplar	no	yes	yes	yes	yes
PROCESS					
A. Pre-planning task	N->R->I	N->R->I	N->R->I	N->R->I	N->R->I
B. Planning task	N	N	N	N	N
c.	I	I	I	I -> S	I -> S
d.	I	I+	I	S	S
e.	P (D,I,I)	P (D,I,I)	P (D,I,I)	P (D,S->I,I)	P (D,D,I)
f.	D	D	D	D	D
g.	R	R	R	D	D
h.	D	I	I	D	D
C. Develop preliminary	I -->>	I+	I+	I+ -> S+	I -> S+
(informal) specification	N -->>				
	R -->> I				
D. Develop formal	I+	I+	I+	S+ -->>	S+
(processable) spec.				N -->>	
E. Document	N -->> D	P+	P+	N -->>	P(D,D,I)
write-up				P(D,S->I,D)	
F. Documentation	D -->>	D+	D+	D+	D+
integration	N -->> I				
G. Document review	R	R	R	N -->> R	D
H. Prepare for	D -->>	I+	N -->> I+	N -->> I+	D+
Delivery	N -->> I				

Findings

- Highest (lowest) *quality* product (measured by automated tools): T1 (T5)
- Highest (lowest) *productivity* (self reported time expended): T5 (T1)
- Note the *coincidental* relationship
- Effectiveness of planning, automated tool use, asset reuse *not* clearly associated with high(low) quality or high(low) productivity

Findings

- Teams enacting primarily into Negotiative and Integrative structures had higher quality
- Teams enacting primarily into Delegative, Pre-discriminative or Separative structures had higher productivity
- Computer supported work environments must account for teamwork structures as a usage parameter to be most effective.

Transforming organizations through computing innovation studies (1990-2000)

Going meta

Case study: Designing large-scale production operations

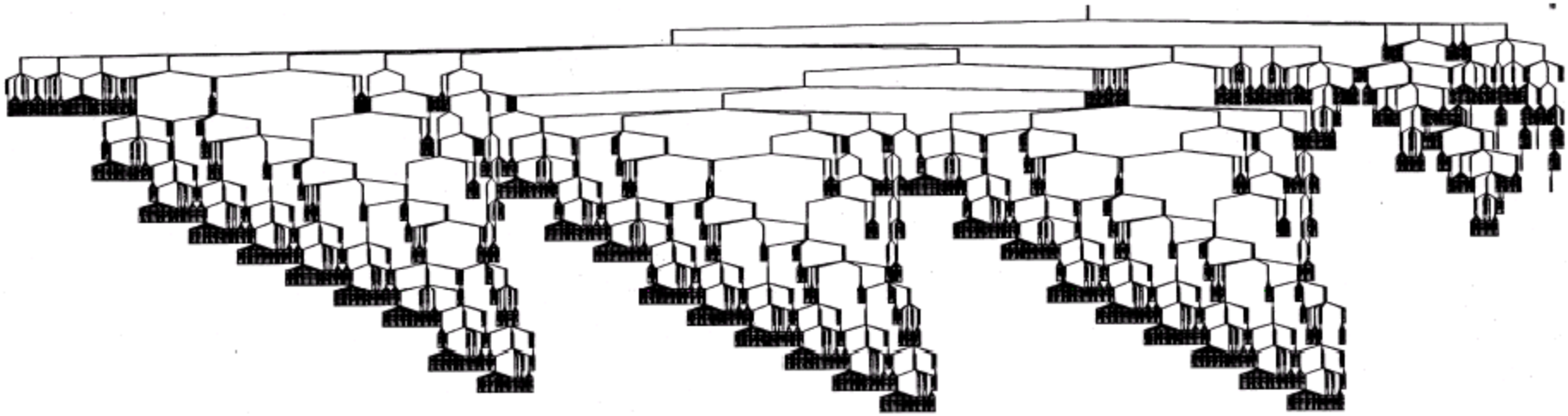
- Major TelCo (AT&T) wants to develop broadband multi-media telecommunications system
- Anticipates $1B development, up to1500 system developers working 2-3 years
- Seeks industrial partners to provide supporting infrastructure to reduce risk
- IT partner (HP) wants to showcase new “process support technology” products as sales lead
- IT partner brings in my academic research team (USC Atrium Lab) to analyze and advise TelCo on “production process design issues”

The story continues

- Team, IT partner, and TelCo jointly elicit, capture, codify (*formalize*) and inter-relate TO-BE system development process.
  - (Re)Design organizational computing innovation
- Team employs IT partner's products to present results of their "process analysis"
- Team view of their effort -- a major computing innovation success for publication (and re-publication)

P.K. Garg, P. Mi, T. Pham, W. Scacchi, and G. Thunquest, The SMART Approach to Software Process Engineering, *Proc. 16th. Intern. Conf. Software Engineering* , IEEE Computer Society, Sorrento, Italy, pp. 341-350, (May 1994). Reprinted in *Process-Centered Software Engineering Environments* , P.K. Garg and M. Jazayeri (eds.), IEEE Computer Society, pp. 131-140, (1996)

A complex organizational process: a *decomposition-precedence* relationship view (19 levels of decomposition, 400+ tasks)



W. Scacchi, Experience with Software Process Simulation and Modeling, *J. Systems and Software*, 46(2/3):183-192,1999.

The story ends

- Team suggests overall process won't succeed -- too complex, too much delegation, problematic hand-offs ("throwing it over the wall")
- TelCo and IT partner dismisses academic team
- Less than one year later, IT vendor abandons innovative process technology product
- Two years later, business press reports TelCo experiences major project failure and losses greater than $200M, and no operational system.

