707.009
Foundations of Knowledge Management
„Knowledge Types and Processes“

Markus Strohmaier

Univ. Ass. / Assistant Professor
Knowledge Management Institute
Graz University of Technology, Austria

e-mail: markus.strohmaier@tugraz.at
web: http://www.kmi.tugraz.at/staff/markus

Overview

Agenda

- Implicit vs. explicit forms of knowledge
- Knowledge conversion processes
- Skills, Rules and Knowledge

Knowledge Management Institute

Preliminary Schedule I

Week	Date	Title, Slides	Comments and Links
Week 1 slides	4.10.2007	**Overview and Motivation** (slides)	In this class, we will discuss the course organization and give a basic motivation for and introduction to the course. **Readings**: P.F. Drucker, Knowledge-Worker Productivity. The Biggest Challenge, California Management Review 41 79--94 (1999) [Protected Access]
Week 2 slides	11.10.2007	**Knowledge Types and Processes** (slides)	What is knowledge? What forms of knowledge can we identify? We will discuss some basic distinctions and characterizations. **Readings**: D. Kirsh, When is information explicitly represented?, Information, Language and Cognition - The Vancouver Studies in Cognitive Science.: 340--365, 1990. [Protected Access]
Week 3 slides	18.10.2007	**Knowledge Management Strategies** (slides)	A series of different "schools of knowledge management" have been proposed by KM researchers: We will discuss selected perspectives and some implications for knowledge management. **Readings**: M.T. Hansen and N. Nohria and T. Tierney, What's your Strategy for Managing Knowledge?, Harvard Business Review, 1999. [Protected Access] M. Earl, Knowledge Management Strategies: Toward a Taxonomy, Journal of Management Information Systems 18 215--233, 2001. [Protected Access]
Week 4 slides	25.10.2007	**Knowledge Organization** (slides)	How can knowledge be organized? We will discuss some basic principles of knowledge organization. **Readings**: C.B. Mervis and E. Rosch, Categorization of Natural Objects, Annual Review of Psychology 32 89--115, 1981 [Protected Access]
Week 5 slides	8.11.2007	**Broad Knowledge Bases** (slides)	What kind of broad knowledge bases exist ? We will discuss different forms of knowledge bases and representations, such as metadata, wordnet, framenet, cyc, openmind and others. **Readings**: T. Berners-Lee and J. Hendler and O. Lassila, The semantic Web, Scientific American, 284 (5) 2001.
Week 6 slides	15.11.2007	**Knowledge Acquisition** (slides)	How can knowledge be acquired in a way that is amenable to computation and/or analysis? **Readings**: L. von Ahn, Games with a Purpose, Computer, 39(6): 92--94, 2006.
Week 7 slides	22.11.2007	**Knowledge Transfer** (slides)	How can knowledge transfer be characterized and what factors can influence knowledge transfer? We will discuss these and further issues. **Readings**: M. E. Nissen and R. E. Levitt, Agent-Based Modeling of Knowledge Flows: Illustration from the Domain of Information Systems Design, Proceedings of the 37th Hawaii International Conference on System Sciences, 2004. A. Cabrera and E.F. Cabrera, Knowledge-sharing dilemmas, Organization Studies 23 687-710 (2002)

