Process Management

Process Management

- Characteristics of (Good) Coordination
- A Taxonomy of Coordination Mechanisms
  - *decoupling*
  - predefined *processes*
  - predefined *organizations*
  - *emergent* coordination
- Lessons & Future Directions

What is Coordination?

- help agents decide *what to do when* given inter-agent dependencies
- required for selfish *or* altruistic agents
- a *control uncertainty reduction* mechanism
- leads to the creation of (implicit or explicit) agent *commitments*

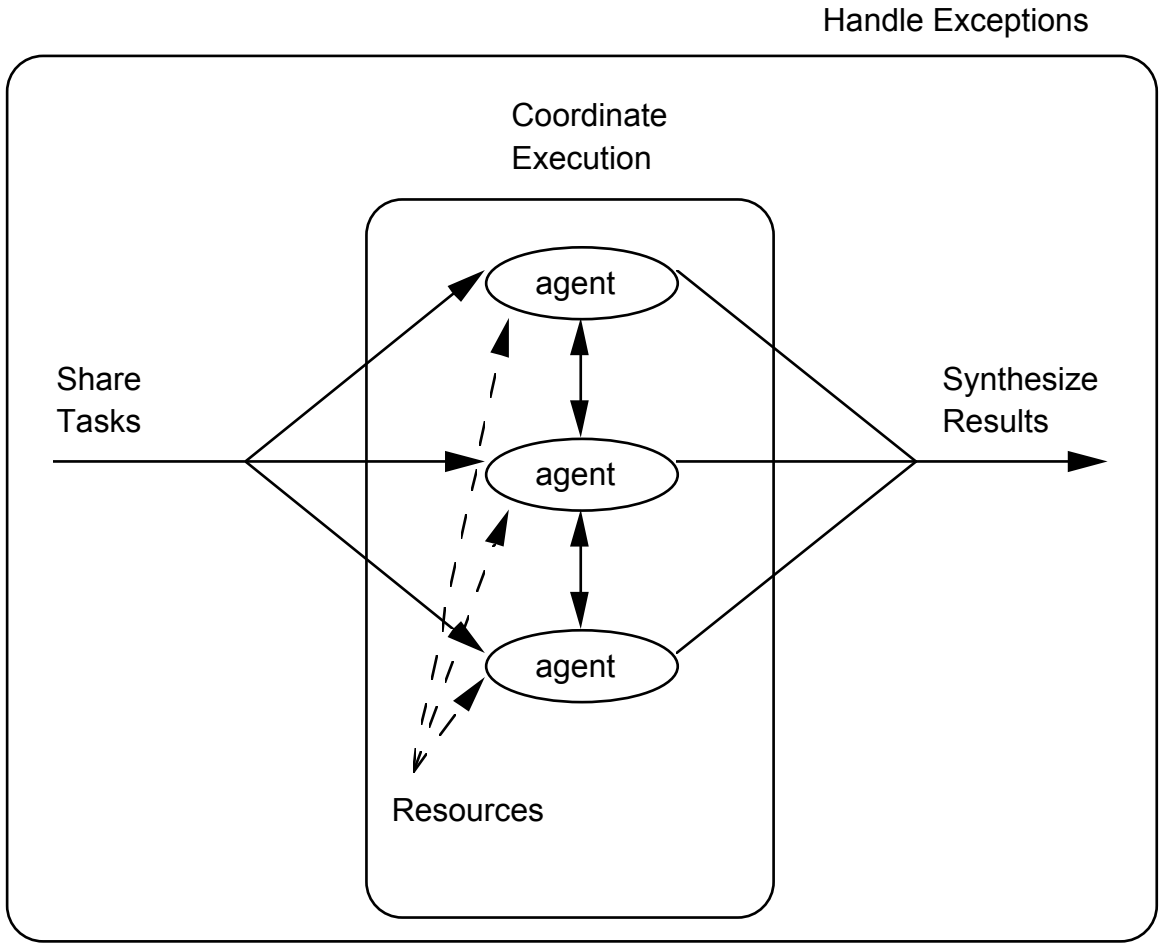
What is *Good* Coordination?

- solution quality
- efficiency
  - reduced by both under- *and* over-coordination!
- clarity
- robustness

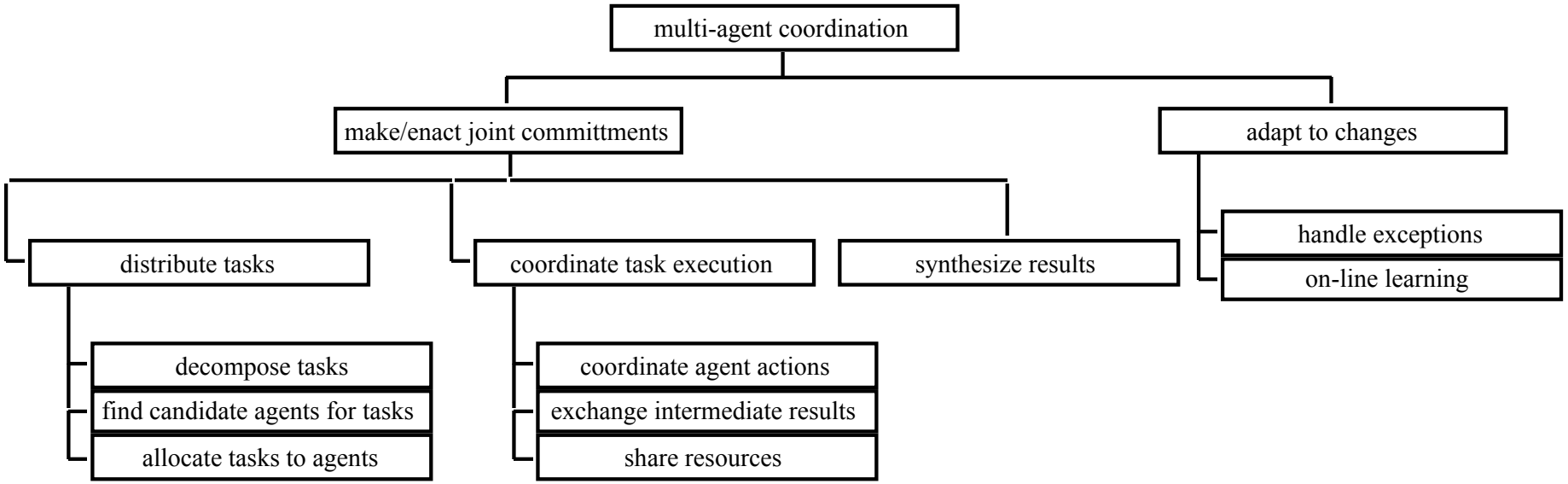
What is *Good* Coordination? cont.

- works in realistic domains
  - no assumption of knowledge sharing
  - no global viewpoint or control
  - "large grain size" agents

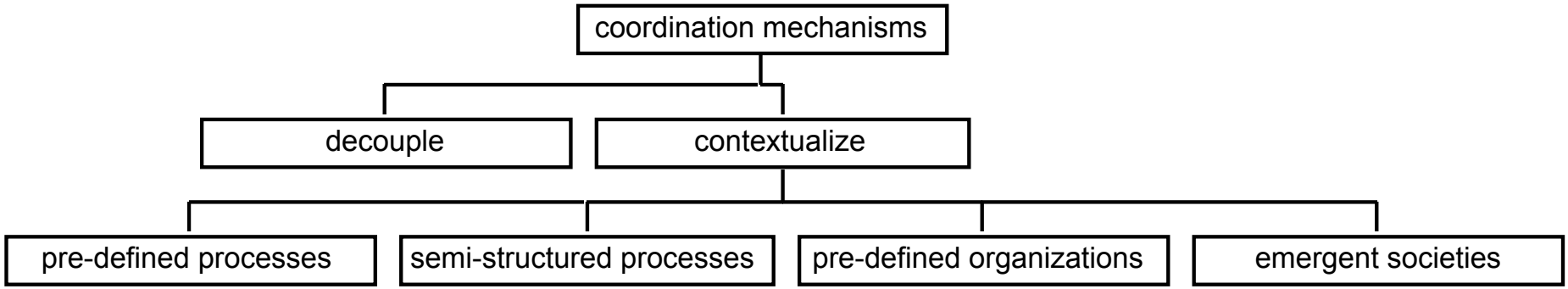
A Model of Coordination



Coordination Tasks



A Coordination Taxonomy



Decoupling vs Contextualization

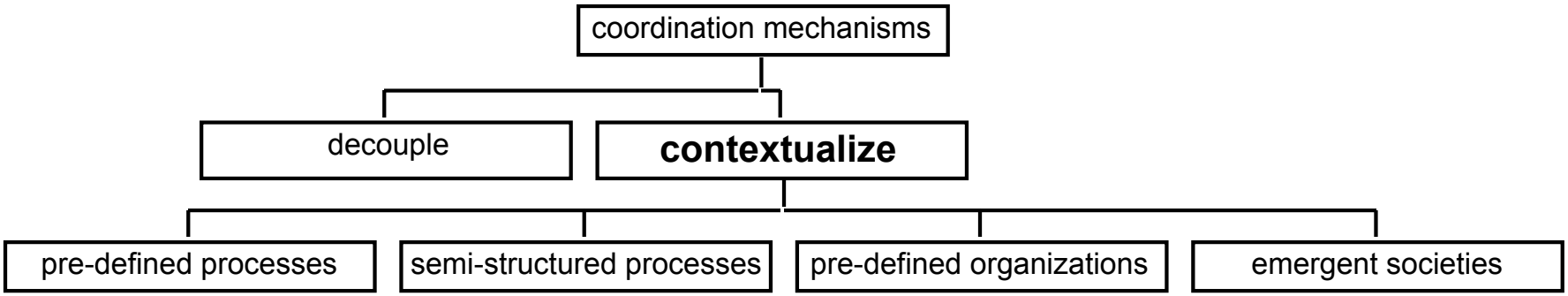
- define independent tasks
  - decompose into [mostly] unconnected dependency graphs
  - predefine decision constraints
- replicate resources
  - data
  - functions
  - I/O buffering (“slack”)

Tradeoffs

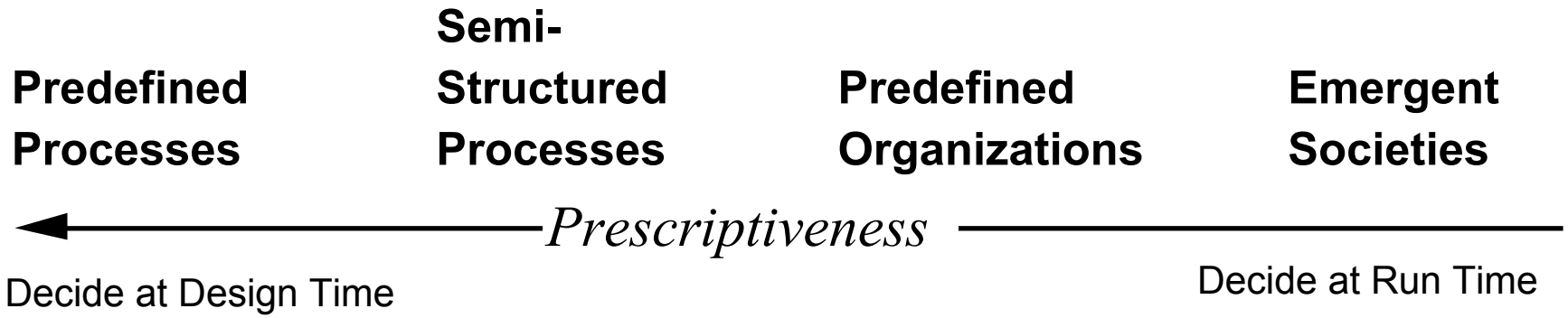
Mechanism	Pros	Cons
decouple	• less control reasoning	• often leads to non-optimal solutions • difficult in some domains
contextualize	• potential for optimality • adaptive	• more control reasoning

Decoupling can be used to *reduce*, rather than *eliminate*, the need for coordination

Contextualized Coordination



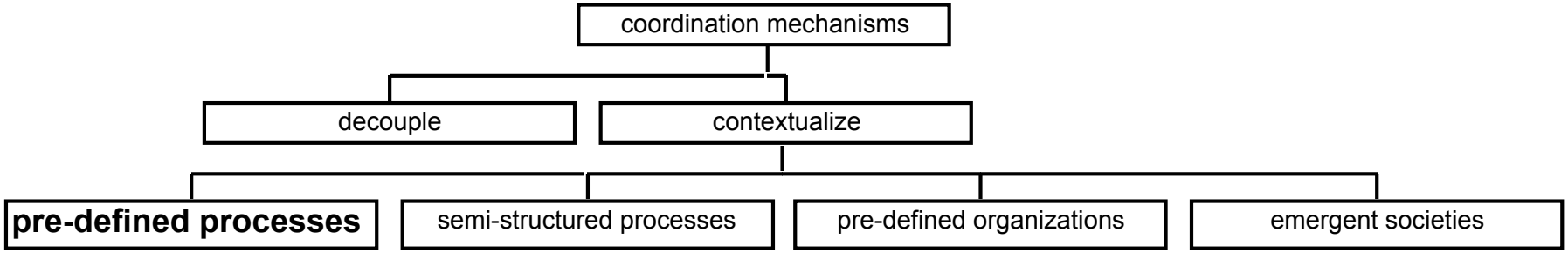
The Prescriptiveness Continuum



Tradeoffs

Issue	Predefined	Emergent
underlying metaphor	command and control	economics, biology
appropriate domains	predictable, centralized	dynamic, distributed
Issues favoring centrally predefined mechanisms		
theoretical optima?	yes	no
predictability of system	at individual level	only at aggregate level
needs high bandwidth and coordination-savvy agents?	no	yes
technology maturity	high	low
Issues favoring distributed emergent mechanisms		
match to distributed reality	low	high
adaptability/robustness	low	high
ease of development	low	high
agent homogeneity constraints	restrictive	nonrestrictive

