

Information Dynamics

A Fresh Look at Information
Its Properties and Implications

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What **Information** does
this picture carry ?

Has it changed recently?

















What **Information** does
this sequence carry ?

What is the basic nature
of Information?

**Only Sentient entities
handle it!**

What is Information ?

- Information is **different** from its representation !!

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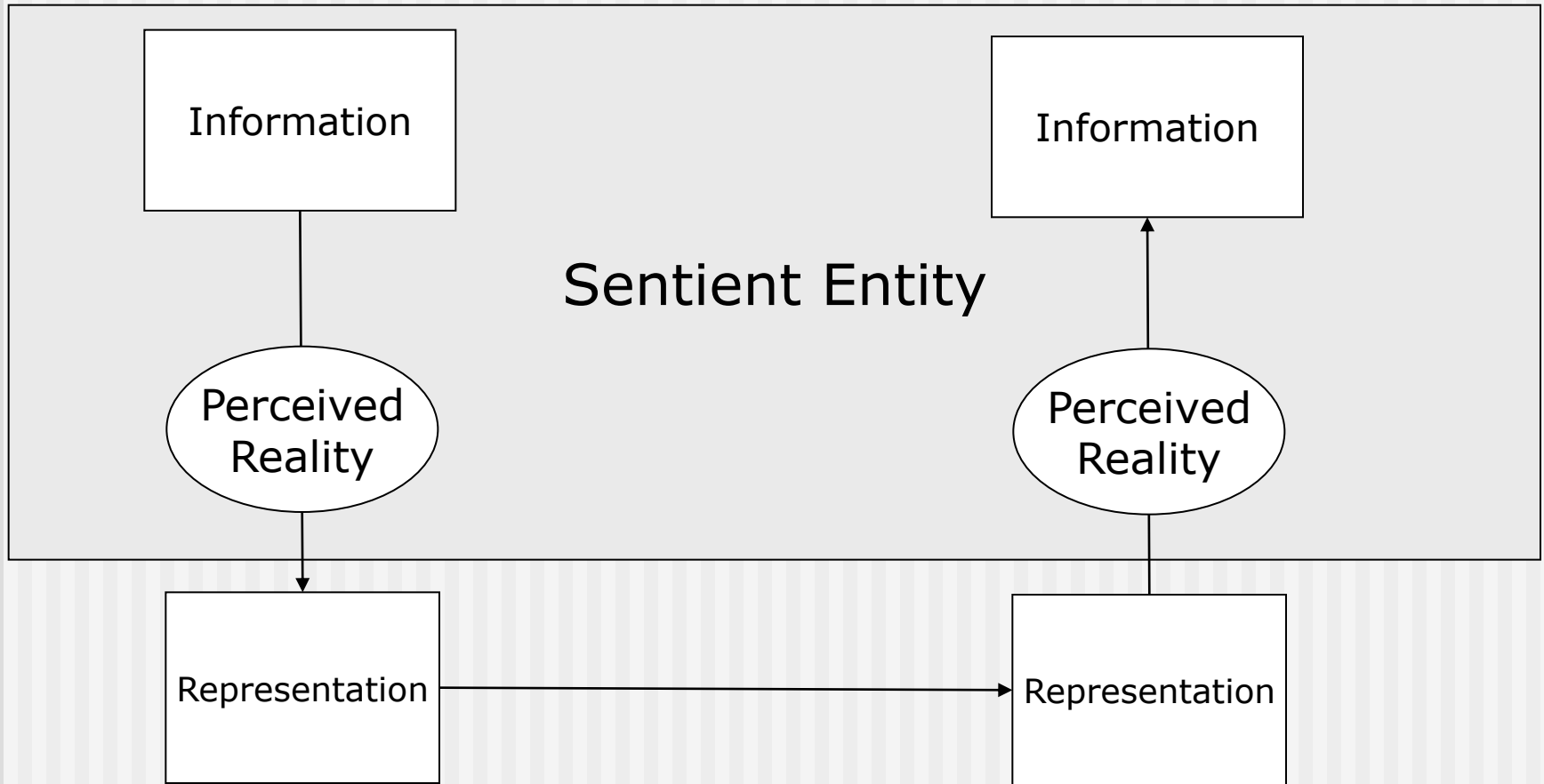
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- Can have many representations
 - Are they equivalent??