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Preliminary Schedule I

Week 8 slides	29.11.2007	**Organizational Knowledge Repositories** (slides)	How can knowledge repositories be designed and deployed? We will discuss concepts such as knowledge reuse, discretionary databases, experience factories and selected concepts from case based reasoning. **Readings**: V. R. Basili and G. Caldiera and D.H. Rombach, Experience Factory, Encyclopedia of Software Engineering 469-476 (1994)
Week 9 slides	6.12.2007	**Psychology in Knowledge Management** (slides)	In this class, we will discuss some fundamental psychological concepts in the context of knowledge management, including for example Knowledge Space Theory. Guest Lecture: T. Ley, Know-Center **Readings**: TBA
Week 10 slides	13.12.2007	**Multimedia & Semantic Metadata** (slides)	In this class, we will discuss different forms of semantic annotation of multimedia documents. Guest Lecture: M. Lux, Klagenfurt University **Readings**: TBA
Week 11 slides	10.1.2008	**Business Process Oriented Knowledge Management** (slides)	In this class, we will discuss different approaches aimed at integrating knowledge management into an organization's business processes. **Readings**: TBA
Week 12 slides	17.1.2008	**Agent- and Goal-Oriented Analysis of Information Systems** (slides)	What are the requirements for effective information systems? In this class, we will discuss an agent-oriented framework for early requirements engineering. **Readings**: TBA
Week 13 slides	24.1.2008	**Knowledge-based Analysis** (slides)	How can socio-technological systems be organized from a knowledge perspective? We will discuss an agent-oriented modeling approach for analyzing knowledge transfer instruments. **Readings**: M. Strohmaier, E. Yu, J. Horkoff, J. Aranda and S. Easterbrook, Analyzing Knowledge Transfer Effectiveness – An Agent-Oriented Approach, In Proceedings of the 40th Hawaii International Conference on System Sciences (HICSS-40 2007), January 3-9, IEEE Computer Society, Hawaii, USA, 2007.
Week 14 slides	31.1.2008	**Final Exam**	No aids are allowed at the final exam.

Motivation [Maier 2005]

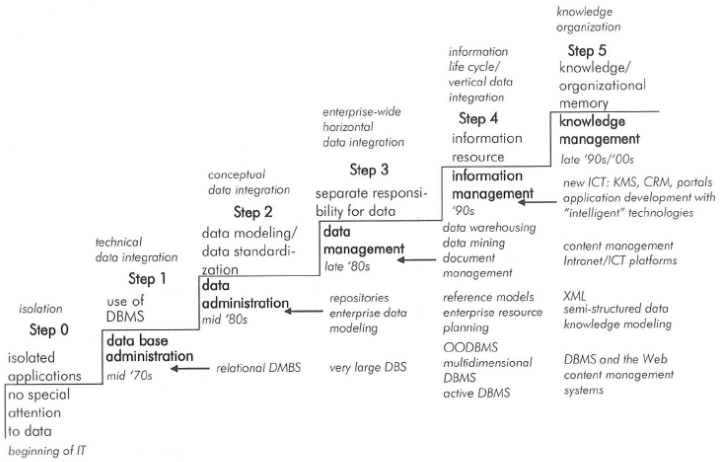


Figure 1-8. Historical development of information processing with focus on data (based on Ortner 1991)

Motivation [Maier 2005]