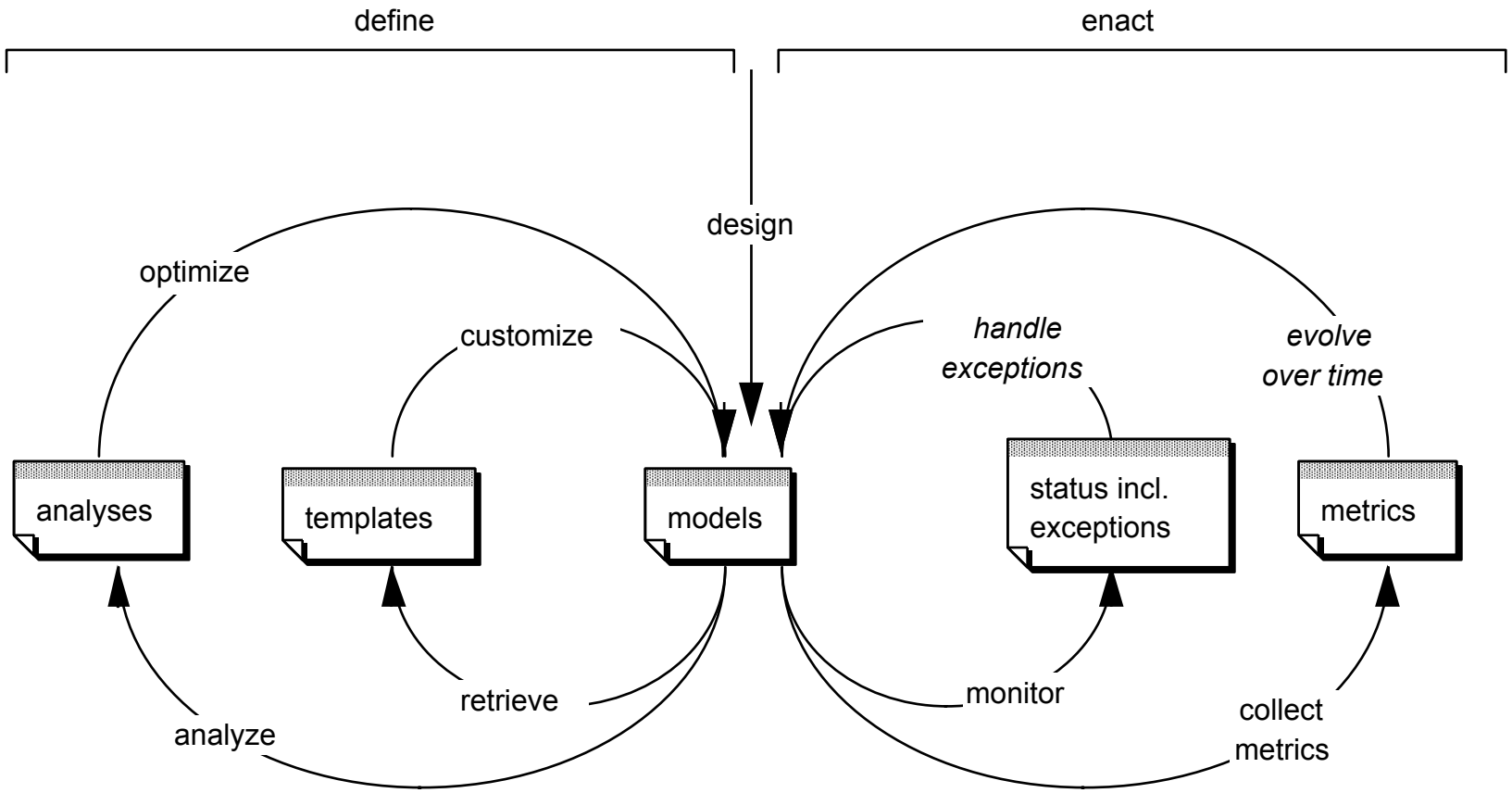
Predefined Process Models



A Dominant Approach

- mature technology
- successful for consistent high volume processes
  - manufacturing control (CIM)
  - finance & insurance business processes (workflow)

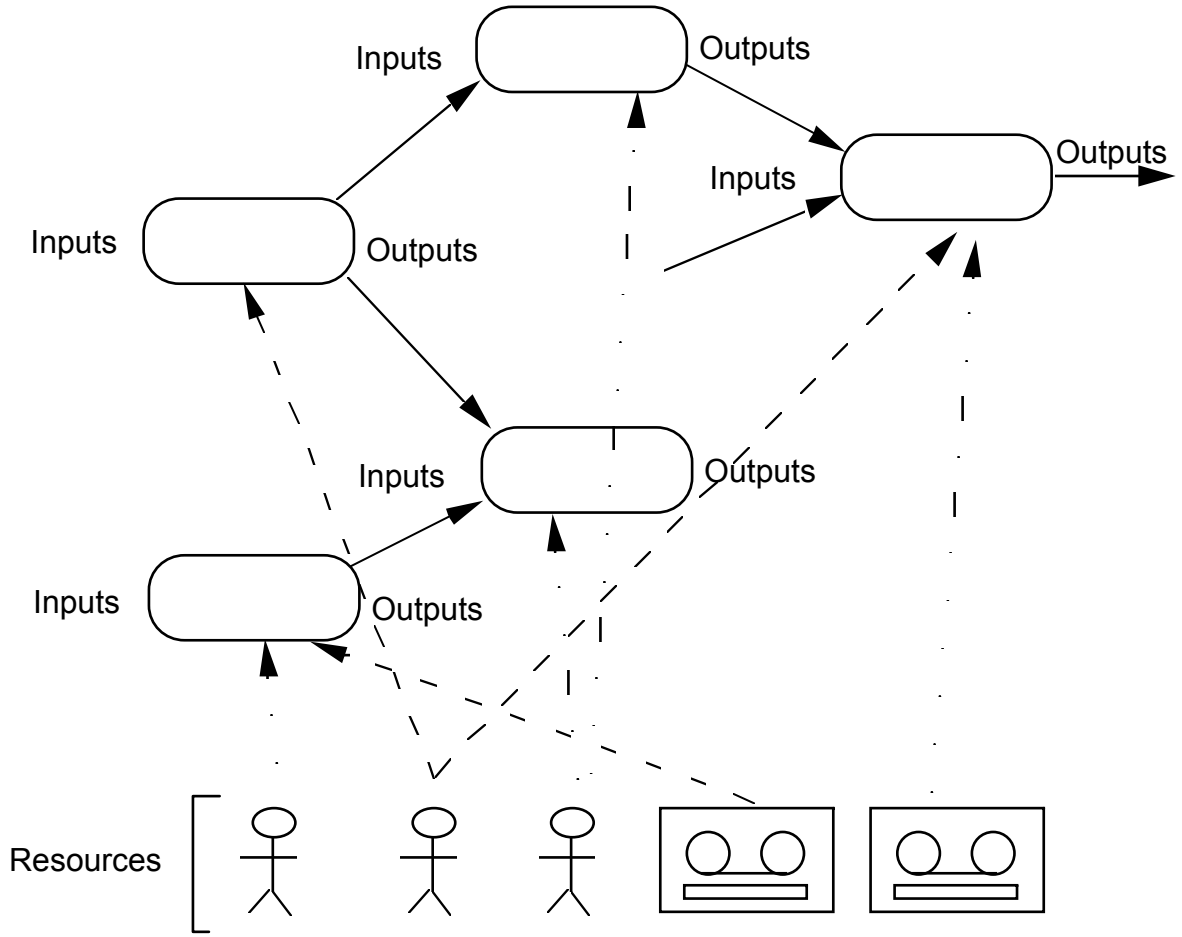
Types of Process Management Technology



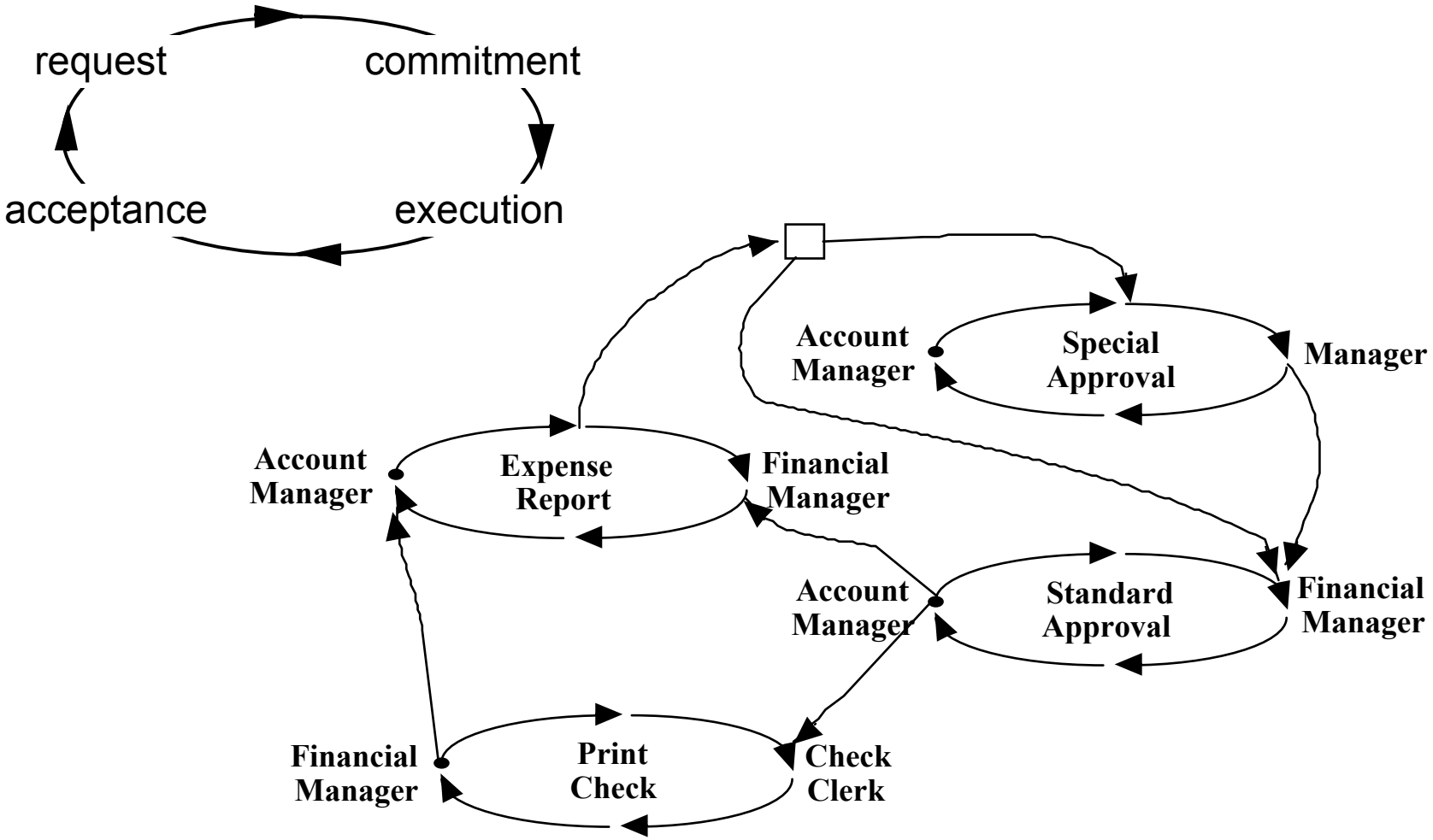
Process Modelling

- What It Does
  - Creates formal model of collaborative work tasks, resources, artifacts & their relations
- Many COTS tools available
  - IDEF is dominant standard, but others (TI IETF, CIMOSA) also exist
  - bundled with many tool types (e.g. project management, workflow ...)

IPO Representations



Speech Act-Based Models



Tradeoffs

Type	Pros	Cons
IPO	• standardized • manage at arbitrary level of detail	• weak methodology
speech act based	• good thinking tool	• verbose • learning curve

Benefits

- Sharable Process Models
  - Discussion
  - Training
- The Opportunity to Re-Think Processes
- Enables Uses
  - analysis
  - enactment

Process Analysis

- What it Does
  - produce evaluation metrics without enactment
- Many mature COTS tools available
  - especially for simulation
- Benefits
  - cheaper/safer/quicker than the “real thing”
  - allows exploring more options
  - useful as teaching tool

Types of Analysis Technology

Type	Pros	Cons
simulation	• mature	• model quality is bottleneck • requires careful experimental design • low-level metrics
deduction (e.g. critical path, deadlock, concurrency)	• no need for experiment design etc	• very limiting assumptions • limited info

Matrix Model Analysis

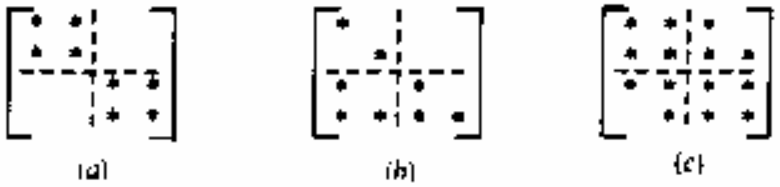


Figure 1 Three types of matrices: (a) uncoupled matrix; (b) decoupled matrix; (c) coupled matrix.

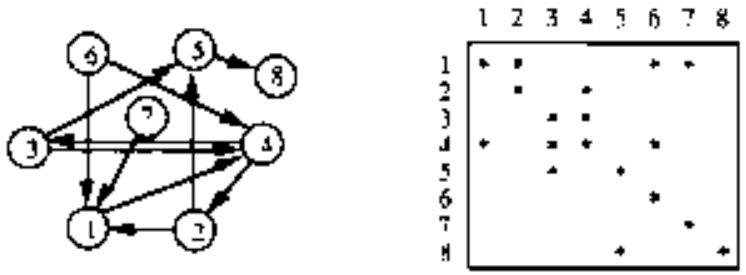


Figure 2. Digraph of activities and the corresponding incidence matrix.