Case Study: Transforming procurement processes at ONR

- Present an approach for how to optimize business processes including software production
- Identify key concepts, techniques, and tools that enable better optimization
- Describe optimization transformations from business process redesign studies
- Describe opportunity areas for exploitation and use

Definitions and Differences

- *Software production*: enterprise processes and resources that produce software
- *Production strategies*: business strategies guiding overall approach to building software systems
- *Production architecture*: configuration of enterprise capabilities to enact strategies
- *Optimizing production*: minimizing enterprise configuration to maximize strategic outcomes

(Re)designing production processes

- Which process first: **to-be** goal vs. **as-is** mess?
  - *If you don't know where you are, any road will do* (proverb)
  - Observation: people at work cannot describe the processes they do with high fidelity (tacit knowledge lemma)
  - Redesign necessitates understanding as-is, to-be, and *here-to-there processes*
- Creating high-performance work groups
  - Empowerment, participation, incentivization (resource sovereignty), and recognition (patronage, status, accomplishment)

W. Scacchi, Redesigning Contracted Service Procurement for Internet-based Electronic Commerce: A Case Study, *J. Information Technology and Management,* 2(3), 313-334, 2001.

Generic Strategies

- Reduce costs
- Reduce cycle time
- Improve cash flow
- Increase customer satisfaction
- Increase sales
- Improve customer service
- Increase productivity
- Open new markets
- Open new “channels”
- Become innovation leader
- Increase market share
- Enable just-in-time service delivery

Enterprise Production Architecture

- A *composite model* that interrelates
  - software system architecture
  - software production architecture
  - development organization architecture
  - information network infrastructure and development tools/environment configuration
  - documentation architecture
  - customer-support knowledge base architecture

P. Mi and W. Scacchi, A Meta-Model for Formulating Knowledge-Based Models of Software Development, *Decision Support Systems*, 17(4):313-330, 1996.

Optimizing Production

- Strategies provide global constraints or opportunities for optimizing production
- Constraints and opportunities realized in production setting
- Constraints and opportunities are distributed across the production architecture

Optimizing Production

- Optimization must address composite production architecture
- Local optimization of any component architecture does not guarantee global optimality of software production
- *Diagnostic analyses* and *transformation heuristics* applied to composite architectural models lead to optimization opportunities

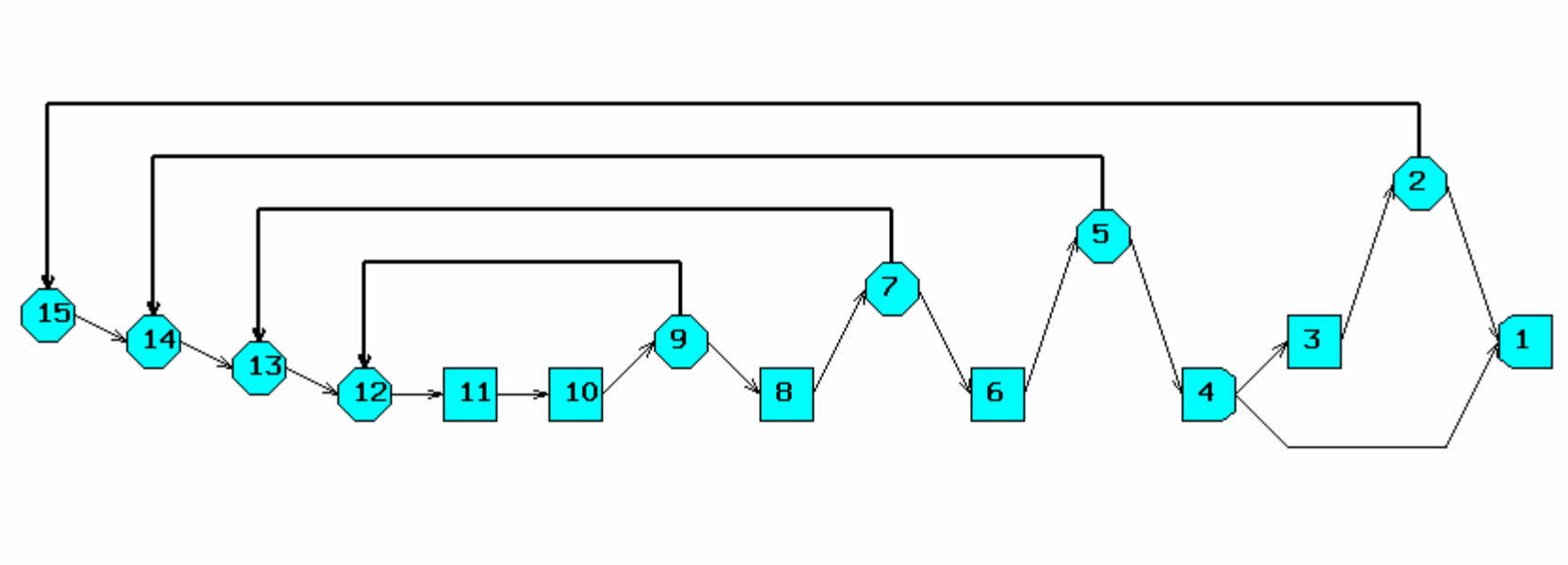
Optimizing Production

- Transformation heuristics classified taxonomically
- Taxonomy classifies *domain-independent* (DI) and *domain-specific* (DS) heuristics
- DI transformations applied in *any* software production setting
- DS transformations applied to specific component architectures

Optimizing Production

- DI transformation classes (sample):
  - Job scope
  - Worker empowerment
  - Organization design
  - Workflow streamlining
  - Information technology (IT)

Research grant justification and approval process at Office of Naval Research (c. 1995)



