The Social Organization of Distributed Cognition

How the cognitive properties of groups can be different from the cognitive properties of the individuals in the group

Distribution of cognitive labor

- Distribution of knowledge
  - Specialization of knowledge.
- Coordinating the distributed parts, interactions among specialists
- Producing and reproducing expertise

Society as a distributed memory (Roberts)

- Native American groups have different kinds of social organization, and these give rise to different memory properties.
- Factors that affect memory retrieval
  - Group size
  - Distribution of knowledge among individuals
  - Patterns of interaction among individuals
  - Changes in patterns of interaction through time

Coordinating the distributed parts

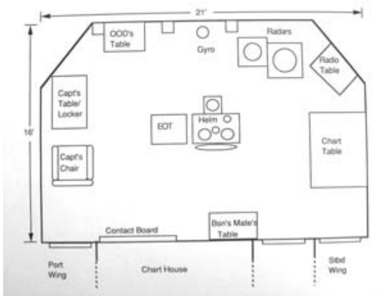
- There are many ways to do this, social organization of distributed cognition
- Stigmergy: reacting to structure left by others, (e.g., ants)
- Aggregation: voting schemes, juries, markets, Wisdom of crowds.
- Society of agent specialists, distribution of knowledge and distribution of responsibility.
- Hierarchies, and chain of command
- Distributed AI, Chandrasekeran, natural and social system metaphors.

Social Organization as Computational Architecture

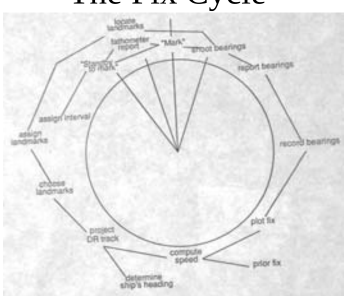
- Social organizations take the form they do for many reasons
- No matter what form a social organization takes, it will have cognitive consequences.

The navigation team as a distributed cognitive system

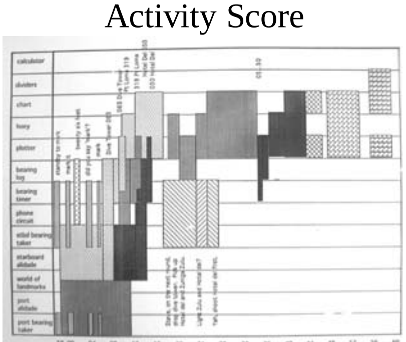
Bridge Layout



The Fix Cycle



Activity Score



Properties of the system

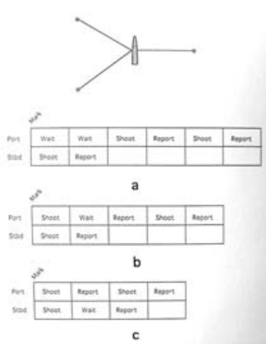
- Computation via propagation of representational state
- Parallel activity
- bottom-up and top-down processes
- readbacks and redundant representation
- Buffers and demons (depth and bearing triggers)

Sequential control of action/production systems

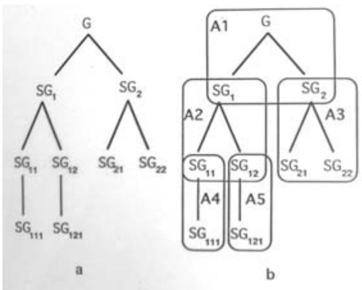
- Condition/action pairs
- Agents waiting for conditions that trigger actions.
- With the right distribution of productions, a complex procedure can be accomplished without any agent knowing the plan.

Shoot the beam bearing first

Three ways to sequence the actions of the bearing takers.



Coordinating Goal Structure and Social Structure



Cognitive properties of the navigation team are twice removed from the cognitive properties of the members of the team.

- Cognitive properties of individuals are transformed by the functional systems they form when they interact with technology
- Social organization of distributed cognition produces effects at the group level that are simply not those of the individual level.

Advantages of distributed architectures

- Decomposition to control complexity (modularity), limiting complexity of input encountered by any individual
- Also enables parallel activity for efficiency
- Filtering reduces processing costs
- Organizing activity on the basis of social relations rather than domain content. (Take care of syntax and semantics will take care of itself. Take care of social relations, and syntax will take care of itself.)

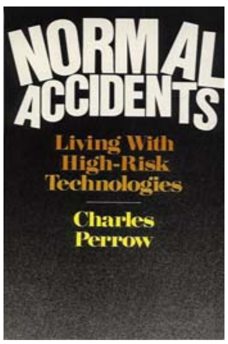
Advantage of distribution: Graceful degradation

- Robust adaptation or gradual reduction in capacity rather than catastrophic failure.
- Redundant knowledge and skills
- Intersubjectively shared understanding of the task and filling in for other agents.