Information

- Many forms
 - Technical – Shannon
 - Everyday use
- Distinction between information and its Representation

Information and Representation



Information versus its Representation

- No one-to-one mapping
- Representation is meaningless without a relation to the appropriate **contextual** information
- Must understand the relationship of the representation to the appropriate information
- Representations are transmitted across boundaries via physical means (messaging, voices, etc.)
- All typical manipulations of information are through manipulations of its representation
- How is the mapping carried out?

Perceived Reality

- All a sentient entity knows...
 - Facts
 - Figures
 - Relationships
 - Models
 - ...
- ...about
 - The environment
 - another entity or system
 - Itself

Perceived Reality

- Any local node maintains its view of the universe and other entities in the form of *Perceived Reality*
- Perceived reality is based on
 - Prior **Model** of the Universe and Other Entities
 - Explicit information received and processed
 - Explicit information is processed to integrate it with the perceived reality
 - This integration is based on the model of the universe
 - Information may change the model
- All actions are initiated using the knowledge of the perceived reality
- *All systems have been bootstrapped with information to start its "life"*

Models

- Abstraction of an entity or a system.
- Contains properties and relationships **believed** to be true.
- One part of an entity's perceived reality is the model of another entity.
- Constantly refined by information:
 - New, Refuting, Removing, ...

Perceived Reality

- When a message is received
 - Its contents are converted into information based on the current perceived reality
 - That information is assimilated into the current perceived reality
- A message (representation) can not be converted into information unless the perceived reality contains the means for reverse mapping
 - Language – Symbols - ...

What is Information ?

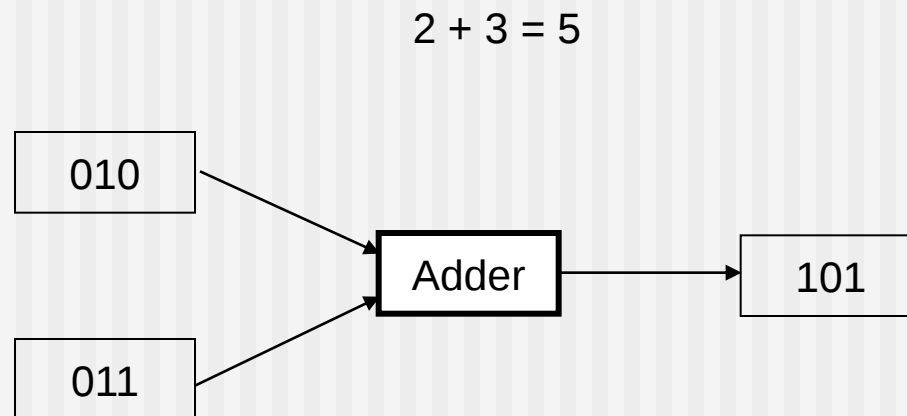
- *Information Entity*
- Information has many
 - interrelationships
 - attributes
 - properties
- Interrelationships are information also
- Such interrelationships exist whether they are enumerated/identified or not