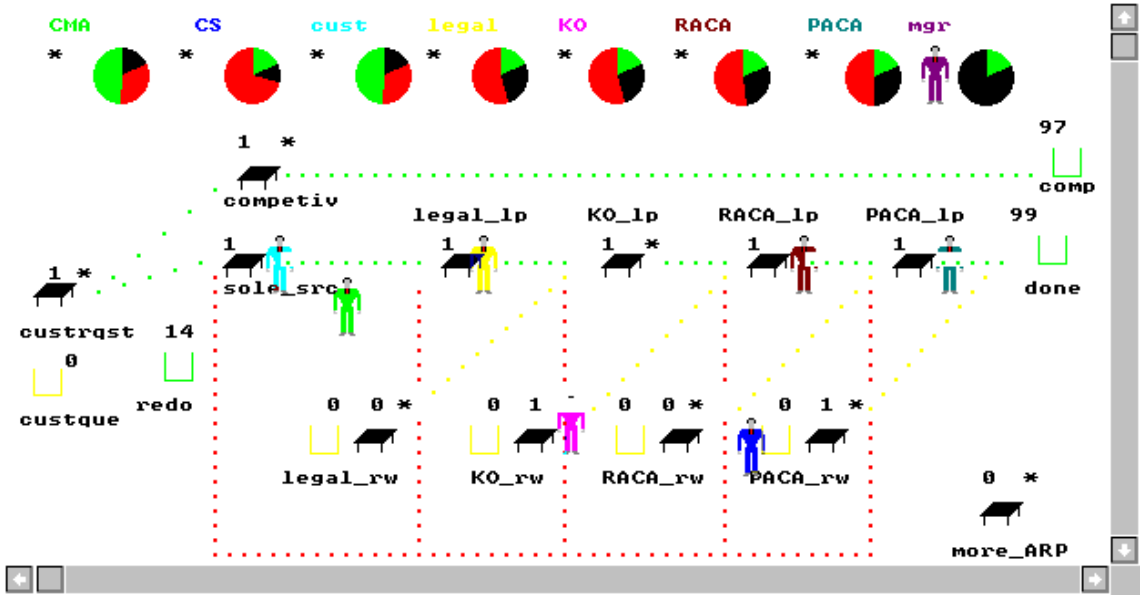
W. Scacchi and J. Noll, Process-Driven Intranets: Life Cycle Support for Process Reengineering , *IEEE Internet Computing*, 1(5):42-49, 1997.

Optimizing Production

- IT transformation sub-classes (sample):
  - Extend IT-based *support* to manual process steps
  - Extend IT-based *communication* facilities to encourage information sharing activities
  - Extend IT-based *automation* to incorporate new kinds of application packages
  - Extend IT-based *integration* to interconnect and interrelate existing "islands of automation"

Example DI process redesign hueristics applied at ONR

As-is Diagnosis	*Applicable Hueristics*	*Expected ROI*
Many manual steps	Consolidate and automate (workflow and IT-support)	Med-High
Many linear step sequences	Identify parallelization opportunities (workflow)	High
Many reviews steps	Joint collaborative reviews (job scope, organization design)	High
Many data validation steps	Rule-based review system (IT-automation)	Med-High
Many data validation steps	Push validation responsiblities upstream (job scope)	Med-High
Manual assembly of compound documents	Rule-based document builder (IT-automation)	Low-Med
Duplicating and circulating documents	Automate distribution and archiving (IT-communication)	Med-Very High
Replace paper documents	Employ electronic proposals and grant documents (IT-communication)	High-Very High
Islands of automation	Intranet with process support, data integration, and product navigation (IT-integration)	Low-High
Wide-area workflow	Internet-based process enactment (IT-support, IT-communication, IT-integration, IT-automation)	Med-High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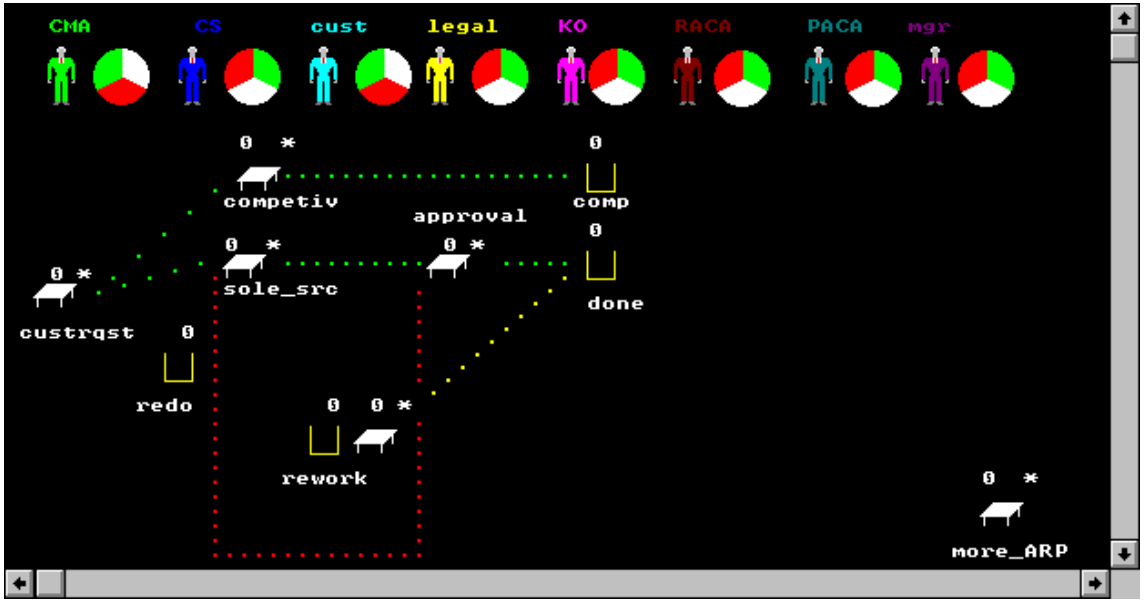
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Redesign/Optimization (Innovation) Results

- Reduction in *procurement process* cycle times of 20X, annual operational savings of $10M-15M.
  - Via transformation and realignment of information systems, business processes, corporate strategy, and work practices in a 1-2 year time frame.
  - Participatory design, development and refinement of computational models of new work processes, resource configurations and work practices, together as an *organizational system*.