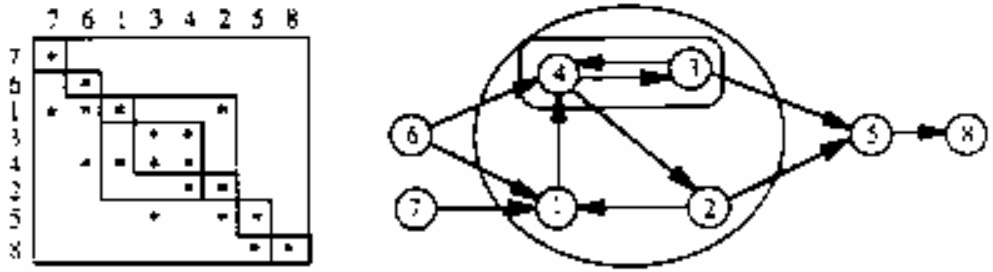
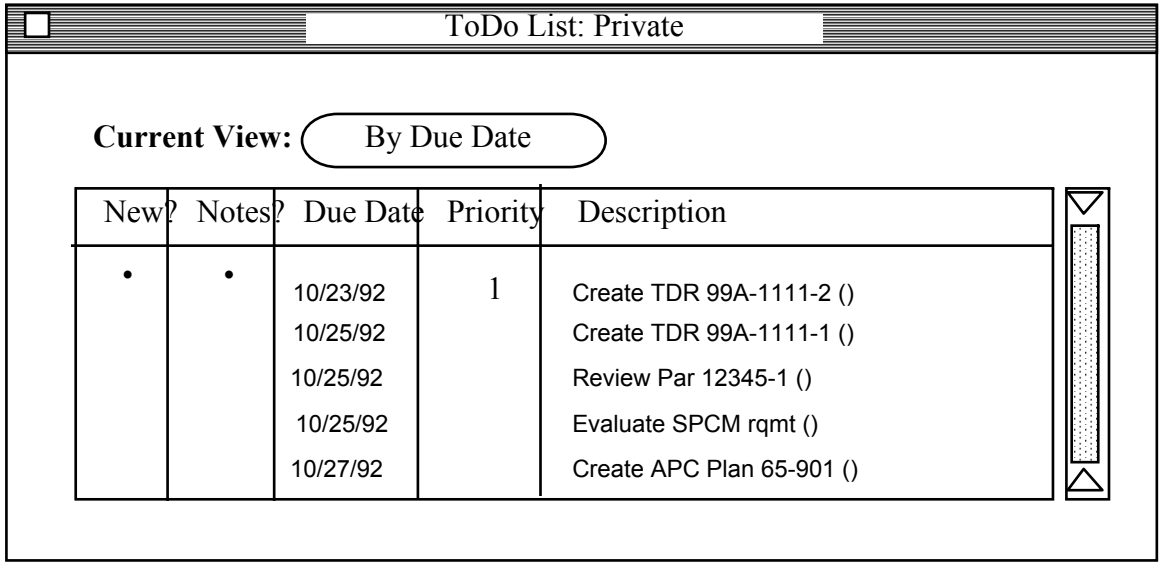


Figure 3. Ordered incidence matrix and the corresponding digraph

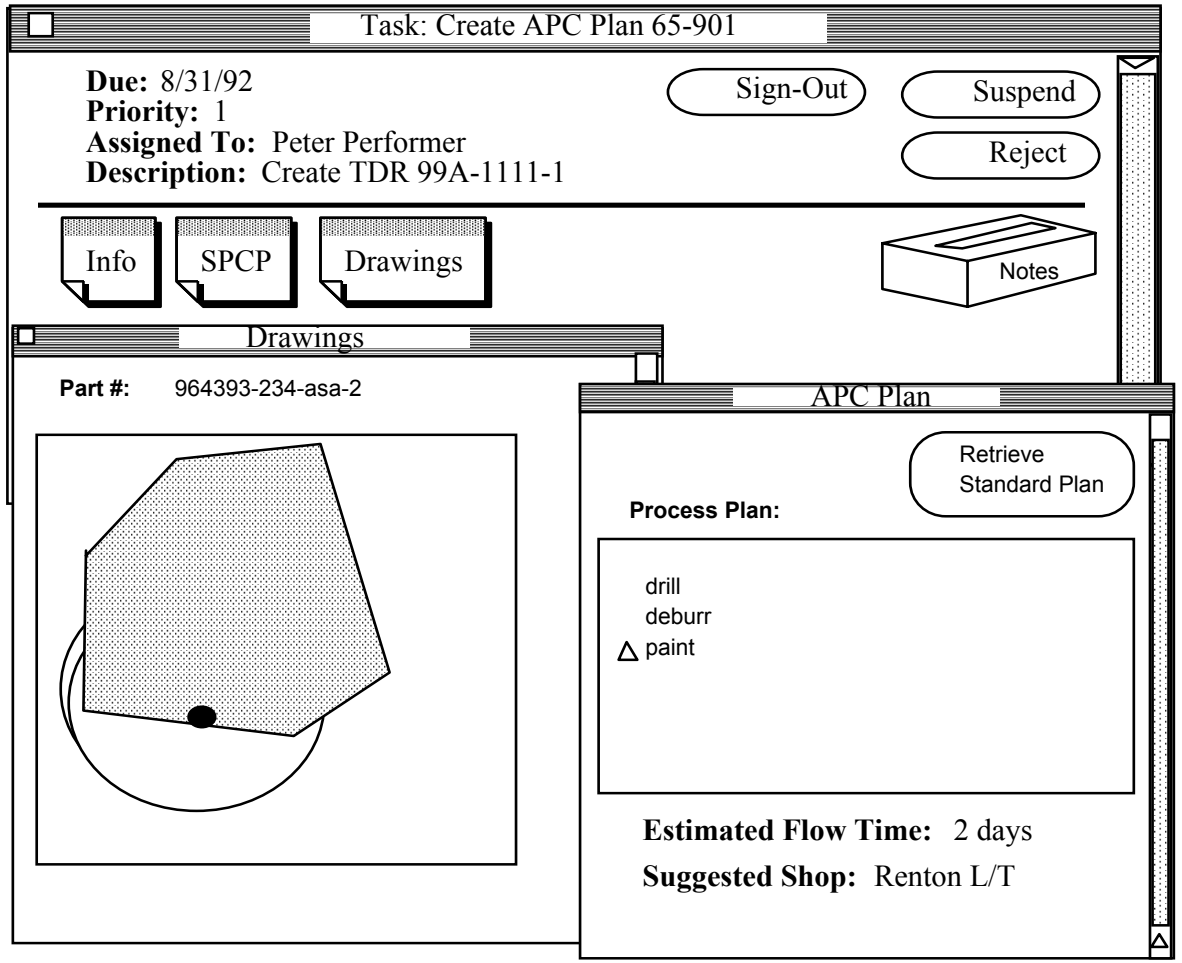
Process Enactment (Workflow)

- workflow addresses key weaknesses of manual business processes
  - information access: 80% of task performance time is information access (Xerox)
  - 80% of errors are clerical (Boeing)
  - tracking and metrics (for CQI)
- a billion-dollar industry, including 70+ products and all major players (IBM, HP, Xerox, Microsoft ...)

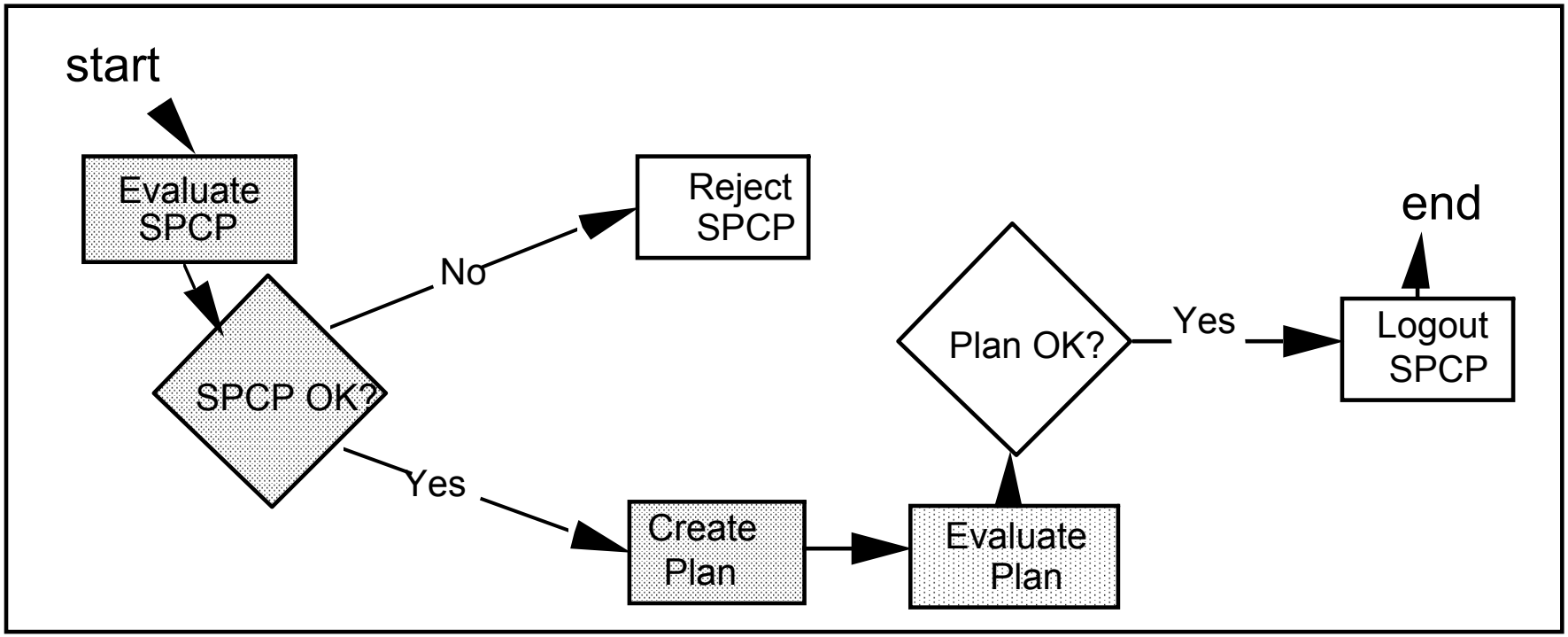
ToDo Lists



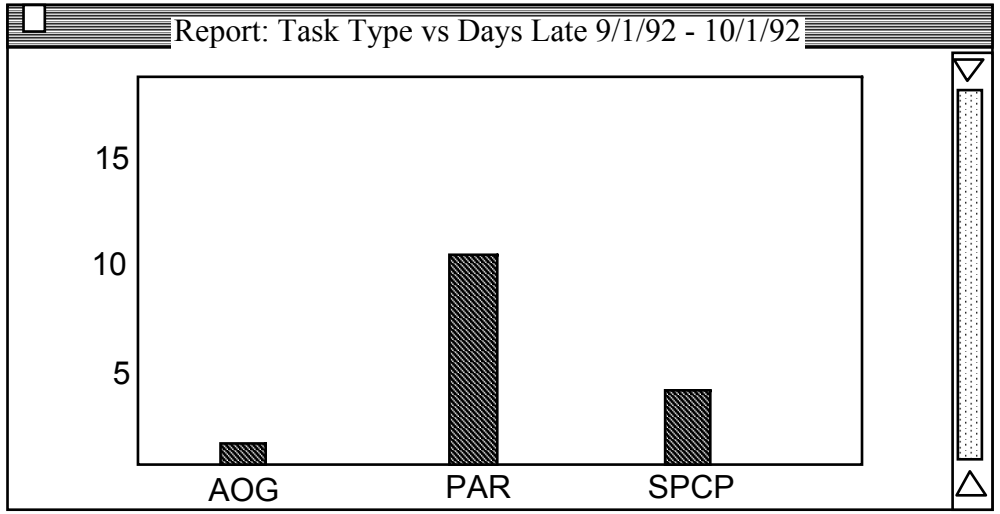
Task Performance Environment



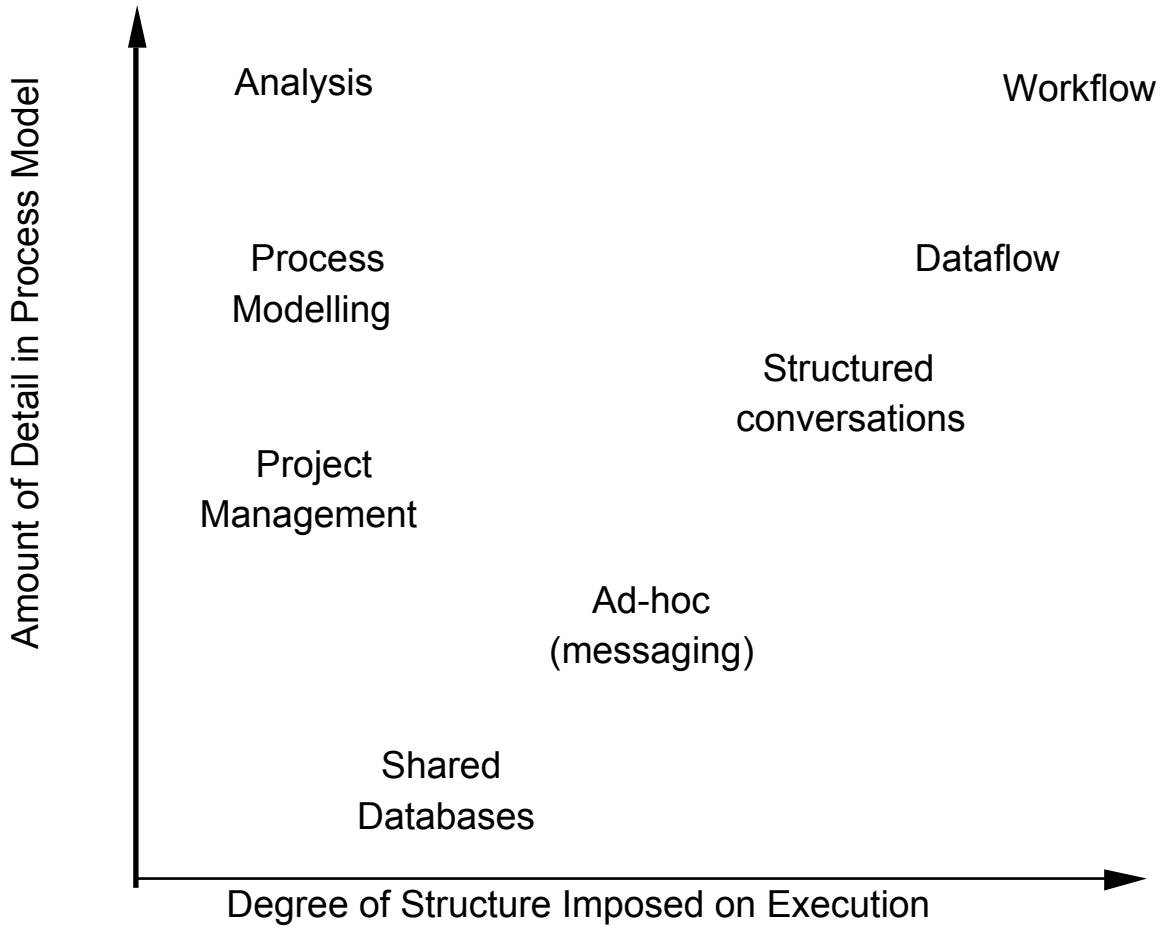
Status Tracking



Metrics Collection



Process Technology Space



Workflow vs Dataflow

Dataflow	*Workflow*
Focus: communication among computer systems on multiple platforms	Focus: business processes with human participants
Passes *information* among agents	Passes *tasks* among agents
Dataflows are pre-defined and rigid (scientific computing)	Workflows may not be pre-defined and can have exceptions
Systems are FIFO	People have tasks queue and reason about ordering/merging
Systems are inter-changeable	People have unique skills and positions - proper task assignment is important
Systems just require input data	People require task execution *environment*