Information and Representation

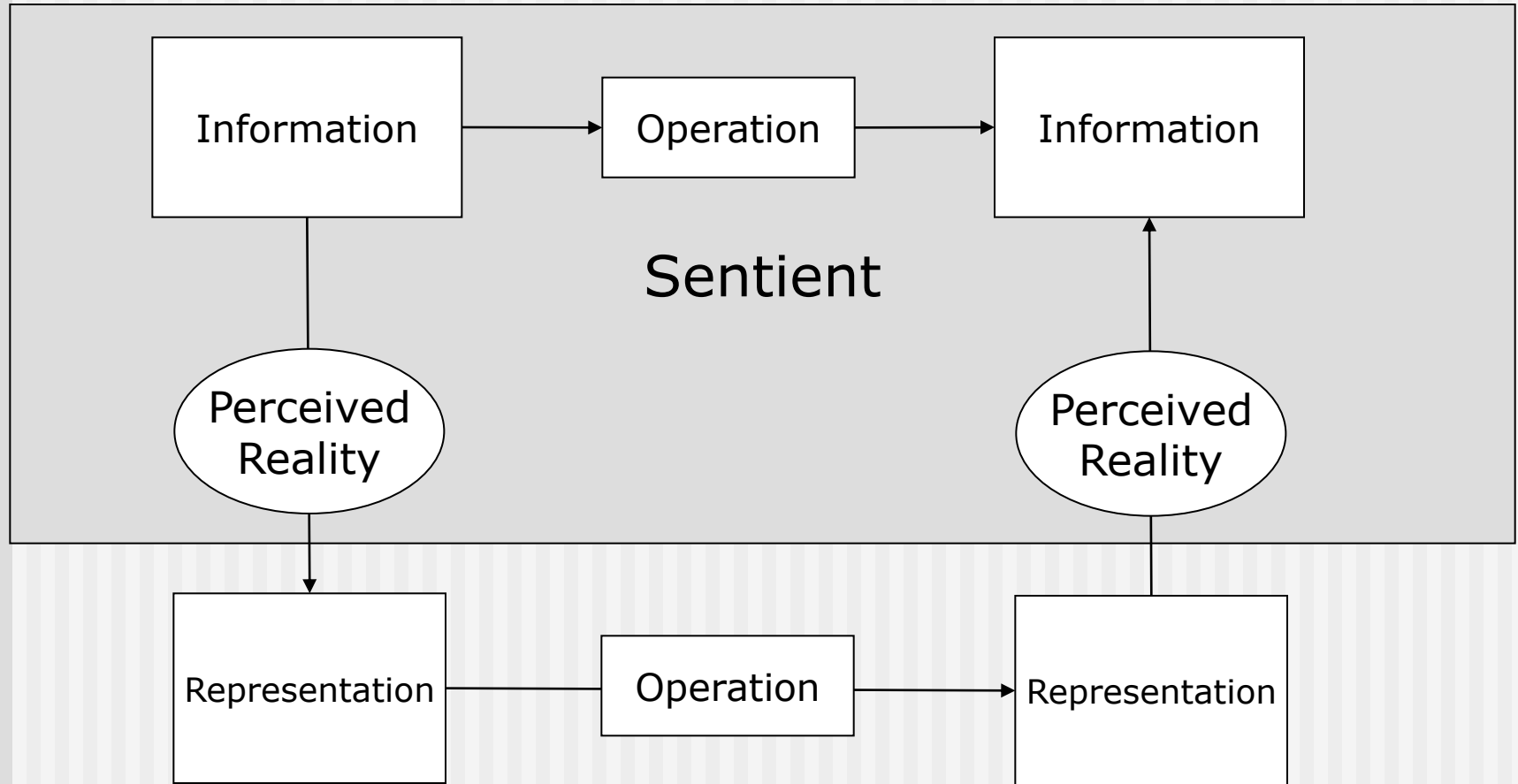
- From Information to Representation:
 - Some facts will not be retained!
 - Loss of relationships!
- Manipulation:
 - Informational
 - Representational

What is Information ?

- Information is handled by Sentient Entities
- Its representations can be handled by machines
- Machines only manipulate representations of information.



Information and Representation



What Is Information ?

- It is a property /description/characteristics of something
- That something may be another piece of information
 - An object – Physical, logical, virtual, conceptual – group
 - An action
 - A trigger
 - A relationship
- Significance of Information is its interrelationships
 - May be direct or indirect
 - Exist whether enumerated or not
 - May be static or dynamic

Typically retain only small amount of information considered relevant in any system

Nature of Information

■ Quantifiable

■ Only in the context

- Temperature in this room
 - Scale
 - Accuracy
 - Time it was recorded
 - Who took it
 - What instrument was used - precision

■ Non-quantifiable

- Most of the information we deal with is of this type

Information Representation

- Representations are essential to store, move, or process information
- Capture only some aspects/views/projections of information –
 - A good system designer carries other aspects in her head.
- Example: Data Structure
 - Contains not only representation of some quantities but also of some relationships

Information Representation

- Use – Requires associating meaning to it
 - Meaning can only be assigned in context
- Context
 - Integer between 50 and 100
 - Represents temperature in this room in degrees F.
- If both sides understand the context
 - Only need representation of integer number
- If not
 - Common understanding may be English
 - Include description along with the temperature value