W. Scacchi, Redesigning Contracted Service Procurement for Internet-Based Electronic Commerce: A Case Study, *Information Technology and Management*, 2(3):313-334, 2001.

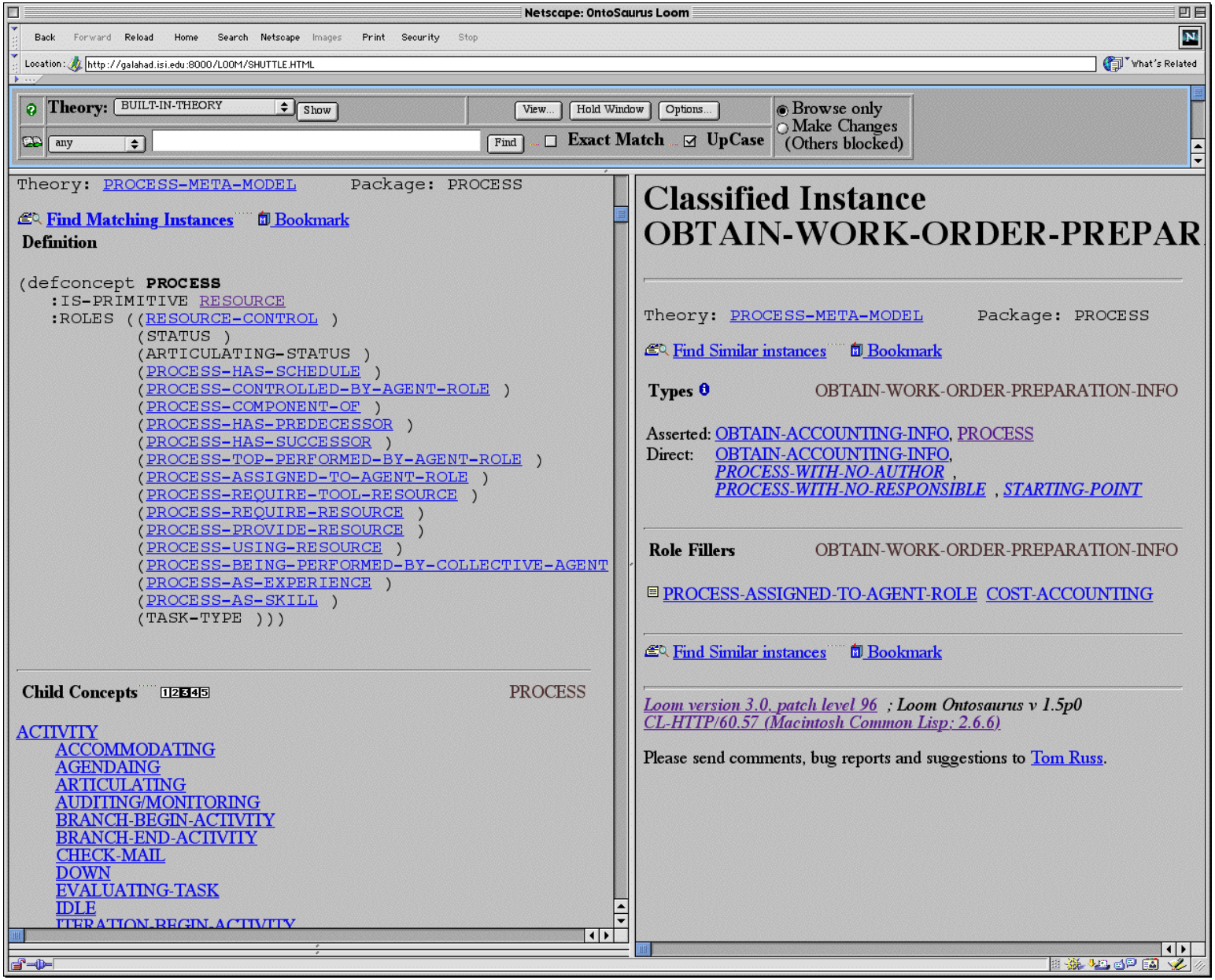
Tools and Techniques

- Software process redesign case web
- Knowledge web for software production
- Process-driven intranets
- Organizational transformation

Computing innovations enabling other computing innovations

- Process redesign (organizational innovation) case web
- Knowledge web for producing and consuming computing innovations:
  - Software production ontology
  - Taxonomy for as-is diagnosis, redesign heuristics
  - Best practices and lessons learned cross-linked
- Engage in organizational transformation projects