Key Challenges

Weaknesses in “traditional” process model representations underly most problems with process management technology

they’re too expensive to define

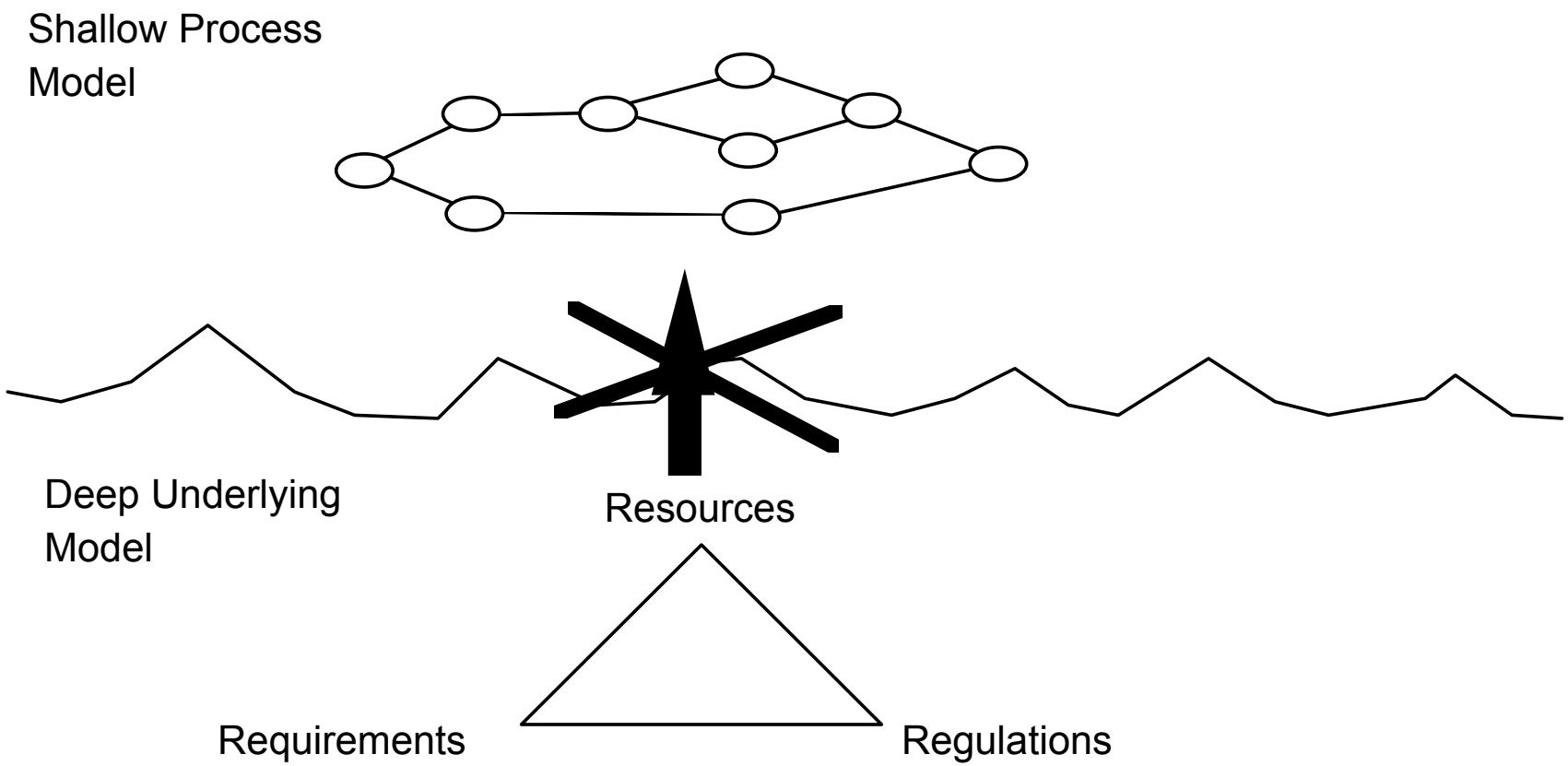
we don’t get what we need

Too Expensive to Define

- ... from scratch
  - sheer size & complexity
  - exceptional conditions
  - single-user bottleneck
- ... by customizing cases
  - weak *indexing*
  - no process *rationale*

You Don't Get What You Need

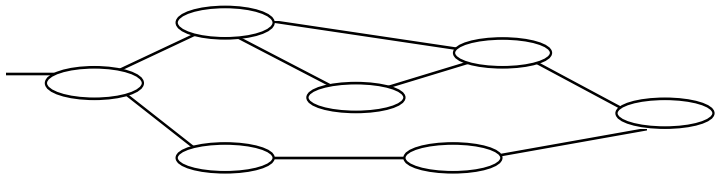
Formalizes Haphazard Evolution



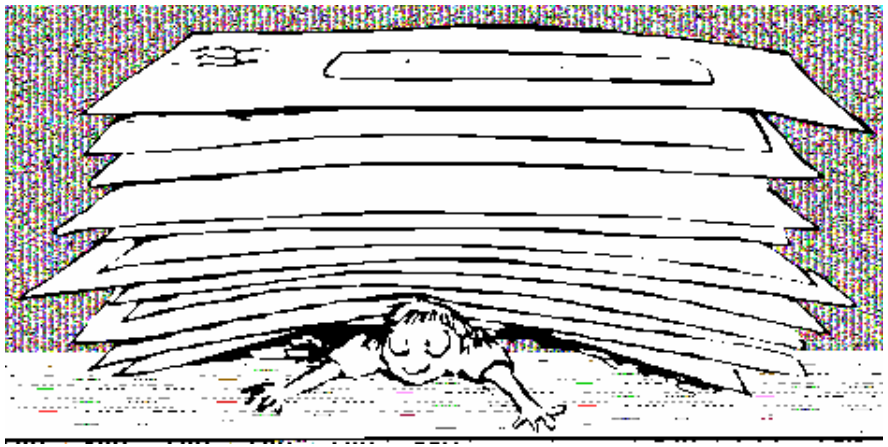
Process Obsolescence

The Big White Lie

The Myth



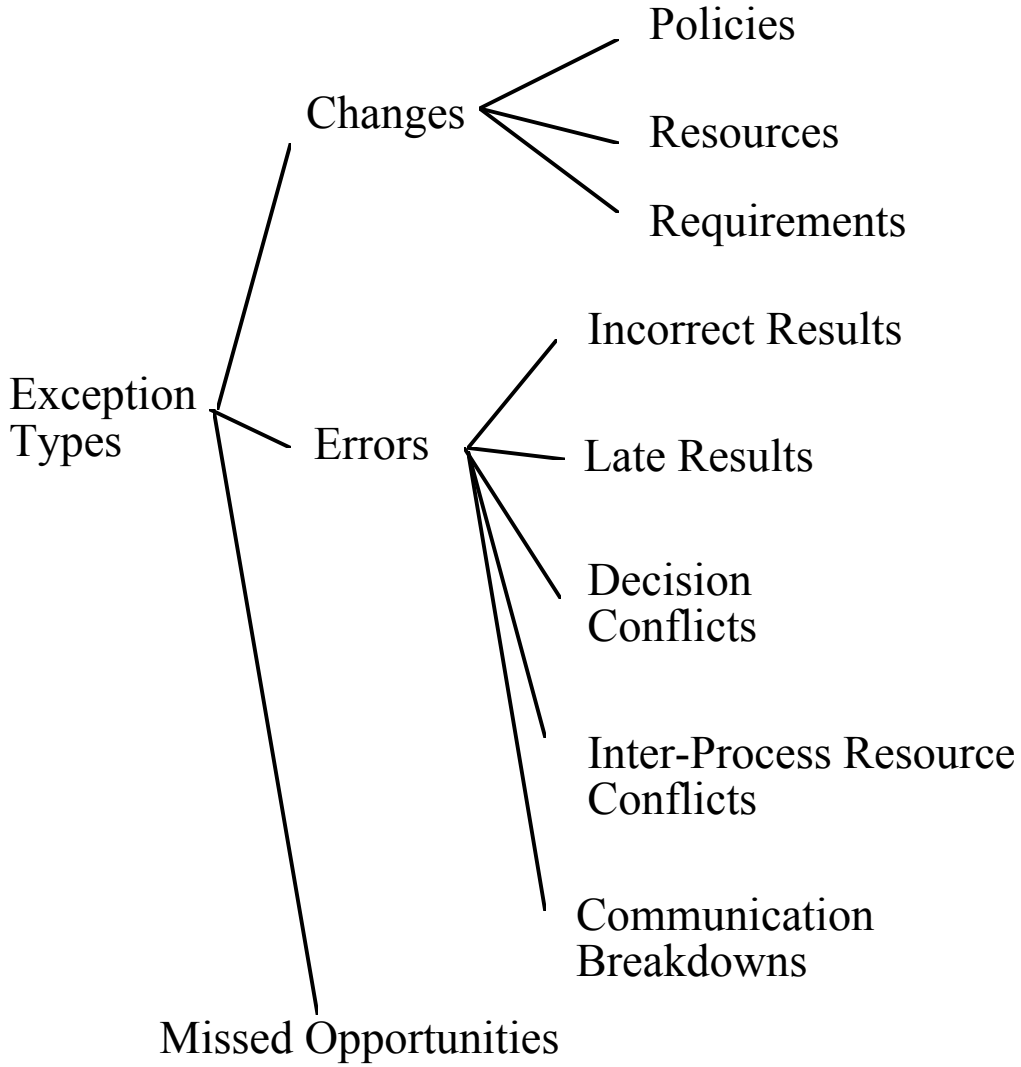
The Reality



Tough to Represent Semi-Structured Processes

- "throw over walls" can be wrong metaphor
  - e.g. for multi-disciplinary design teams - tasks interact, new tasks arise constantly
- excessive prescriptiveness can be harmful
  - Real-life processes are often discretionary & opportunistic
  - exceptions and their appropriate resolutions can be difficult to predict

Vulnerable to Exceptions



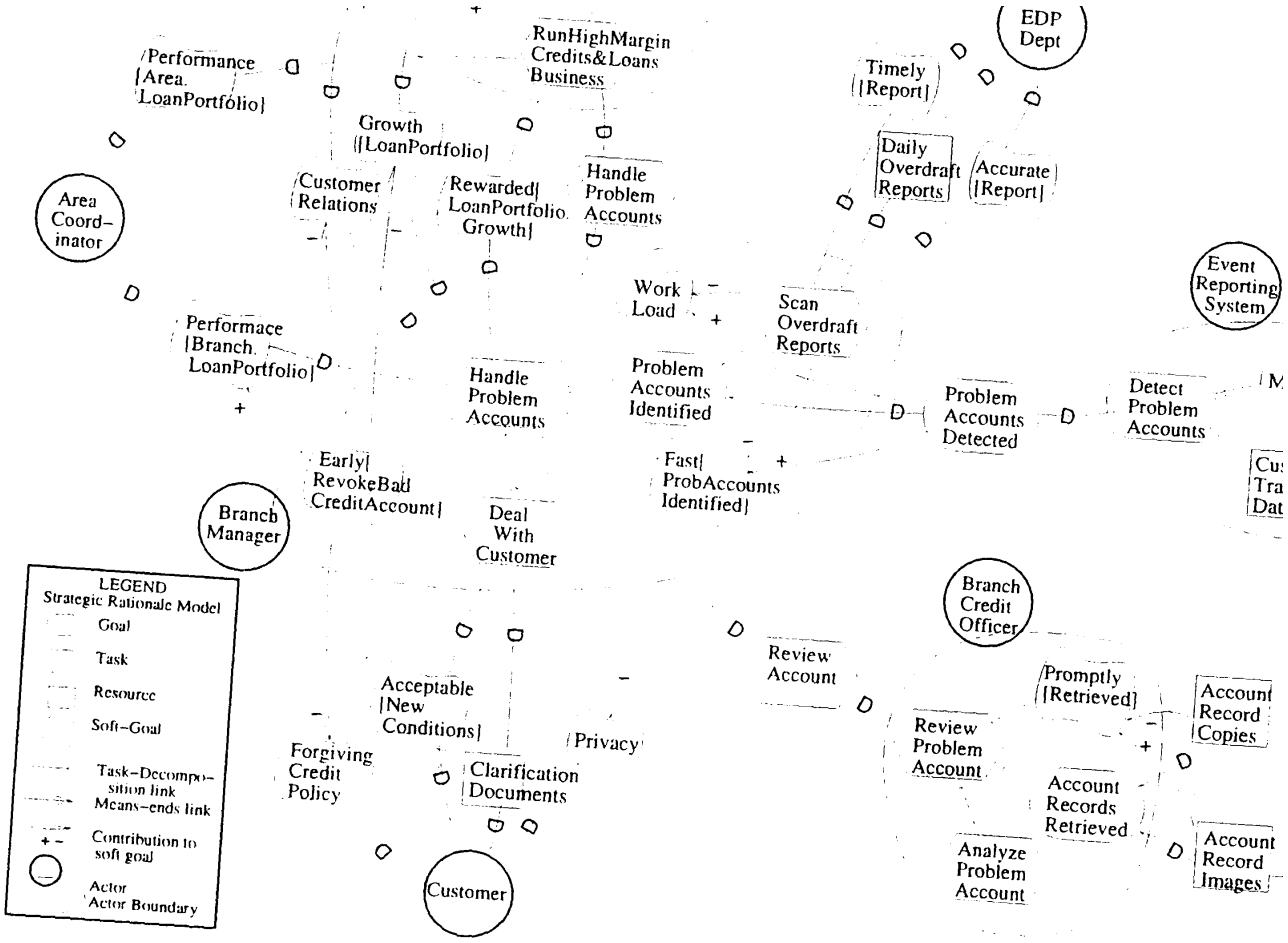
Key Lessons

- successful in its place
  - technology is mature
  - good for predictable high-volume processes
- key weaknesses
  - modelling is a bottleneck
  - inappropriate for semi-structured and exception-prone work contexts
- future
  - shakeout in workflow arena
  - emerging standards