Illustration

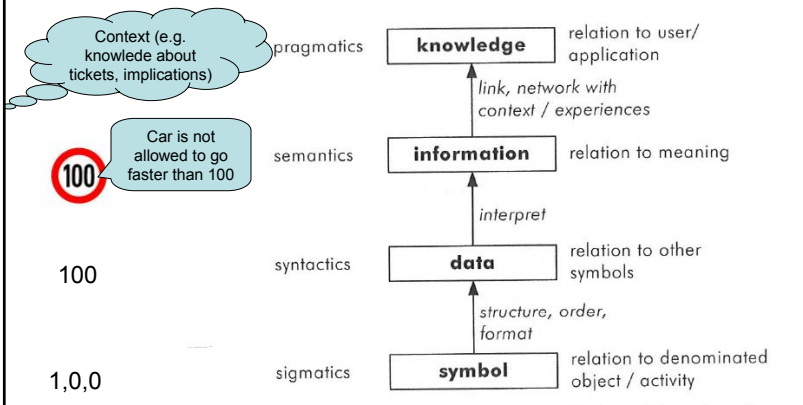
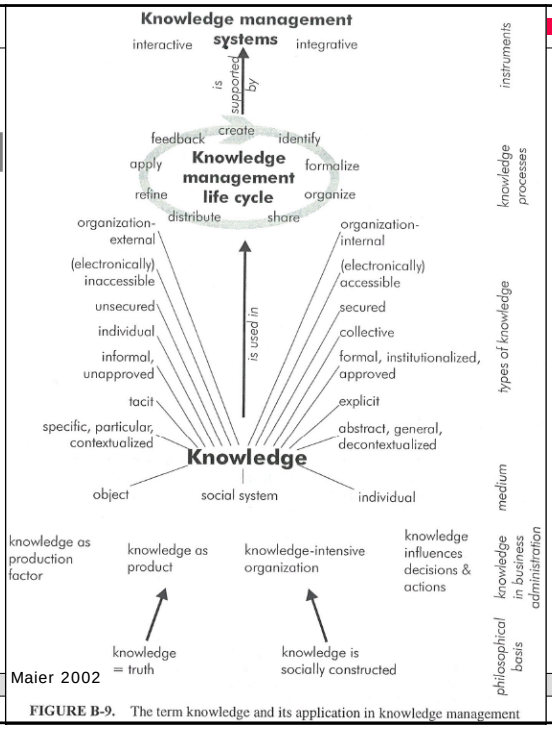


Figure 1-1. Data, information and knowledge as hierarchy of terms

Knowledge [Maier 2002]



Maier 2002

FIGURE B-9. The term knowledge and its application in knowledge management

Motivation [Maier 2005]

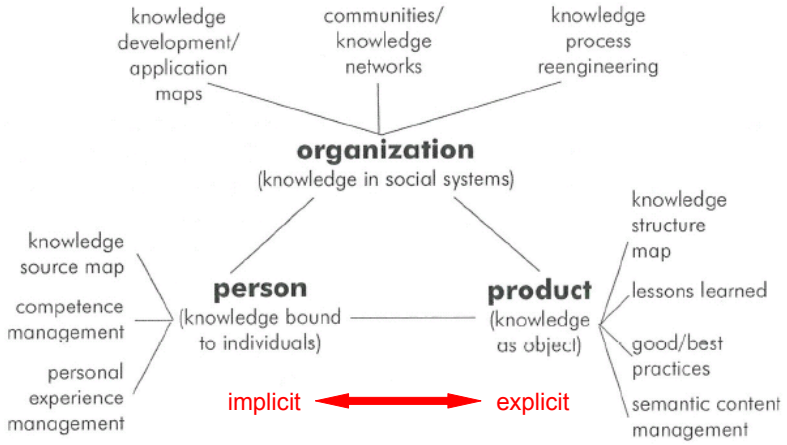


Figure 1-10. Knowledge management instruments

Motivation

Can you give examples of implicit / explicit information?

What is the difference between implicit and explicit information?

Implicit vs. Explicit Knowledge naive distinction

Four naive properties of explicit representations [Kirsh1990]:

- **Locality**: visible structures with a definite location
- **Movability**: no matter where in a book a word is to be found, the word retains ist meaning, words maintain meaning across time and space
- **Meaning**: words have a definite semantic content
- **Availability**: the semantic content of a word is directly available to cognizers, no translation or interpretation is necessary, immediate readability

Information is explicit when it is local, movable, available and when it has a definite meaning.

Explicit

- Knowledge outside the head
- Examples: A book, a sentence, a piece of code, a database entry

Implicit

- Knowledge inside the head
- Examples: experiences, skills, gut feelings

BUT...

Explicit or Implicit? [Kirsh1990]

1. Is 5 as the solution to $\sqrt[3]{125}$ explicit in $\sqrt[3]{125}$?
2. Is the $200^{100^{100}}$ digit of π explicit?
3. Is 3 explicit in A: {1,5,3,7,4,4}?
4. Is the cardinality of A explicit in A: {1,5,3,7,4,4}?
5. Is (6754, 9629) in a matrix of 10,000 x 10,000 explicit?
6. Is the answer to „Why does the pop star *P!nk* perform 4 Non Blondes songs at her concert" explicit on the web?