W. Scacchi and A. Valente, Developing a Knowledge Web for Business Process Redesign, Presented at the *1999 Knowledge Acquisition Workshop*, Banff, Canada, October 1999.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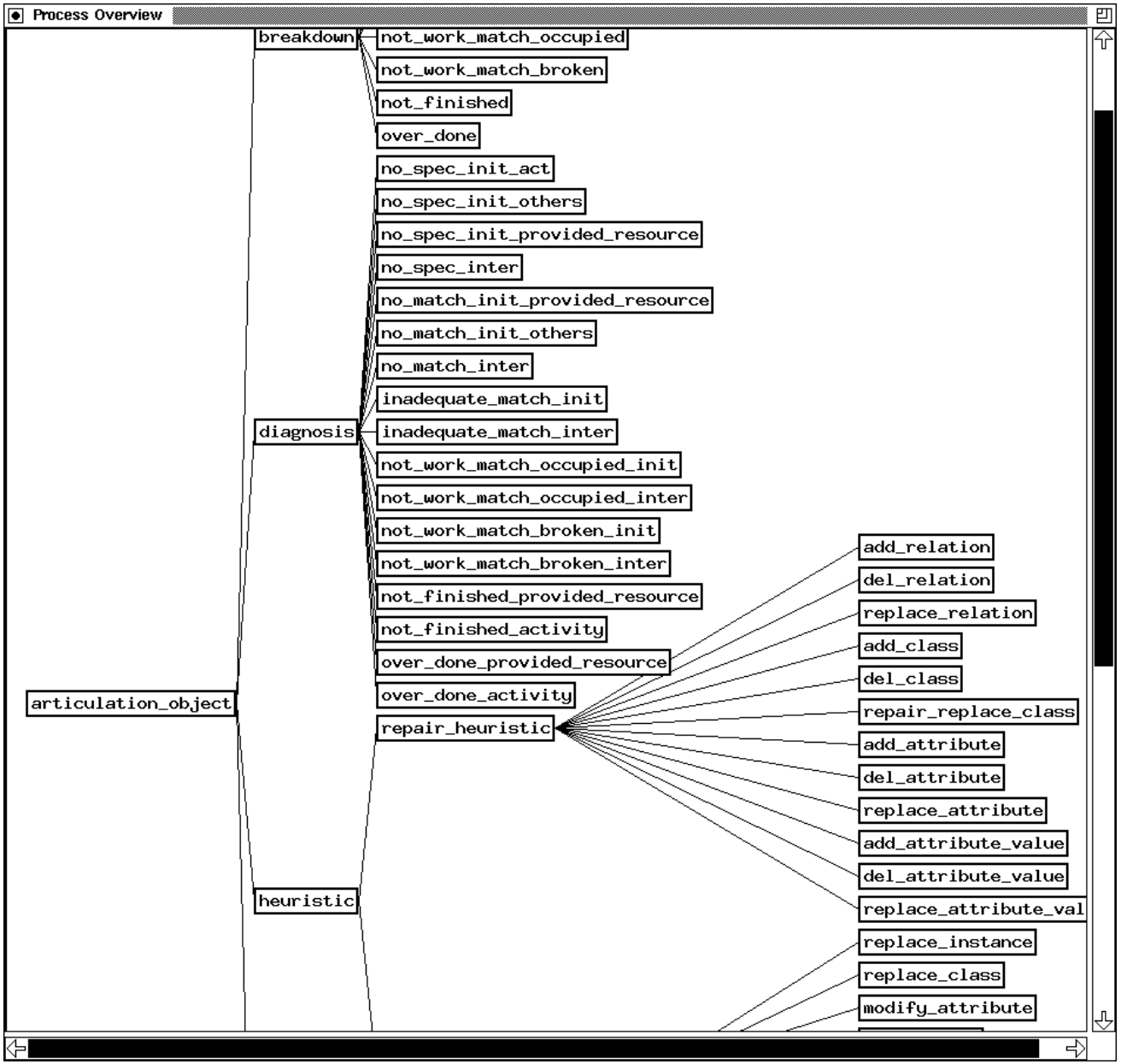
CL-HTTP/60.57 (Macintosh Common Lisp; 2.6.6)
Please send comments, bug reports and suggestions to Tom Russ.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Multi-modal computing innovation studies (>2000)