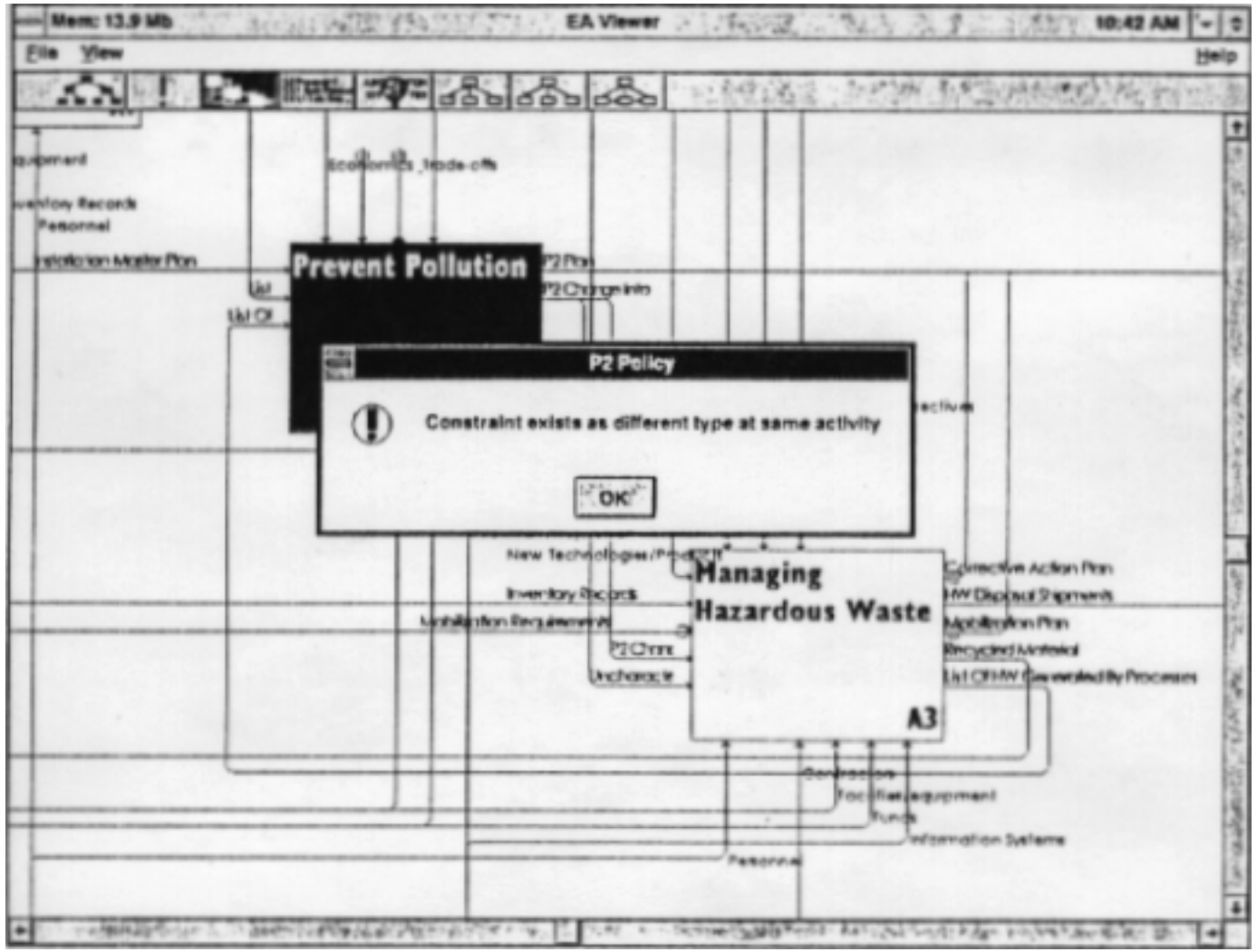
Promising Directions

- process rationale
- collaborative process design
- template-based design

Process Rationale



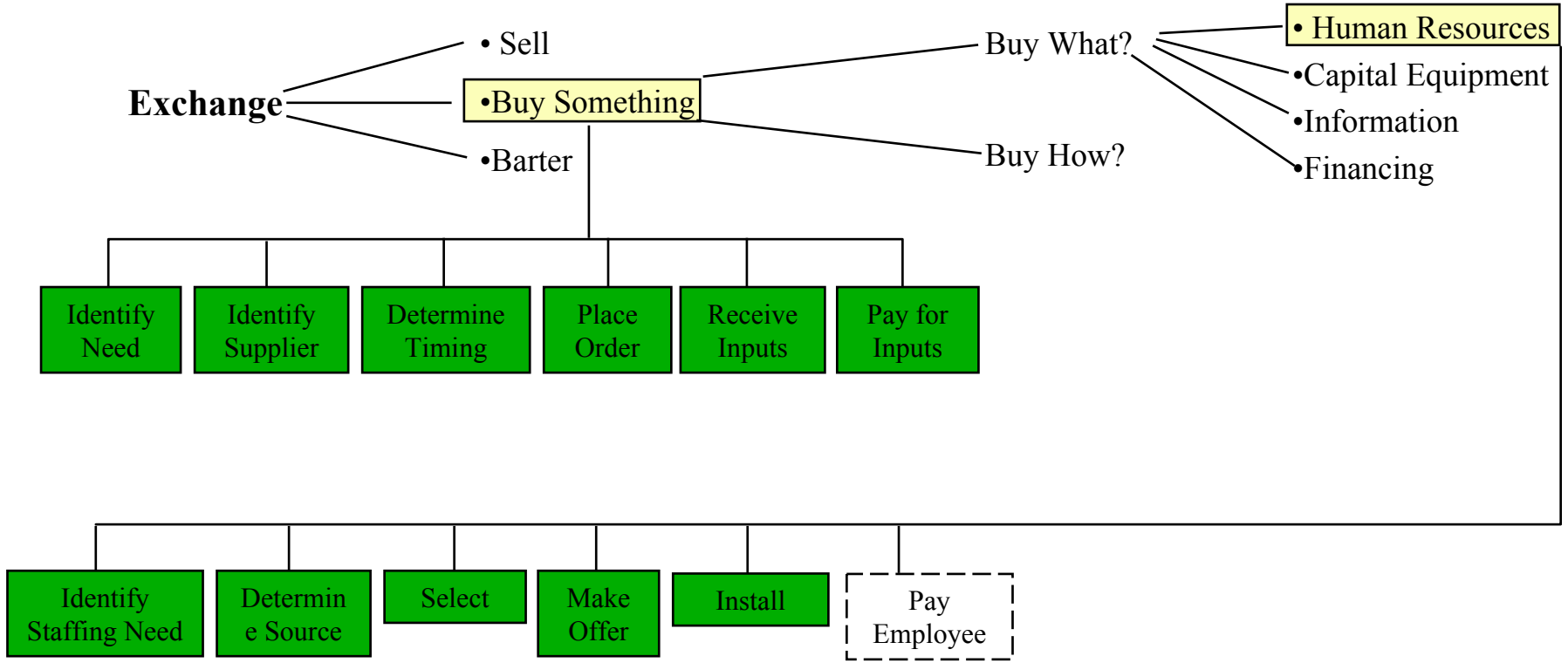
Collaborative Process Design



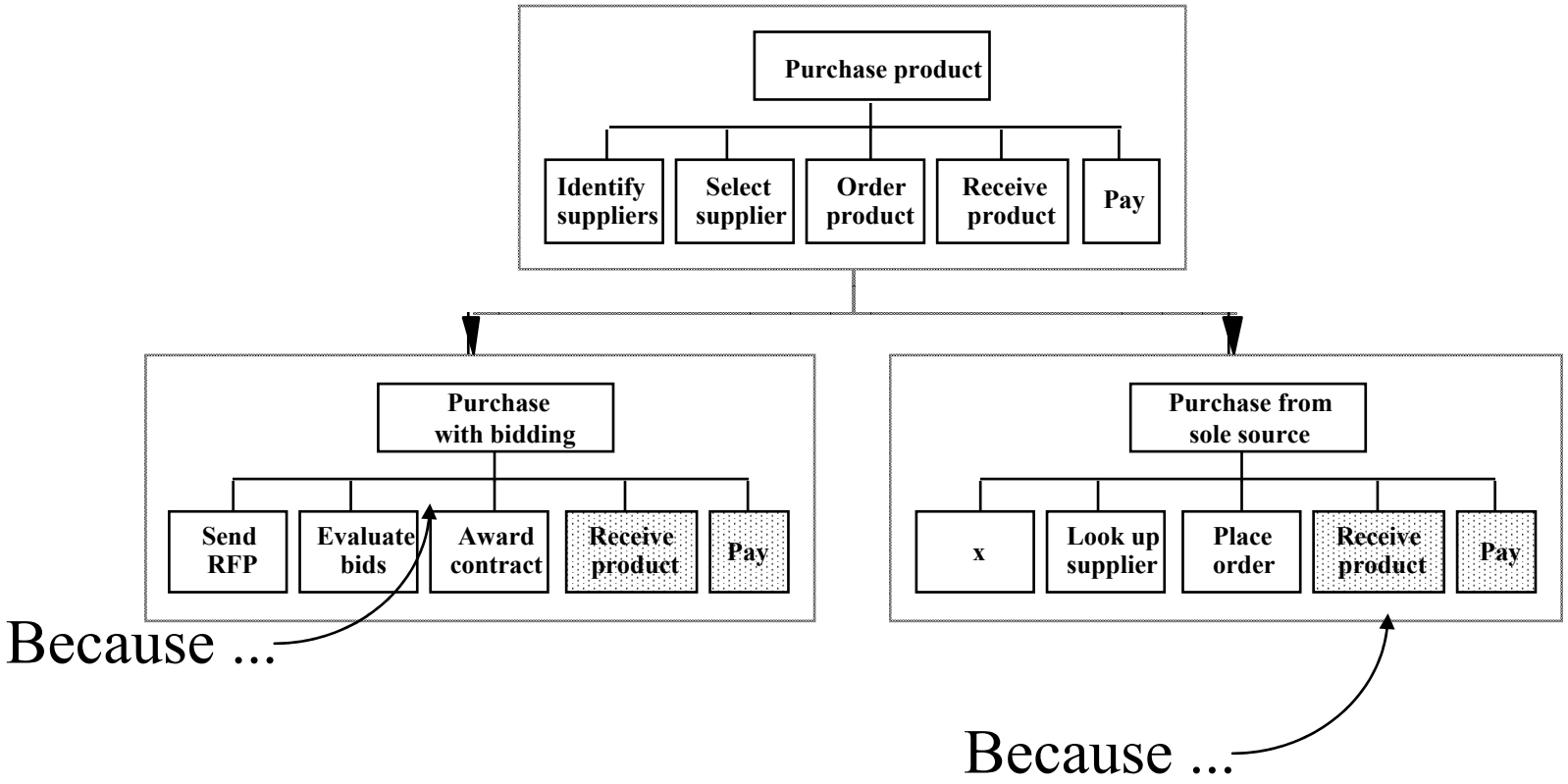
Template-Based Design

Company	***Interesting Practice***
Marriott	Voice response system for candidates which screens & prequalifies
AES Corp	Lets employees do hiring
Doubletree	Identifies employee success dimensions and seeks to hire candidates with same traits
BMW	Use of simulations to select new hires (assembly line)
Cessna	Role playing and simulations for executive hires
AT&T Universal Card	Employee skills database
Whirlpool	Human capital war room
Best Software	On line recruitment management software to post jobs and route resumes
LS Electro	Hires in advance of need
Monsanto	Active policy of seeking candidates at conferences

Process Taxonomy



Task Inheritance



A Tradeoff Table

Processes	Price	Service	Comments
"Spot" Purchasing - Buy one at a time	Mid-High	Low	Suited for limited volume, custom products. High variabilty in price and service with numerous suppliers.
Single Source - Buy from one supplier under contract	Mid	High	Suited for mid-to-high volume products, requiring compatibility or standardization. Emerging technology. User must use specified brand.
Approved Vendor List - Buy from several suppliers, each under contract	Low - Mid	Mid - High	Suited for high volume, standard products (low tech and high tech). User chooses among several approved suppliers.

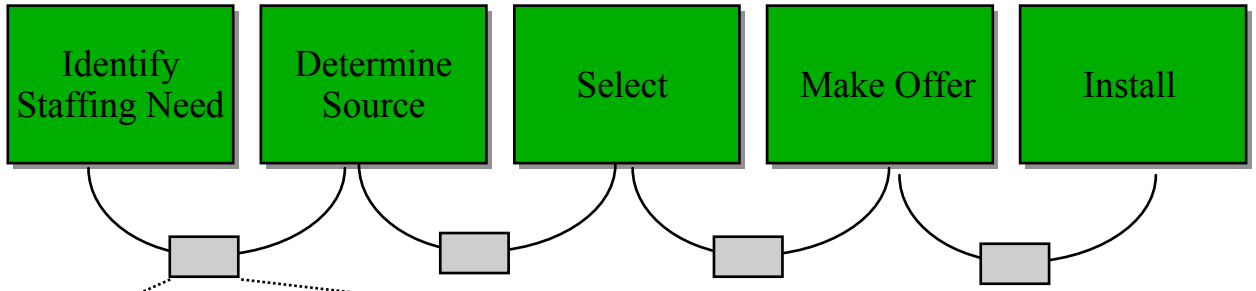
Process Redesign Method

Identify Need	*Determine Source*	*Select (by whom)*	*Select (how)*	*Offer*	*Install*
• Standards • Committee • Manager • Computer Agent	• Internet • Self ID • Network Organization • Journal • Advertising • Mailing List • Catalog • Search Firms • Database • Job Fairs	• External Agency: - Prof. Agency - Computer Agent • Internal: - Managers - Employees - HR • - Computer Agent	• Aptitude or other Success Dimensions • Interview: - on line - group - screen • - individual • Trial: -Internship • -Probation • Qualification: - certification - education • Reference Check	• Purchasing • Electronic Requisition • Electronic Catalog • Blanket Order	• Standards • Customized