Questions: Do we count accessing times as part of the reading process (availability)? Should we differentiate between *locating* and *computing* information? What is immediate readability?

Locality [Kirsh1990]

Locality: visible structures with a definite location (naive)

Problem: Overly restrictive. Why exclude distributed information? Can information never be explicit on a distributed network?

e.g. an mp3 file on a distributed peer-to-peer network

What is important is that information can be separated from surroundings by a host system.

Movability [Kirsh1990]

Movability: no matter where in a book a word is to be found, the word retains ist meaning (naive)

Problem:

- Does 5 in 105 carry the same meaning as 5 in 501?
- „Police police police police police“
  (Police who are policed by policemen are themselves policers of policemen)

Syntax needs to be taken into account.

Availability [Kirsh1990]

Availability: the semantic content of a word is directly available to cognizers, no translation or interpretation is necessary (naive)

Problem:

What is explicit in a structural sense may not be explicit in a procedural sense.

Example:

- A book without index
- Encrypted messages (is „hans“ explicit in „ibot“?)

We cannot decide what is explicit without knowing in detail how a system works.

Meaning
[Kirsh1990]

Meaning: words have a definite semantic content (naive)

Problem:

- **polysemous** words (Polysemy)
  e.g. bank (river bank, financial institution)
- "Then John read *him* his rights". Who is him?
- A symbol explicitly encodes a certain semantic if a system S can immediately recognize its meaning.

We need to take the semantic context into account.

Implicit vs. Explicit
[Kirsh1990]

Four Conditions revisited

1. The states, structures or processes – henceforth symbols – which explicitly encode information must be **easily separable** from each other (Locality)
2. An ambiguous language may explicitly encode information only if it is **trivial to identify** the syntactic and semantic identity of the symbol. (Movability)

   Trivial: if there is a mechanical process that identifies the relevant property in constant time (independant of the size of the problem instance) or within a given attention span

   Example: is a given binary number even or odd?

   Answer: Depends on the system's algorithm and the operators attention span to determine it

Implicit vs. Explicit [Kirsh1990]

Four Conditions revisited

3. Symbols explicitly encode information if they are either:
   A) readable in constant time or
   B) sufficiently small to fall in the attention span of an **operator**
   (Availability)
4. The information which a symbol explicitly encodes is given by the set of associated states, structures or processes it **activates** in constant time
   (Meaning)

Implicit vs. Explicit Summarization [Kirsh1990]

„Explicitness really concerns how quickly information can be accessed, retrieved or in some other manner put to use. It has more to do with what is present in a **process sense***, than with what is present in a* **structural sense***."*

„Representations are inert unless coupled with **processes which interpret them***."*

„It is the **union of structure and process** *which can explicitly encode information."*

Example:
Q: Is the year you started your studies explicit in your Matr. Nr.?
A: Again, this depends on the system's algorithm and the operators attention span to determine it

Implications

What are the implications of the dependencies on

- Algorithms runtime
- Operator / User attention span

for Software Engineering / Software Engineers?

- Access and processing times determine the extent to which knowledge can be regarded to be explicit
- Different attention spans of different users yield different degrees of expliciteness

Tacit, Implicit, Explicit

- Tacit: can not be made explicit
  - Examples: Gut feeling, expert knowledge, etc
- Implicit: not explicit, but can be made explicit
  - Key criteria: time
  - Examples: Why does P!nk perform 4 Non Blondes songs on stage?
- Explicit: easily recoverable and cognitizable
  - According to the four conditions
  - Example: Is any given binary number even or odd?