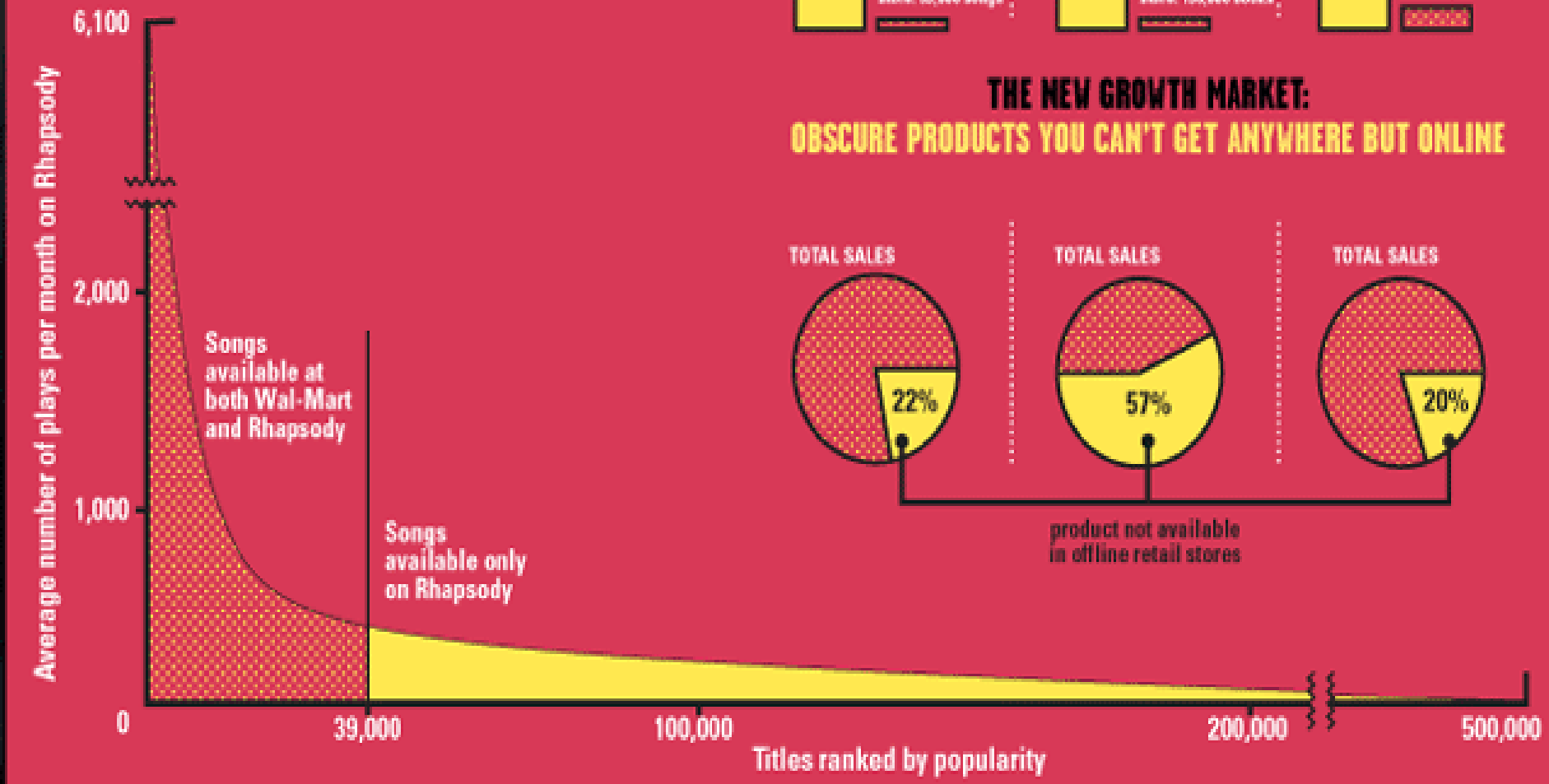
How to go exponential

Current field studies

- Understanding open source software practices and processes in different domains
  - Academic research <---> Commercial development
    - Deep space astronomy and bioinformatics
    - Internet infrastructure
    - Administrative/electronic business computing
    - Networked computer games
- To produce and compare case studies using
  - (informal) ethnographic narratives
  - (semi-structured) hypertext, and
  - (formal) computational models.

ANATOMY OF THE LONG TAIL

Online services carry far more inventory than traditional retailers. Rhapsody, for example, offers 19 times as many songs as Wal-Mart's stock of 39,000 tunes. The appetite for Rhapsody's more obscure tunes (charted below in yellow) makes up the so-called Long Tail. Meanwhile, even as consumers flock to mainstream books, music, and films (right), there is real demand for niche fare found only online.

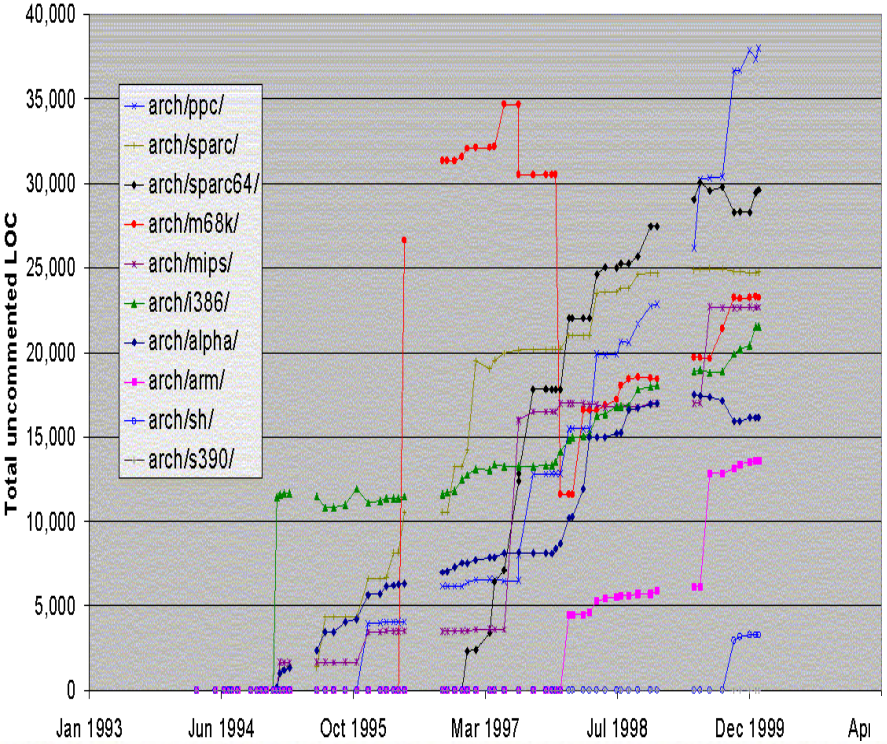


THE NEW GROWTH MARKET:
OBSCURE PRODUCTS YOU CAN'T GET ANYWHERE BUT ONLINE

Sources: Erik Brynjolfsson and Jeffrey Hu, MIT, and Michael Smith, Carnegie Mellon; Barnes & Noble; Netflix; RealNetworks