Trade Off Matrix

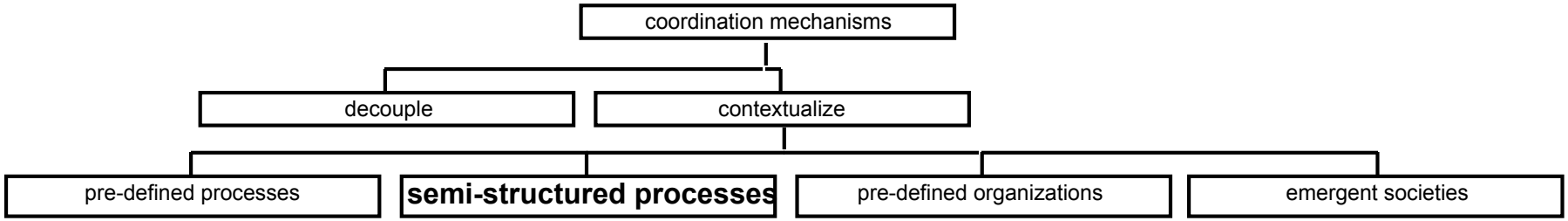
	Speed of Reaching Candidate	Speed of Reaching Candidate	Breadth of Access	Cost	Quality of Candidates
Internet	+	+	-	+	-
Job Fair	-	-	-	-	+
Advertising	+	+	+	-	-

Redesigning Coordination

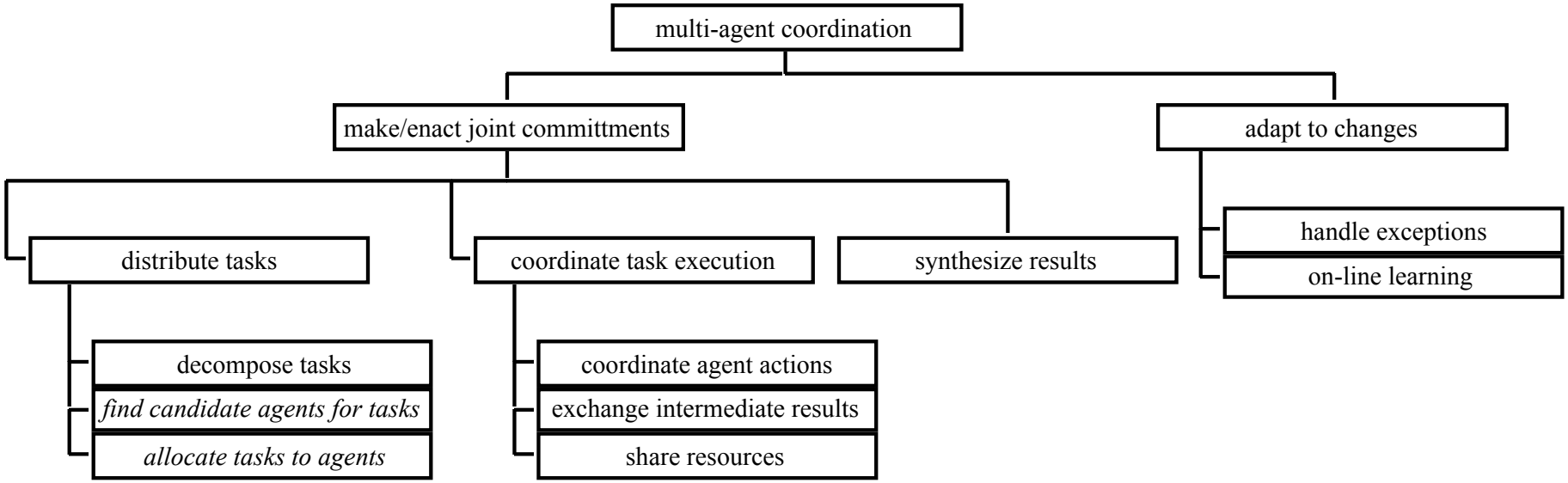


Link	Resource	Existing Coord. Mechanism	Dependency Type	Existing Coord. Process	Options	Ideas
Need - Source	Info	Requisition	Flow: • Prerequisite	Make to Order	Make to Forecast	Staffing needs linked to Bus. Planning " Options" market
					Make to Inventory	Database of inventory
			• Usability	Customer Specified	Standard	Templates for categories of hires
			• Accessibilty	Transport	Make at Point of Use	Manager identifies own candidates Interactive CHAT rooms System Prompts
			Fit	During	After Before (design)	System Assisted Sourcing complete s info
			Sharing	None	First Come/ First Served	No assigned recruiter- first available in queue owns request
					Market Like Bidding	Recruiter bids for work Manager bids for recruiter
					Priority	By size of budget, by seniority

Semi-Structured Processes



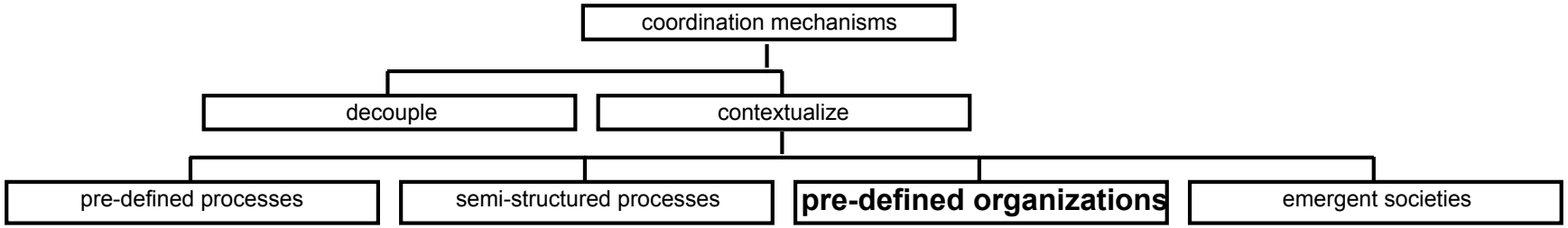
Late-Binding Process Models



Tradeoffs

- pros
  - better load balancing
  - avoids agent unavailable exceptions
  - good if resource availability is unpredictable
- cons
  - harder to predict resource needs precisely

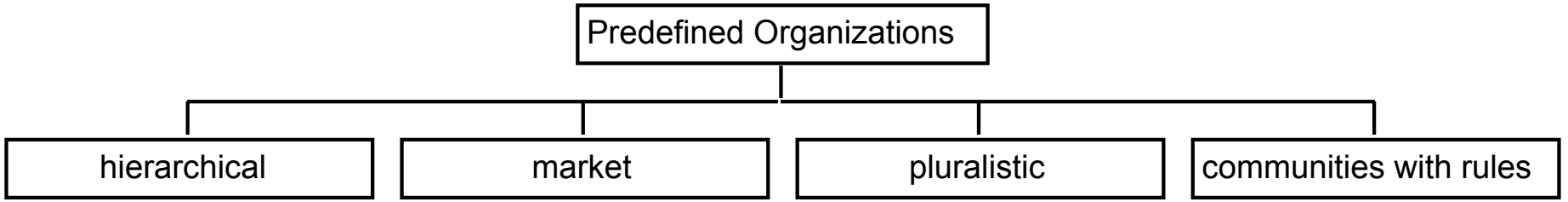
Predefined Organizations



Partial Coordination Constraints

- partially pre-defines coordination
  - communication & authority relationships
  - division of labor
- tradeoffs
  - increased predictability -> greater coherence
  - reduced coordination reasoning complexity
  - prone to organizational obsolescence
- must be combined with other mechanisms

Types of Organizations



Hierarchical

- authority and reporting follows tree structure
- tradeoffs
  - greater global coherence
  - greater bottlenecks
  - reduced responsiveness
  - suboptimal solutions due to bounded rationalty of & abstracted views of higher agents

Markets

- agents engage in negotiated resource exchanges, typically using pricing mechanisms (details later)
  - allows relatively simple agent protocols
  - can engineer useful systemic behavior even with myopic/selfish agents

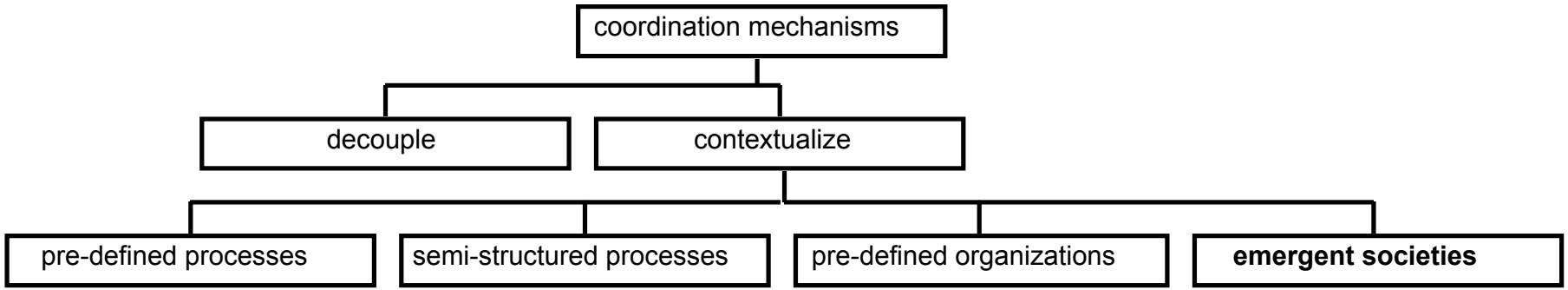
Pluralistic Societies

- divide agents into several roles
  - solution proposers
  - solution critiquers
  - solution supporters
  - solution testers
  - solution refiners
- real-life example: scientific community

Communities with Rules

- build conventional decision policies into agents
  - social constraints
    - reduce harmful interactions
    - fragile if some agents don't follow the rules
    - e.g. traffic rules
  - benevolent (deconstraining) agents
    - [adjustably] try to facilitate other agents' work
    - e.g. put away tools

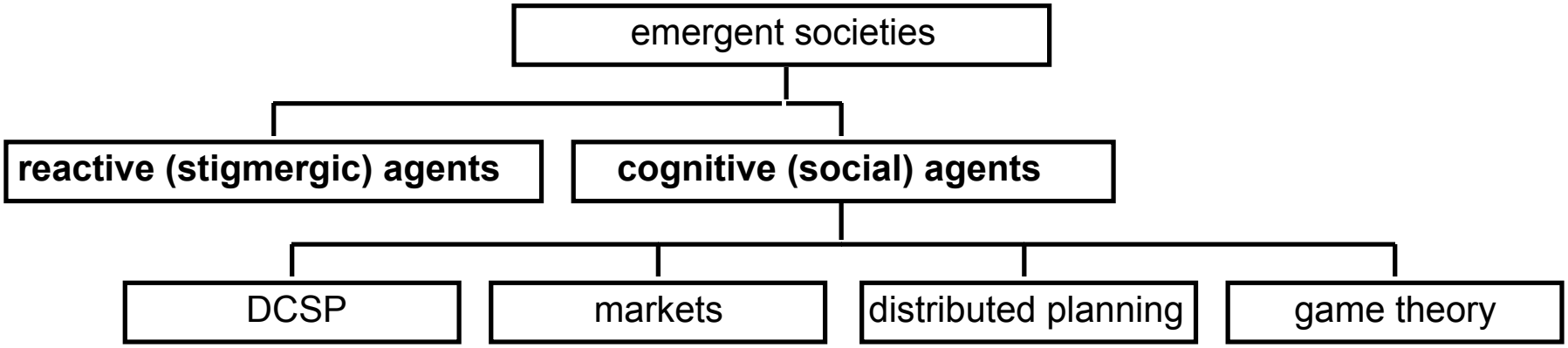
Emergent Societies



At Its Infancy

- strengths
  - less need to forsee future uses; agents tailor decisions to [dynamic] context
- limitations
  - limited maturity
  - heavier weight agents
- current focus
  - portability, security, brokering, agent languages

Stigmergic vs Social Agents



Tradeoffs

type	Pros	Cons
stigmergic: reactive, no world or agent model	• fast & cheap • surprisingly powerful & robust	• requires careful design • short term • slow adaption
socially aware: reasons over explicit model of other agents	• adaptive • proactive	• expensive

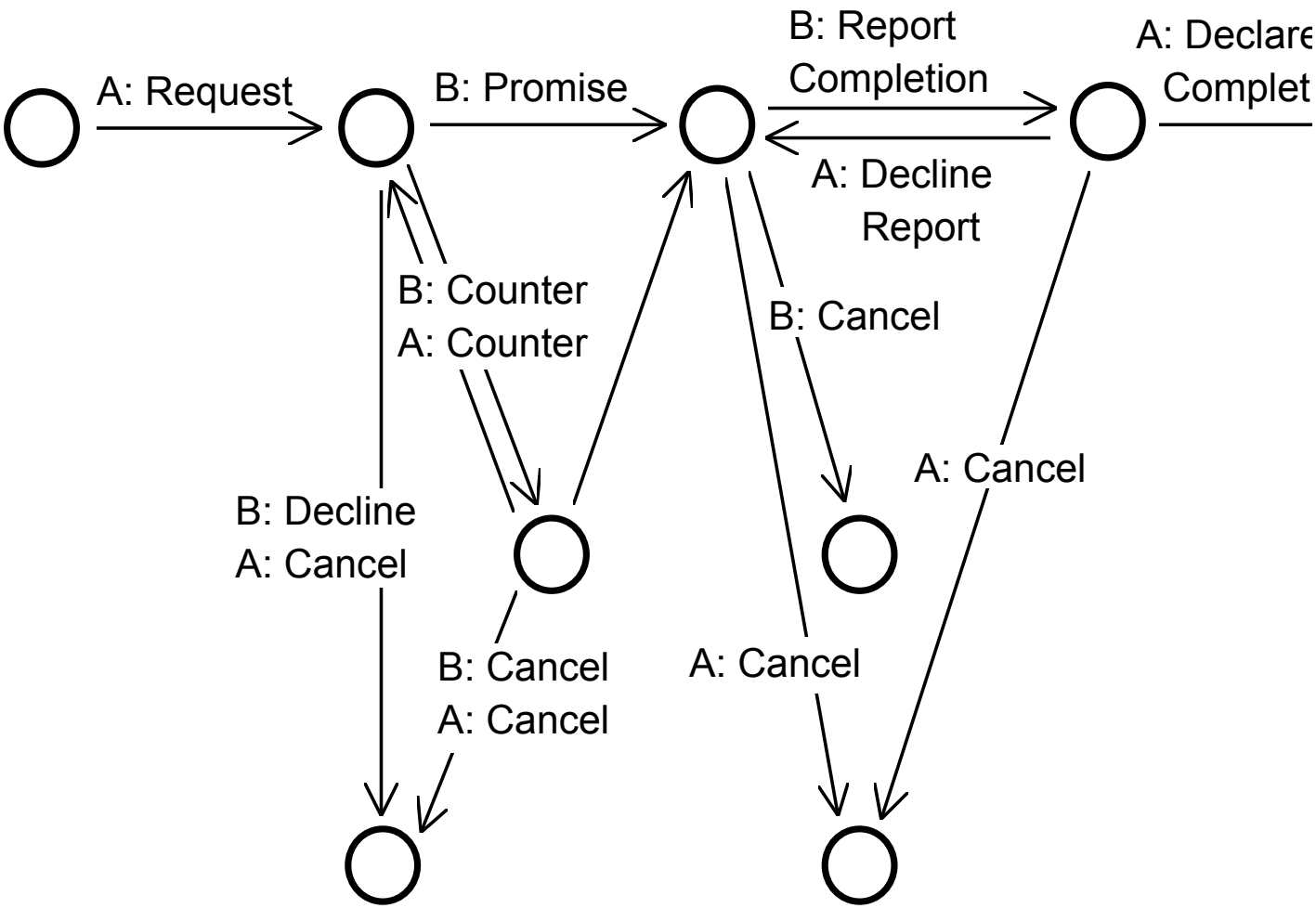
Stigmergic Agents

- interact reactively via effect on environment
  - cue-based: incidental effects of actions
    - e.g. Brooks' insect robots
    - e.g. puck-gathering robots
    - e.g. CMU Robocup winner
  - sign-based: agents leave "signs"
    - e.g. pheremones for building arches in termite nests
    - e.g. sample collection robots leave crumbs to form transport chains