Costs of distributing cognition

- Filtering effects (hard to diagnose causes of failures)
- The need for coordination
- Design of coordination can be difficult (see beam bearings analysis)

Complexity, Coupling, and Catastrophe



Perrow's Predictions (1984)

• **Before 1984**	• **Since 1984**
• Three Mile Island	• Chernobl
• Petrochemical	• Bhopal
• Teneriffe, etc.	• TWA 800, etc.
• Torrey Canyon	• Exxon Valdez
• Gemini, Apollo 13	• Challenger, Columbia
• HMS Canberra	• Gulf War I and II

System elements

- Part (a single component)
- Unit (a functionally related collection of parts)
- Subsystems (an array of units)
- System

Incident

- Damage limited to parts or a unit, whether the failure disrupts the system or not.
- There are many more incidents than accidents.

Accident

- A failure in a subsystem or the system as a whole, that damages more than one unit and in doing so disrupts the on-going or future output of the system.

Component Failure Accident

- One or more component failures (part, unit, or subsystem) that are linked in an anticipated sequence.

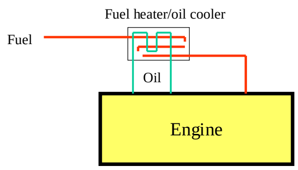
System (Normal) Accident

- An accident involving unanticipated interactions of multiple failures.

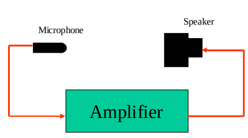
Victims

- First party (operators)
- Second party (non-operating system personnel or system users)
- Third party (innocent bystanders)
- Fourth party (fetuses and future generations)

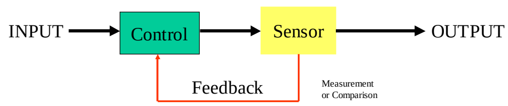
Common-mode connections



Typical Positive Feedback loop

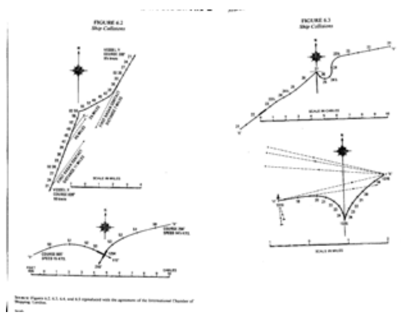


Typical Negative Feedback loop



Radar Assisted Collisions

The danger of safety systems



Linear Systems

- Spatial segregation
- Dedicated connections (not common-mode)
- Segregated sub-systems
- Easy Substitutions
- Few feedback loops
- Single purpose controls
- Direct information
- Extensive understanding

Complex Systems

- Proximity of components
- Common-mode connections
- Interconnected sub-systems
- Limited Substitutions
- Feedback loops
- Multiple and interacting controls
- Indirect information
- Limited Understanding

Specialization and knowledge

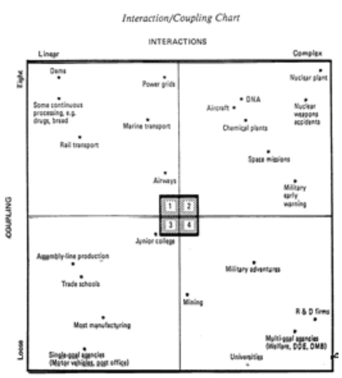
- "Specialized personnel tend not to bridge the wide range of possible interactions…"
- As we saw with Taylorism, the organization of work activities affects the distribution of knowledge, which in this case affects the ability of the system to recover from error and failures.

Tight Coupling

- Delays in processing not possible
- Invariant sequences
- Unifinality (only one way to do the job)
- Little slack
- Buffers designed-in
- Substitutions designed-in

Loose Coupling

- Processing delays possible
- Order of sequences can be changed
- Alternative methods available
- Slack in resources
- Buffers and redundancies fortuitously available
- Substitution fortuitously available



Necessary Conditions for Detecting Error

- Access
- Knowledge or expectation
- Attention
- Perspective

Access

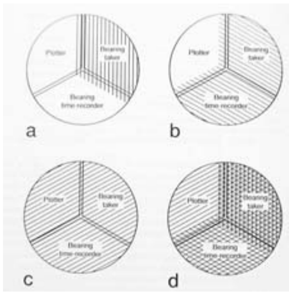
- One must be able to sense the behavior that is in error.
- Affected by a person's location in the system and by **what information goes where, when, in what form.**
  - Open interactions
  - Open tools

Knowledge

- One must have knowledge or expectation about the correct outcome. **Error detection requires a comparison between two representations of the same thing.**
- What is the distribution of knowledge in the system?
- How is that distribution produced and maintained?

Jobs in sea and anchor detail

Overlap of knowledge



Attention

- One must attend to the sensed information in terms of the knowledge or expectation.
- This may be affected by
  - the nature of the tasks being done
  - arousal state
  - competing cognitive tasks
- High workload can lead to increased error production and decreased error detection

Perspective

- One’s place in the system or one’s job may make certain kinds of errors easier to detect.
- Monitoring and performing are different activities with different perspectives.

Should we strive to Eliminate Error?

- Human systems always lose experts and acquire novices.
- Expertise is maintained through learning.
- Detected errors are opportunities for learning.
- A paradoxical property of human systems: some non-zero amount of error may be adaptive.