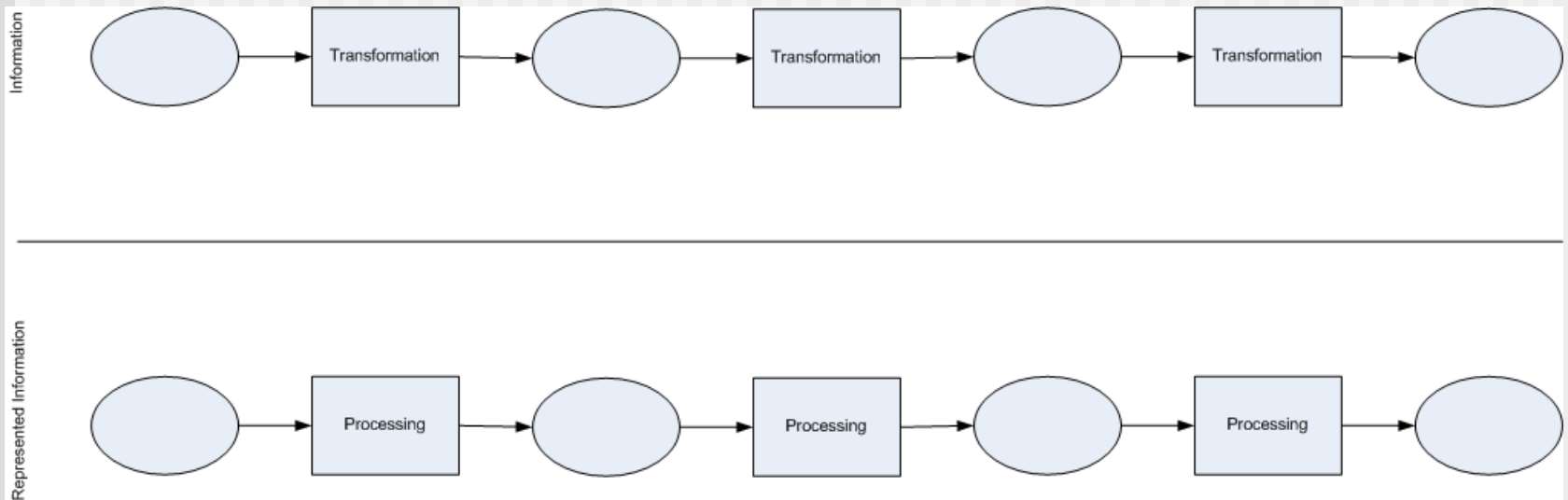
Information Representation

■ Algorithm

■ Sequence of steps

- Have common understanding of elemental steps
 - Depend on the way they are expressed
 - Machine instructions
 - Higher level language
 - Pseudocode
 - ...

Multi-step Processing



Explicit and Implicit Information

- Explicit
 - Conveyed explicitly through messages etc.
- Implicit
 - Derived from explicit and the current knowledge of its relationships - **perceived reality- models**
 - Requires **processing**
 - Spending Resources: Time and Energy
 - **Can be different for different agents !!**

Meta-Information

- Ontology
- Levels of Meta Information?

What can we do with information

Using Information requires **ACTION**

- Create/capture
- Store
- Move/Retrieve
- Use
 - To derive implicit information – making it explicit
 - To determine some other action to be taken (Choice)
 - To activate a physical operation (output)

Storage of information

- In order to store any information which is explicit we need a **representation** for it
- In order to use it as information we need to retrieve it from storage
- A representation of information suitable for storage may not retain many interrelationships.
 - On retrieving
 - some may be recalculated
 - some may be lost forever
 - In particular – information relating to **time** will be lost unless time stamping is done
- Storing/Retrieving of Information are actions

Note that any and all actions generate lot more information than can be captured

Movement of information

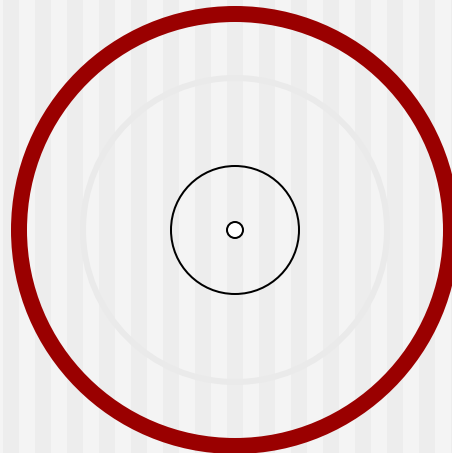
- Only explicit (represented) information can be moved from one location to the other
- Information to be moved must be in a representation which is understood
 - and can be interpreted by the sender and the receiver.
- The understanding can come from explicitly represented agreements (which in turn require conventions - **Protocols**)
- It must be storable
- Requires an action

Information movement infrastructure

- Network
 - Provides the ability to move info from location x to y
 - Who initiates the move
 - When
 - Why
- How does y know that x has some information it needs?
- How does x know that y needs that information?
- Knowledge about where what information is?
 - Search Engines !!
 - Have to know where the search engine is and how to access it.