Social Models

- represent goals/plans/beliefs for
  - *predicting agent actions*
  - evaluating incoming data (consider the source)
  - deciding where to get needed info
- NB can be social w/o communication
  - plan recognition e.g. among fighter pilots
  - game theoretic

Speech Acts



KQML

- emerging agent system speech act standard

  (<KQML-performative>

  :sender <agent-name>

  :receiver <agent-name>

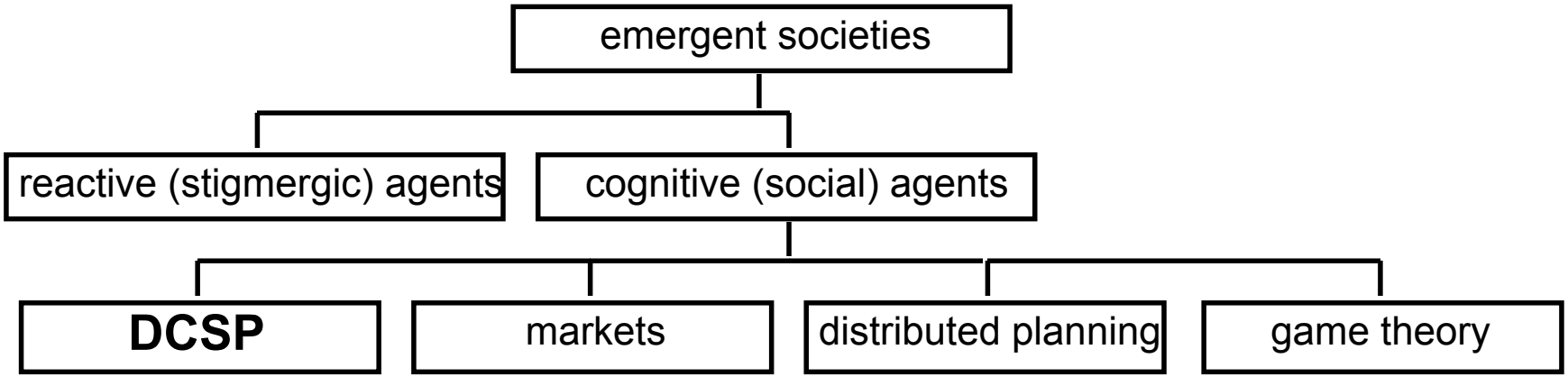
  :language <language-name> (usually KIF)

  :ontology <ontology-name> (multiple emerging ontologies)

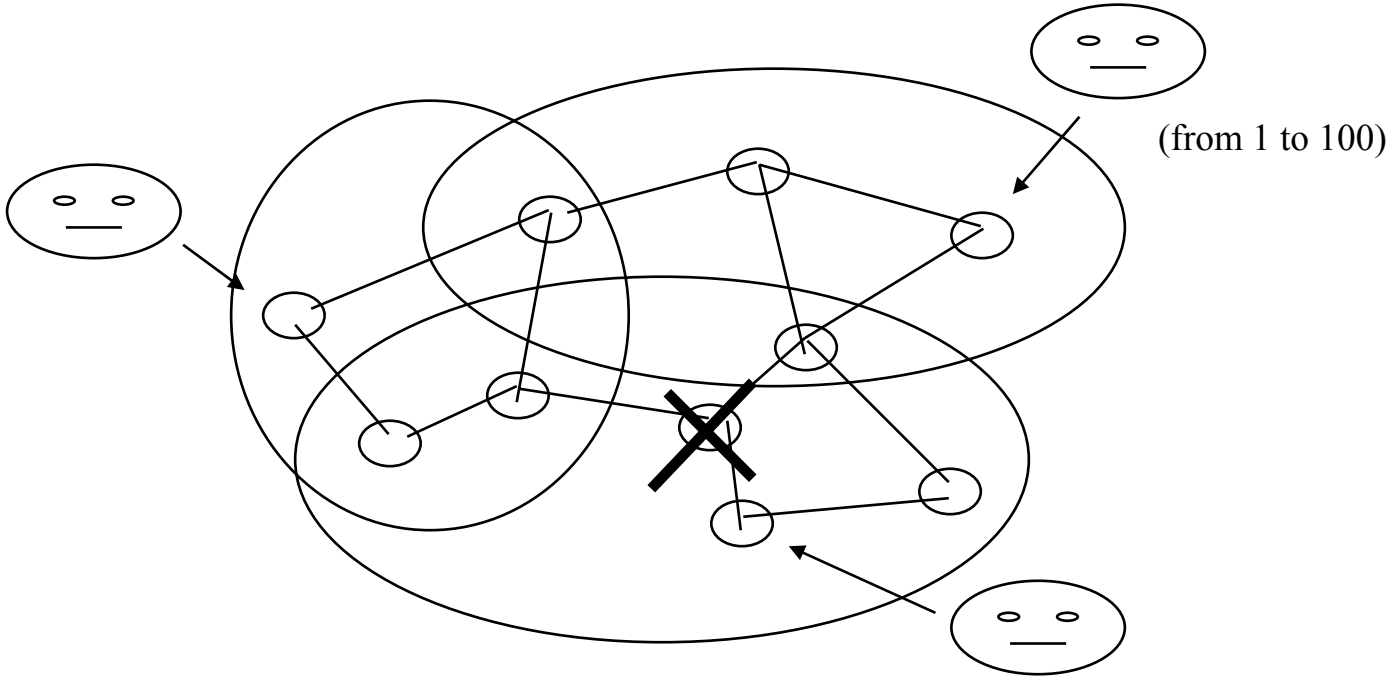
  :content <expression in language using ontology>)

- aimed at information exchange only - necessary but not sufficient

Distributed Constraint Satisfaction



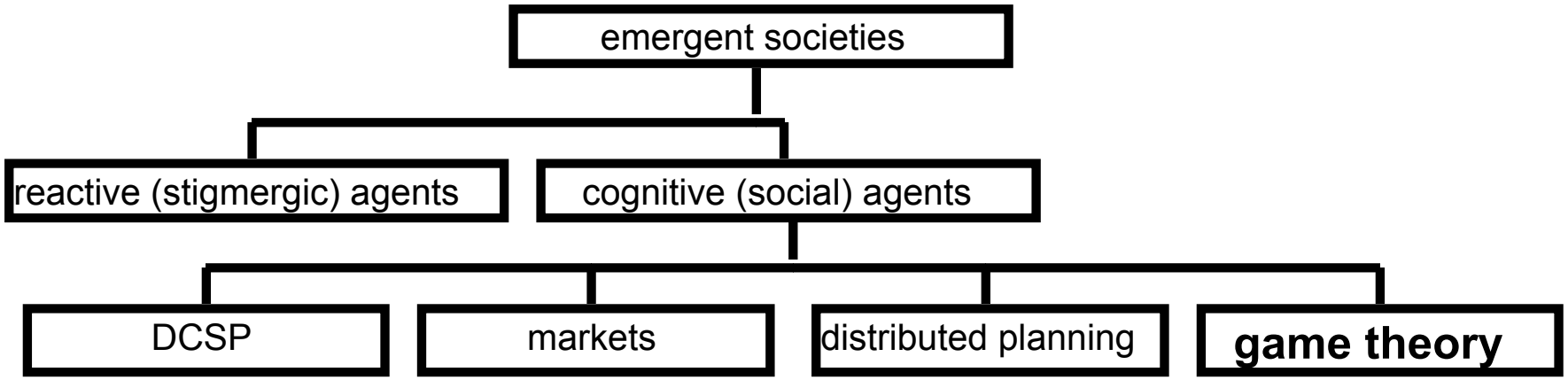
Exchanging Attribute Value Constraints



Texture Measures

- agents exchange abstracted state info to prune communication and search
- e.g. Sycara job-shop scheduler
  - resource agents manage machines
  - order agents manage job sequences
  - agents exchange availability constraints
  - also exchanged texture measures: resource utilization gaps, bottleneck identification ...

Game Theory



Game Theory

- based on mutually known payoff matrices
- enables provable properties
- example 1: coord w/o communication

	Action 1 (Agent A)	Action 2 (Agent A)
Action 3 (Agent B)	3 3	4 2
Action 4 (Agent B)	1 1	2 4

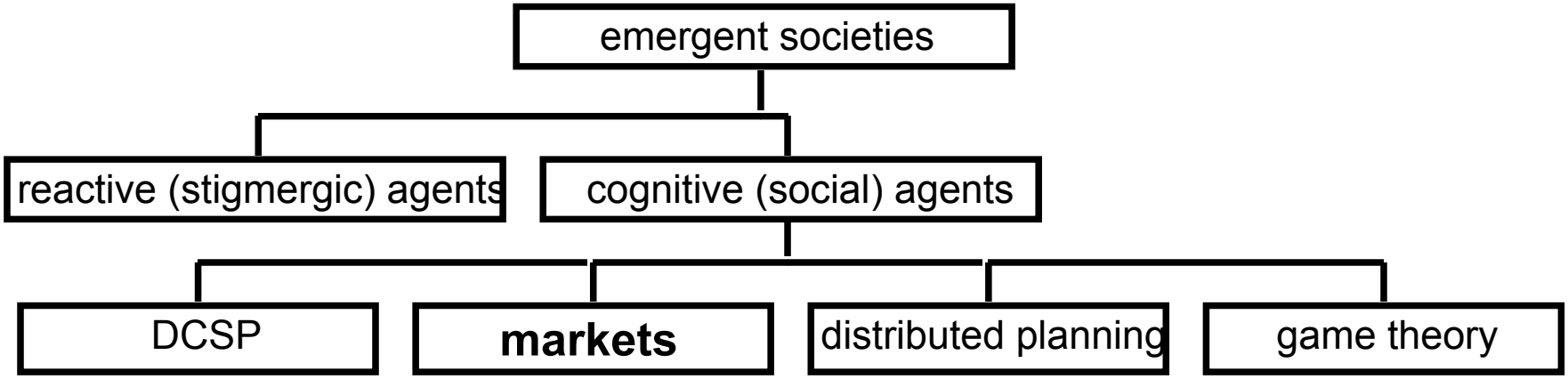
- example 2: negotiate or else

	Action 1 (Agent A)	Action 2 (Agent A)
Action 3 (Agent B)	-1 -1	2 1
Action 4 (Agent B)	1 2	-1 -1

Limiting Assumptions

- limited by strong underlying assumptions
  - fully rational agents
  - fully mutually known tractable payoff matrices
  - past or future is irrelevant/hidden
  - only two agents

Markets



Coordination by Allocation

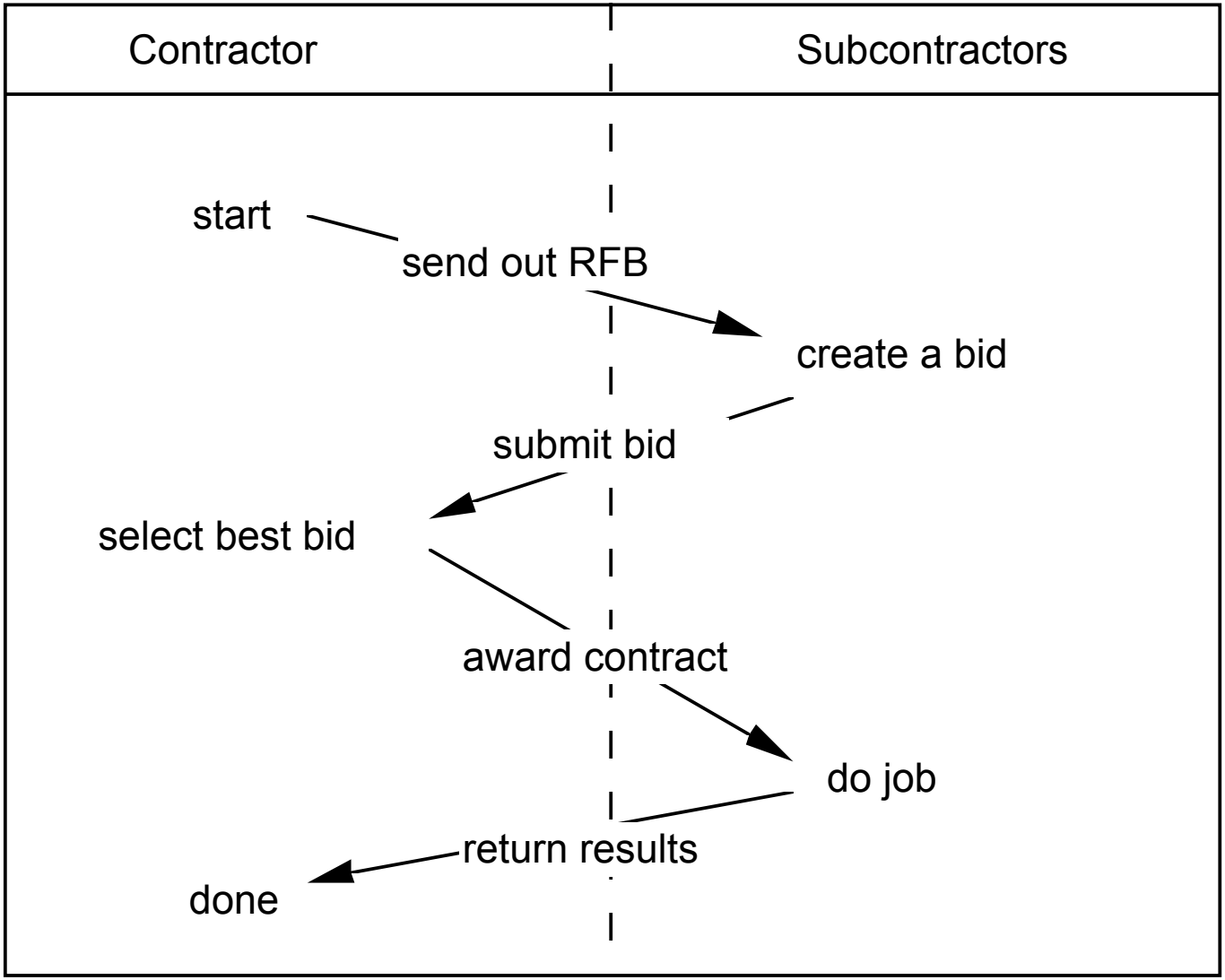
- key components
  - a set of *goods* (resources) to be traded
  - *consumers* with requirements and endowments
  - *producers* with resource I/O relationships
  - an *allocation mechanism* (typically price based)
- can potentially be applied to many domains
- goods & agents are problem-specific; allocation mechanisms are generic