But, the ultimate distinction depends on the system processing the information and the operator's attention span

Types of Knowledge [Alavi & Leidner 2001]

Table 2. Knowledge Taxonomies and Examples

Knowledge Types	Definitions	Examples
Tacit	Knowledge is rooted in actions, experience, and involvement in specific context	Best means of dealing with specific customer
Cognitive tacit:	Mental models	Individual's belief on cause-effect relationships
Technical tacit:	Know-how applicable to specific work	Surgery skills
Explicit	Articulated, generalized knowledge	Knowledge of major customers in a region
Individual	Created by and inherent in the individual	Insights gained from completed project
Social	Created by and inherent in collective actions of a group	Norms for inter-group communication
Declarative	Know-about	What drug is appropriate for an illness
Procedural	Know-how	How to administer a particular drug
Causal	Know-why	Understanding why the drug works
Conditional	Know-when	Understanding when to prescribe the drug
Relational	Know-with	Understanding how the drug interacts with other drugs
Pragmatic	Useful knowledge for an organization	Best practices, business frameworks, project experiences, engineering drawings, market reports

How is one type of knowledge converted into another?

Modes of Knowledge Creation [Maier 2005]

	tacit knowledge	to explicit knowledge
tacit knowledge	**socialization** share experiences: training on the job, brainstorming informal gathering *result: sympathized knowledge*	**externalization** communicate intuitive, subjective experiences: metaphors, analogies, physical models *result: conceptual knowledge*
from explicit knowledge	**internalization** avoid re-inventing wheel: handbooks, diagrams, learning by doing, stories, studies *result: operational knowledge*	**combination** share, integrate knowledge: text/ image/ audio/ video-documents, discussion, formal training & education *result: systemic knowledge*

Figure 1-6. Processes of knowledge conversion (Nonaka/Takeuchi 1995)

Modes of Knowledge Creation [Nonaka 1994]

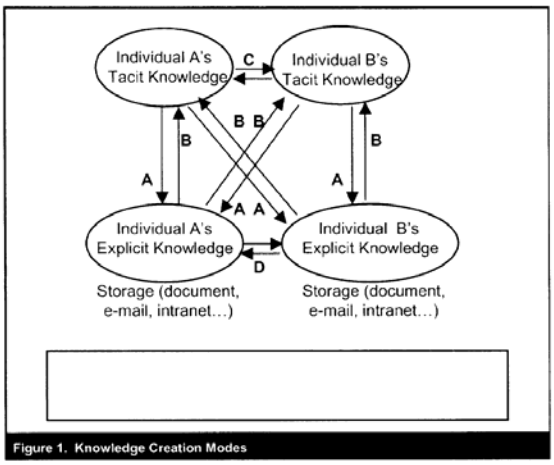


Figure 1. Knowledge Creation Modes

What is cognition?

Wordnet:

„The psychological result of perception and learning and reasoning“

Synonym: knowledge

Britannica:

“the process involved in knowing, or the act of knowing, which in its completeness includes perception and judgment. Cognition includes all processes of consciousness by which knowledge is accumulated, such as perceiving, recognizing, conceiving, and reasoning. Put differently, cognition is an experience of knowing that can be distinguished from an experience.“

German: Wahrnehmung

Cognitive Load Theory

Intrinsic cognitive load

- Inherent difficulty of information content
  - Example: 23 * 4 = ?

Extraneous cognitive load

- Due to the way the information is presented
  - Example: XXIII * IV = ?

By changing how the information is presented the level of cognitive load may be reduced

External Cognition [Scaife 1996]

Internal representations (mental models)

External representations (text, graphics, etc)

Instead of focusing on internal representations, let's focus on external representations. How can they be modified to improve cognition?

1. Computational Offloading
2. Re-representation
3. Graphical constraining

Computational Offloading [Scaife 1996]

Refers to the extent to which external representations reduce the amount of cognitive effort

Example: Which nodes do not share an edge?

Textual Representation:

There is a graph with nodes A, B, C, D. There is an edge between A and B. Another line runs from B to C and from A to D. C and D are connected as well.