OSSD Projects as innovation engines

- Social/technical innovations in OSSD projects emerge via:
  - Enhancing project resources
    - Inter-project mergers
    - Creating new software development artifacts
  - Tuning adjustments or adaptations
    - Intra-team role migration
    - Incremental product releases (“daily builds”)
  - Restructuring transformations
    - Legal incorporation
    - Code refactoring
  - Reinvention practices
    - Learning from others
    - Commercial product feature replication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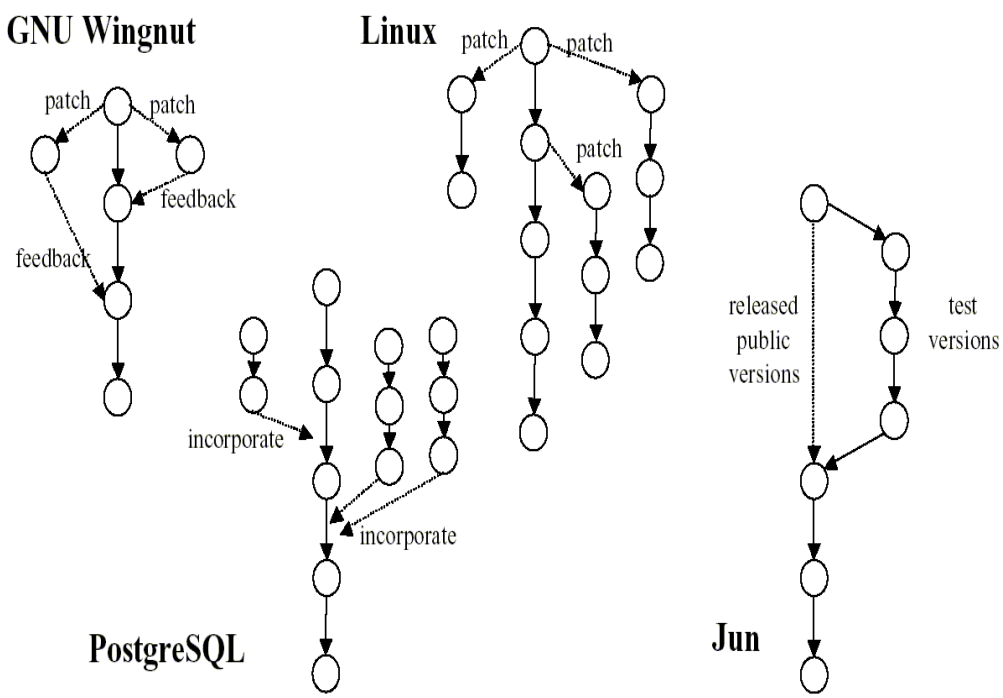
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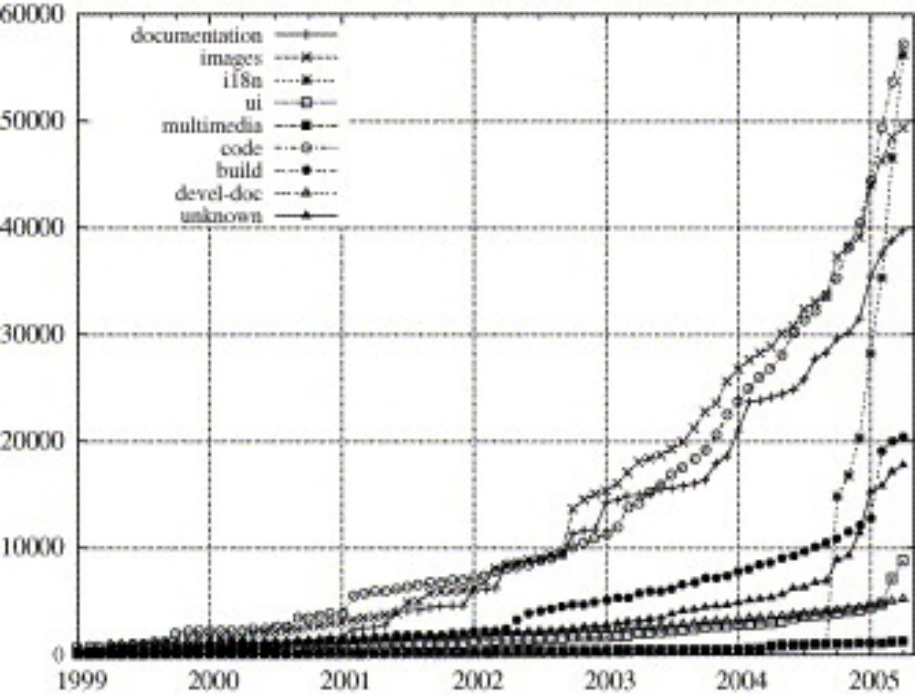
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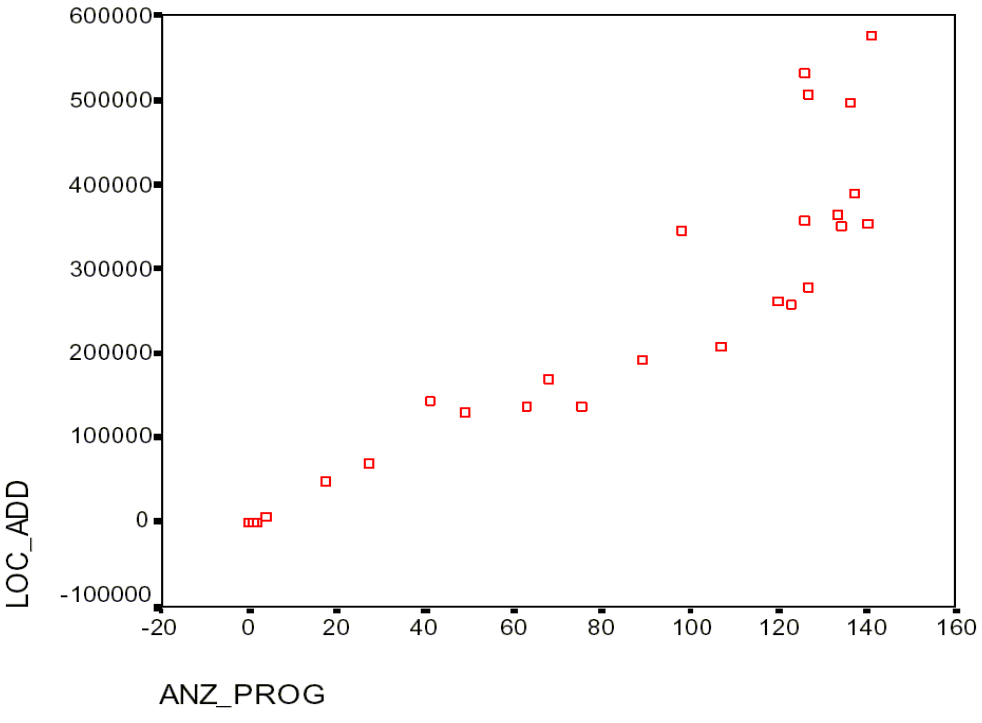
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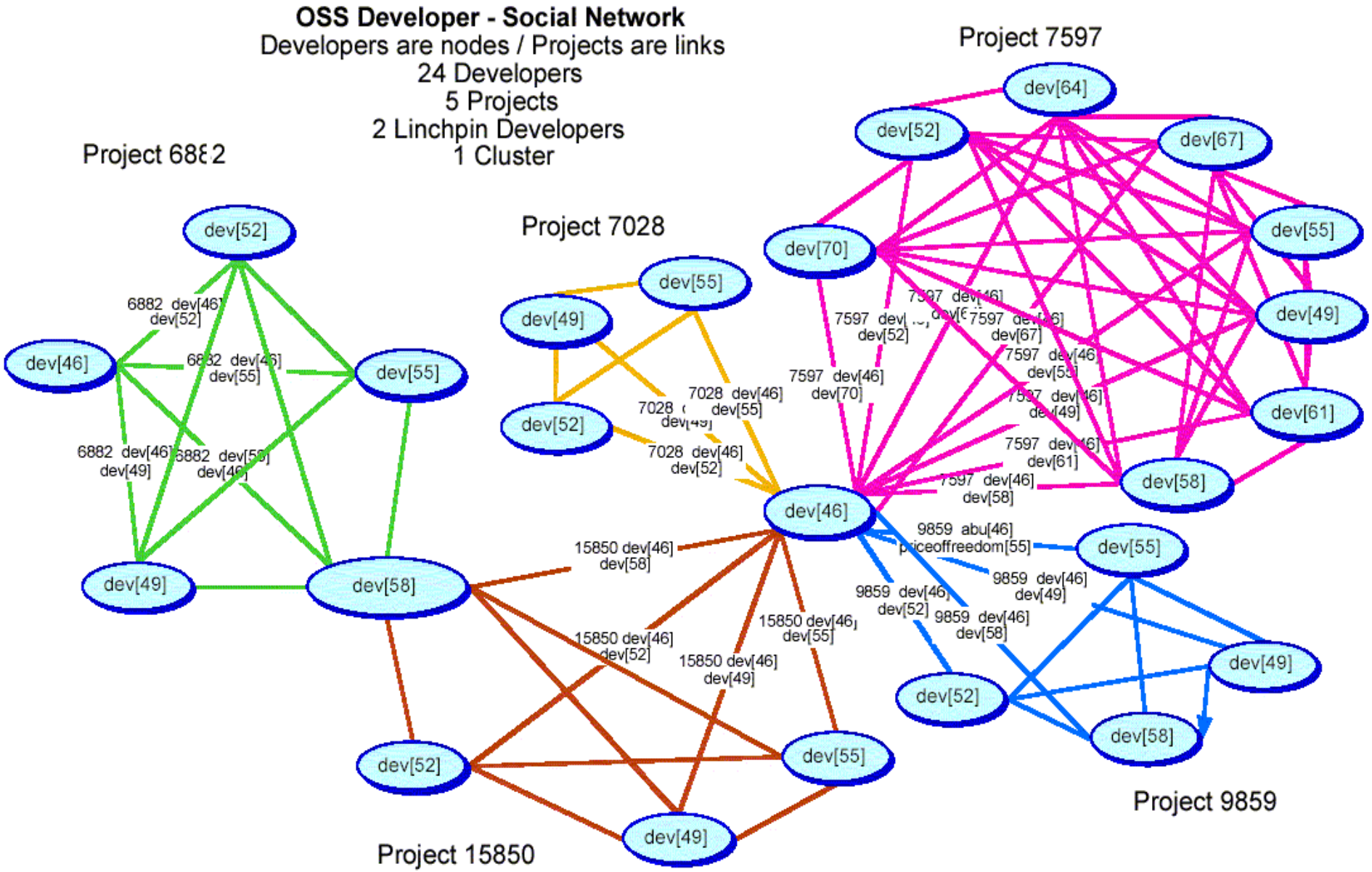
OSSD multi-project ecology as an *innovation frontier*