Allocation Mechanisms

Mediated vs Unmediated Mechanisms

type	pros	cons
mediated	• it may be easier to enforce the negotiation rules (e.g. auction rules) • easier to control dissemination of the infomation within the negotiation process	• performance and failure bottleneck • mediator can be costly • agents have less control about how their [critical] information is distributed
unmediated	• more distribution avoids single failure or performance bottleneck • agents control info exchange on their own • avoids need for potentially costly mediator	• may not scale well to large numbers of agents

The Contract Net



Tradeoffs

- pros
  - dynamic load balancing
  - dynamic agent society membership
- cons
  - no global perspective or lateral interaction
  - sensitive to failures & dishonest agents
- requirements
  - mainly independent coarse grained tasks that match agent skills

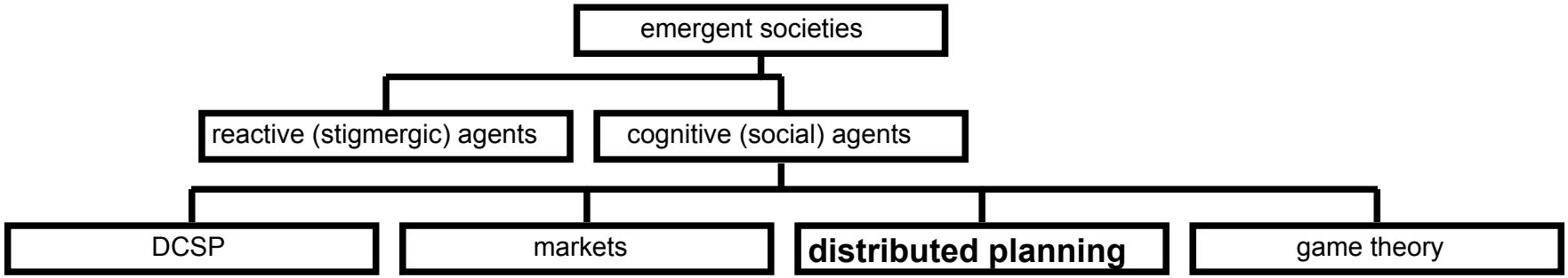
General Equilibrium Markets

- calculate equilibrium for multi-good market
- example: multi-commodity flow
  - goods = cargo movements
  - consumers = shippers
  - producers = carriers & arbitrageurs
- example: configuration design
  - goods = part costs; part capabilities
  - producers = parts
  - consumers = customer for design

Tradeoffs

- pros
  - can be applied to many problem types
  - allows simple protocols & agents
  - provable social properties
- cons
  - market design is more an art than a science
  - “hides” important issues (e.g. committments)
  - prone to “aberrations” (e.g. oscillations)

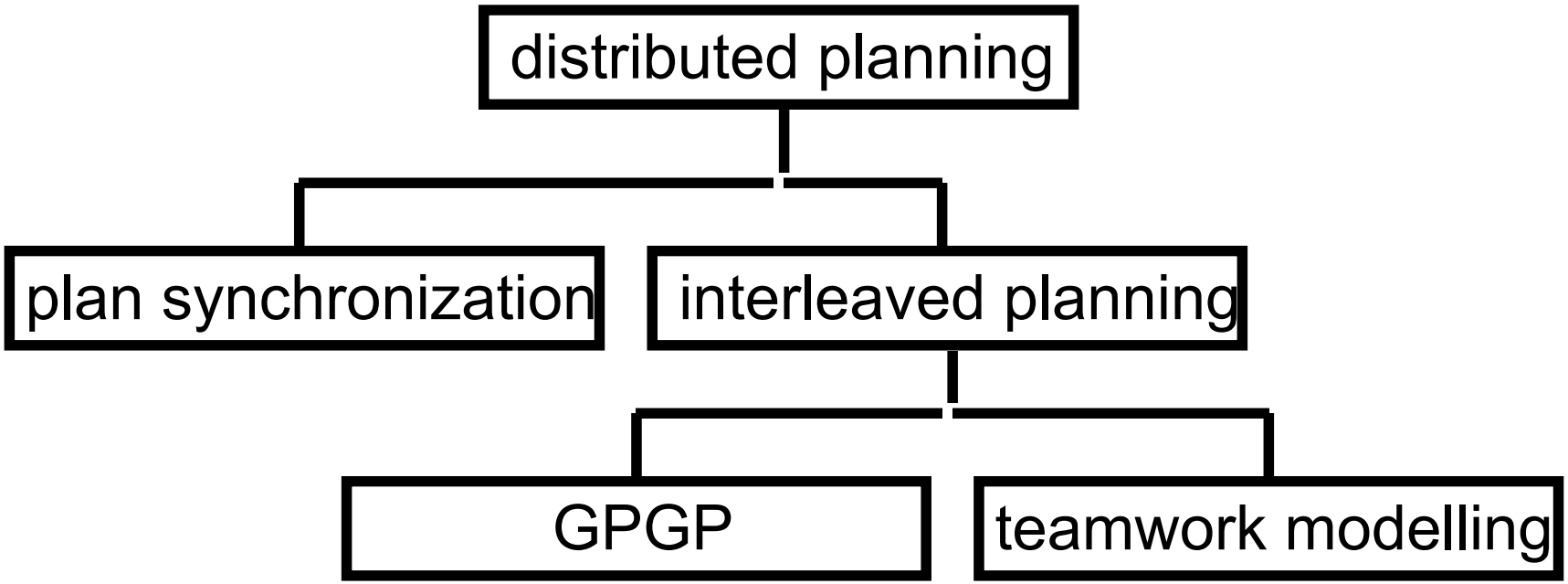
Distributed Planning



Tradeoffs

- agents build joint committments
- pros
  - explicit planning for future
  - good match to human interaction
- cons
  - computation- and communication- intensive

Synchronization vs Interleaving



Plan Synchronization

- procedure
  - agents generate completed plans
  - conflicts are detected and removed
  - plans are enacted
- examples
  - job shop synchronizer
  - air traffic controller

Interleaved Planning

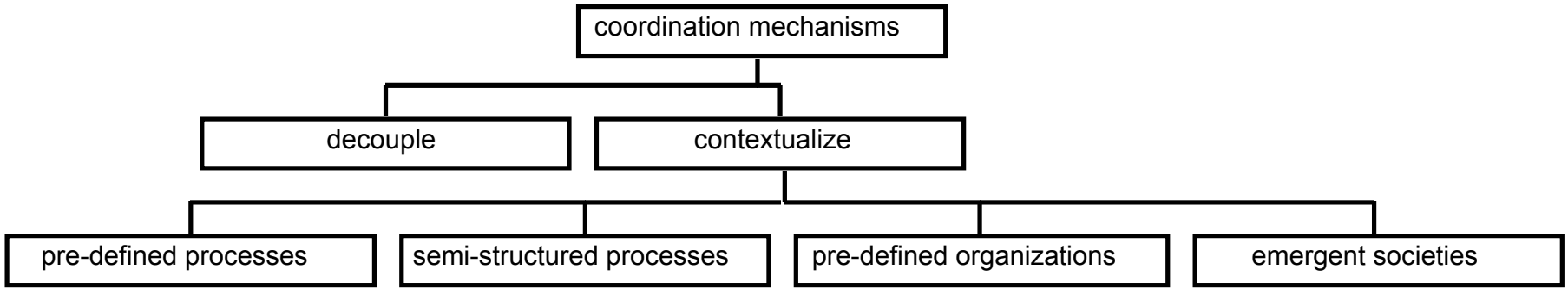
- procedure
  - agents interleave planning, communication and plan enactment
- examples
  - GPGP: agents exchange partial plans
  - STEAM: generic team-building rules

Tradeoffs

type	pros	cons
up-front plan synchronization	• easier to do centralized analysis and repair	• bottleneck • waste time creating original plans • non-optimal conflict fixes • poor reactivity
real-time interleaved planning	• potential of more quicker finding better coordinated plans • more adpative in dynamic domains	• more computation and communication intensive

Summary

A Coordination Taxonomy

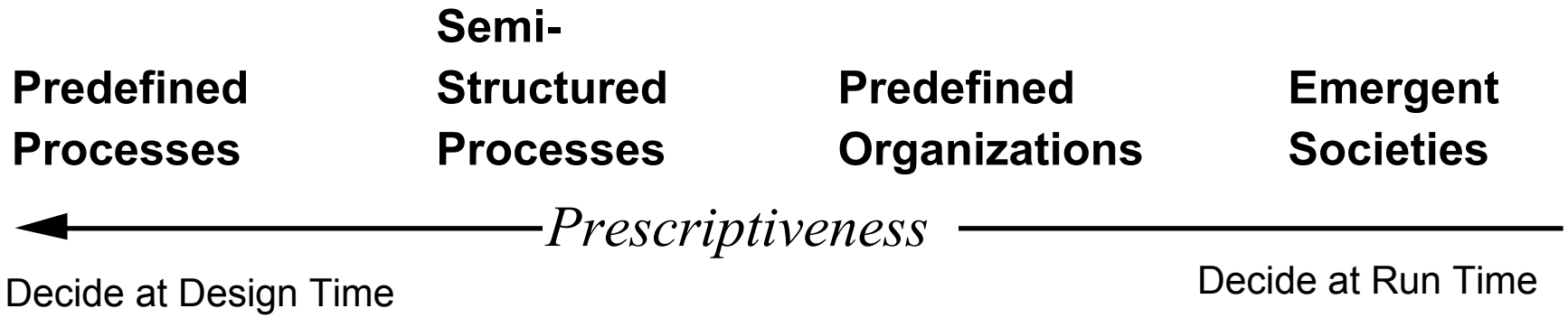


Decouple vs Contextualize

Mechanism	Pros	Cons
decouple	• less control reasoning	• often leads to non-optimal solutions • difficult in some domains
contextualize	• potential for optimality • adaptive	• more control reasoning

Decoupling can be used to *reduce*, rather than *eliminate*, the need for coordination

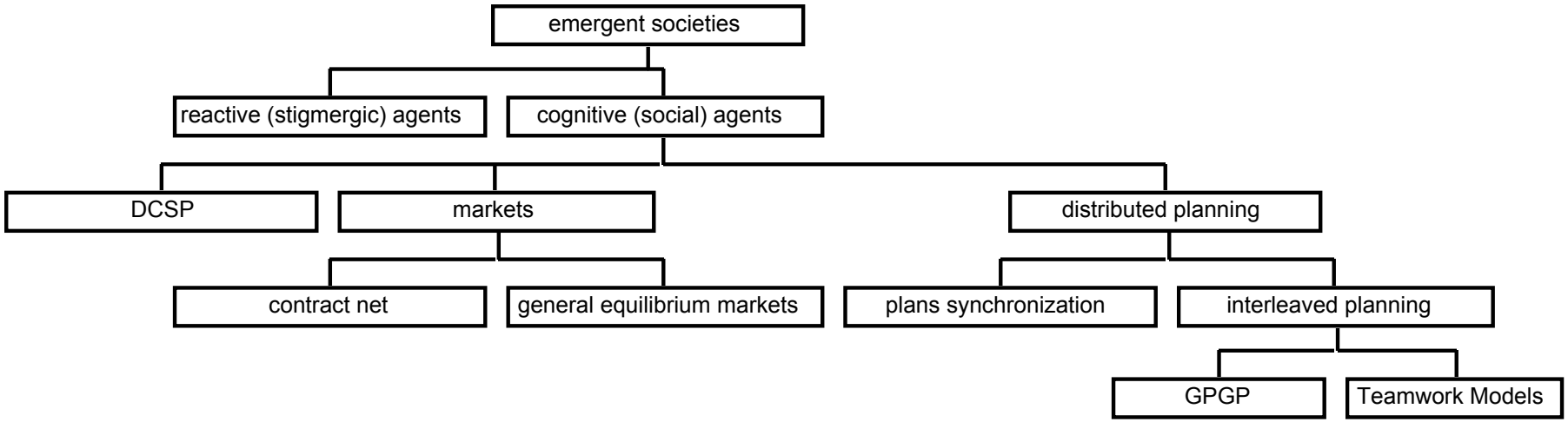
The Prescriptiveness Continuum



Prescriptiveness Tradeoffs in Contextualized Mechanisms

Issue	Predefined	Emergent
underlying metaphor	command and control	economics, biology
appropriate domains	predictable, centralized	dynamic, distributed
Issues favoring centrally predefined mechanisms		
theoretical optima?	yes	no
predictability of system	at individual level	only at aggregate level
needs high bandwidth and coordination-savvy agents?	no	yes
technology maturity	high	low
Issues favoring distributed emergent mechanisms		
match to distributed reality	low	high
adaptability/robustness	low	high
ease of development	low	high
agent homogeneity constraints	restrictive	nonrestrictive

Emergent Mechanisms



Lessons

- pre-defined processes still dominate, but
  - limited by definition cost issues
  - poor for dynamic and semi-structured processes
- emergent mechanisms are coming, but
  - need to be better understood
- exception handling is a critical issue for all coordination mechanisms