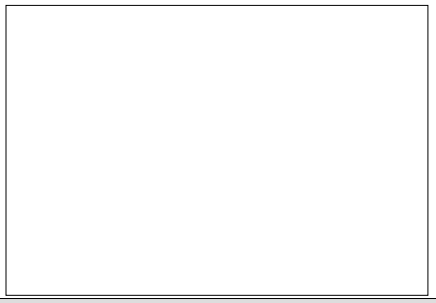
Re-representation [Scaife 1996]

Refers to how different external representations, that have the same abstract structure, make problem-solving easier or more difficult.

Example: Which nodes do not share an edge?

Formal Representation:

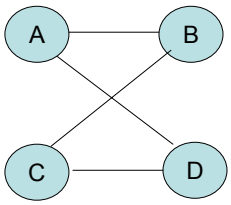
[A,B], [C,D], [A,D], [B,C]



Graphical Constraining [Scaife 1996]

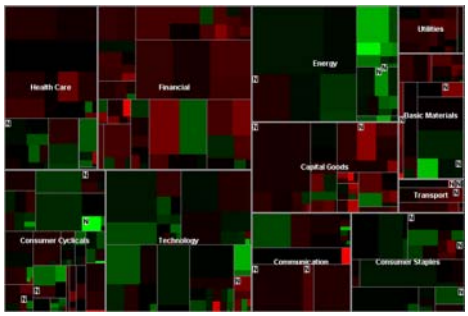
Refers to the way graphical elements in a graphical representation are able to constrain the kinds of inferences that can be made.

What kind of graphical constraints are introduced by the graph below?



External Cognition [Scaife 1996]

Solvers no longer need to solve the problems entirely in their head but can work them out by interacting with the diagrams.



Stock market, http://www.smartmoney.com/marketmap/

External Cognition [Scaife 1996]

Examples: Knowledge Visualization

A periodic table of Visualization Methods

http://www.visual-literacy.org/periodic_table/periodic_table.html

Distributed Cognition [Rogers 2005]

The focus is on explicating *cognitive systems*, which are the interactions between people, artifacts and both internal and external representations.

focuses on the processes that take place in an extended cognitive system. (does not only focus on knowledge „inside the head“)

the explication of the complex interdependencies between people, artifacts and technological systems

Distributed Cognition [Rogers 2005]

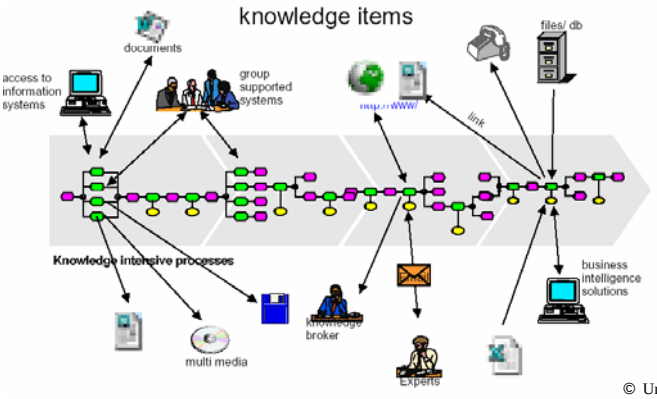
Why is this perspective interesting?

It is possible to determine the processes and properties of such cognitive systems **more reliably** – since they can be **observed directly** in **ways not possible inside a person's head**

skills and the knowledge produced by distributed processes are the mental residua of the process.

Organizational Work

Organizational work becomes increasingly knowledge intensive and complex. [Eppler 1999]



Distributed Cognition [Rogers 2005]

the distributed cognition approach involves explicating:

- the **distributed problem-solving** that takes place (including the way people work together to solve a problem)
- the **role of verbal and non-verbal behavior** (including what is said, what is implied by glances, winks, etc. and what is not said)
- the various **coordinating mechanisms** that are used (e.g., rules, procedures)
- the **various ways communication** takes place as the collaborative activity progresses.
- how **knowledge is shared** and accessed

Distributed Cognition [Walenstein 2002]

Cognition is **not a process localized to an individual** human mind, but one that is spread out amongst possibly many humans and artifacts.