- *OSSD multi-project ecosystem*: a (virtual) enterprise that collectively mobilizes an inter-related group of OSSD projects
  - Barclays Global Investments, Google Summer of Code, Apache Software Foundation, SUN Microsystems, etc.
- *Frontier*: a zone of unsettled land outside the region of existing settlements suitable suitable for exploration and potential development
- *Innovation frontier*: a socio-technical zone for innovation outside of existing enterprise system settlements suitable for exploration and potential development.

Enabling exponential growth for socio-technical innovation frontiers

- The most successful OSSD projects exhibit *sustained exponential growth* via social and technical innovations
- Exponential growth requires critical mass for collective innovation action
  - Critical mass emerges through sufficiently dense socio-technical networks that act as “small worlds”
  - Such networks emerge when participants *enjoy* making social/technical contributions that serve to advance the accumulation of common pool resources


OSS Developer - Social Network
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2 Linchpin Developers
1 Cluster
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Closing remarks

- To be clear, nearly all enterprises and OSSD projects do not obtain exponential innovation growth.
- High, sustained growth OSSD projects do exhibit exponential innovation growth when proper conditions exist.
  - When innovation becomes participatory and self-serving, when innovations contribute to common pool resources, and when sustained collective action emerges as a social movement that transcends enterprise boundaries.
- Possible for enterprises to achieve exponential innovation growth.

Findings

- In addition to those from 1981,
- Innovation in computing is routine
  - Producing computing innovations is “easy”
  - Consuming computing innovation is demanding
- Continuous innovation (in the case of open source software) can enable exponential growth of socio-technical interaction networks
  - What will limit the exponential growth of such innovation?

Details

- W. Scacchi, Understanding Free/Open Source Software Evolution, in N.H. Madhavji, J.F. Ramil and D. Perry (eds.), *Software Evolution and Feedback: Theory and Practice*, 181-206, John Wiley and Sons Inc, New York, 2006.
- W. Scacchi, Emerging Patterns of Intersection and Segmentation when Computerization Movements Interact, to appear in K.L. Kraemer and M. Elliott (eds.), *Computerization Movements and Technology Diffusion: From Mainframes to Ubiquitous Computing*, Information Today, Inc., 2008.
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