A cognitive system will operate better or worse depending upon whether the **appropriate external artifacts** are available, and depending upon how they are designed.

Cognitive support can therefore be understood entirely in computatoinal terms: **support is the provision of computational advantage**

Cognitive Support [Walenstein 2002]

Thus the cognitive support provided by an artifact is the computational advantage that it provides.

Designing cognitive support can be considered as **computational reengineering**

Example: Calculator, Notebook, Calendar

But what distinct classes of cognitive support exist?

Cognitive Support Classes [Walenstein 2002]

The RODS Framework for Analyzing Cognitive Support

- Reduction
- Optimization
- Distribution
- Specialization

Task Reduction [Walenstein 2002]

- Removing unnecessary steps or unused computations
- Example:
  - Programmer‘s editor might insist on having the developer re-read every line of code in a program before each and every edit she makes
  - Unnecessary computations being performed
  - Removing these will decrease the amount of cognitive work done

Algorithmic Optimization [Walenstein 2002]

- Relies on the fact that
  - Differences in encoding or procedure can create differences in performance without changing the outcome
  - Information content remains unchanged
- Example:
  - Arabic and roman numbers: Roman numbers require more complex compution (symbol substitution) for most of us

Distribution [Walenstein 2002]

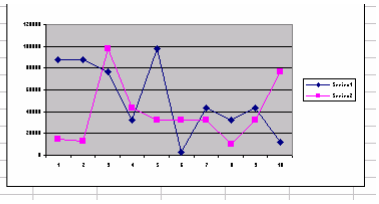
- Divide cognitive work
  - Thereby reduce the work done by each processor
  - Parallelize
  - Cognitive Offloading
- Allows to perform computtations that otherwise might exceed the capabilities of one limited processor
- Using external memory
  - Example: Calculator, Type checker

Specialization [Walenstein 2002]

- Make use of specialized cognitive abilities. These are fast, effort-free and execute at least partially in parallel, in contrast to deliberate reasoning which is slow, serial and effortful
- Example: Visual search

Formal Representation: Graphical Representation:

87876	14321
87676	13243
76587	97657
32423	43533
97667	32432
3132	32324
43211	32432
32233	10032
43212	32143
12344	76655



Cognitive Support [Walenstein 2002]

$\mathcal{R}$ task Reduction
Cmpt Principle: some functions are easier to compute
Substitution Type: substitute simpler tasks for more complicated ones
Example (cmpt): removing redundant or unused computations
Example (HCI): eliminating unnecessary steps
Design Principle: remove unnecessary work; relax task demands

$\mathcal{O}$ algorithmic Optimization
Cmpt Principle: functionally identical algorithms differ in efficiency
Substitution Type: substitute equivalent methods, ADTs, or encodings
Example (cmpt): changing to doubly-linked list; switching sorting algorithm
Example (HCI): switching to Roman numerals
Design Principle: optimize cognitive processes for task & infrastructure

$\mathcal{D}$ Distribution
Cmpt Principle: distribution adds memory or computing resources
Substitution Type: substitute external resources for internal ones
Example (cmpt): caching memory to a hard drive; client-server architecture
Example (HCI): writing down a shopping list; automating constraint checking
Design Principle: distribute (i.e., *re*distribute or *offload*) data or processing

$\mathcal{S}$ Specialization
Cmpt Principle: specialized routines or processors can be more efficient
Substitution Type: substitute specialized processors for more general ones
Example (cmpt): use a FPU or accellerated graphics card
Example (HCI): enable visual search to substitute for "manual" search
Design Principle: change representation to make use of specialized hardware

Fig. 1. Summary of RODS cognitive support classes.

Any questions?

- See you next week!