Implications of Information Movement

- Moving information from location x to location y takes time t_{xy}
- At y we can only get information from x which is at least t_{xy} old



Information Uncertainty

Principle-1

- The perceived reality at any location **CAN NOT** be the same as the actual reality at any remote location of the global reality
 - Due to the transmission and processing delays
- It is not sufficient to receive the information
 - It must be interpreted and processed to integrate it with the current perceived reality
- Perceived reality at a location may be **consistent** with global/remote reality but can not be the **same**
- We can never have a complete model of another entity:
 - **models abstract knowledge**

Information Uncertainty Principle - 2

- Due to finite precision of measurement and representations we can never have complete and precise knowledge of any quantifiable information
- We deal with this uncertainty all the time !!!

Value of Information

- Implicit understanding of the value
- Is entity/agent specific
- Use in selecting – deciding among options for processing and taking action
- Value of information changes with time
 - Different for each agent
 - Depends on his perceived reality
 - Can not assign a fixed ordinal scale to the value

Value of Information

- Value may be captured by uncertainty models
- Example – queue length at a router
 - The knowledge of the queue length at time t may be precise
 - The knowledge at a later time given the value at t will have a variance which will increase with time
 - When we want to know the value of queue length from some other location, the information movement delay increases the variance

Information Fusion

Given Multiple observations –

- How to integrate them into one “view”
- One view may contain multiple options / likely scenarios

Capture of Information

- Two mechanisms
 - Observation –
 - Through direct or indirect observation/ monitoring/measurement
 - Processing of info – **Make implicit information explicit**
 - To enumerate interrelationships
 - To make deductions
 - To make inductions
 - Using models
- Example: Mathematics
 - A set of interrelationships with a description of when they apply
 - A framework for deductions and inductions to add to the information base
 - Analytical Results => defined interrelationships and descriptions of applicability

Action

- Physical Action
 - Results in physical manipulation
 - Non- Physical
 - Thinking
 - Exploring inter-relationships
 - Processing within a computer
- All Actions take **time** and consume **energy**
 - Begins with an information **trigger!**
 - Usually done with respect to an event.

Action

- Requires Processing
- Starts under the control of “Trigger”
- Needs
 - Processor
 - Possibly other resources
 - For some time
 - At a location
 - Information as input
- Outcome
 - Additional Information
 - Explicit from Implicit
 - Trigger(s)
 - Storage
 - Movement
 - Physical results
 - Commands to actuators

Three Levels

- Information
- Represented Information
- Physical

Types of Actions

- Make implicit information explicit
- Carry out interpretation/storage/movement of information
- Carry out a physical action by issuing a command to a physical processor
- Transform some information into some trigger which is used to control some later action

Trigger

- Required for carrying out an action at a particular time/under some conditions
- Defines
 - What action, where, using what resources, at what time or under what conditions (priority, precedence etc.)
- Based on information/location/time/value
- Requires processing to convert information into a Trigger
- When relationships are fixed – hardwired design – Design time Trigger
- When relationships are dynamic trigger has to reflect it

Large Complex System

- A collection of N entities capable of carrying out certain operations
- Has a mission
- Physical resources which can carry out the actions
 - At various locations
- Mechanism for moving information (communication)
- Design Carried out at Information Level

Coordination: A Distributed System

- **Information-centric view**
- Many interacting autonomous agents
 - Who needs what information at what time
 - Why
 - How will he use it
 - Who has that information at what time
 - How to get the right information at the right place at the right time
- Most algorithms – mechanisms for such movement of information with respect to elemental processing capabilities assumed

Role of Time

- Do we need a global/universal clock?
- What type of time is appropriate for Information Dynamics?
 - Absolute Time with a Counter (though it has a value relative to a starting point)
 - Relative Time through Causality

Consistency

- How can coordination take place without consistency of models each entity has from one another?
- Models between communicating entities must be consistent and accurate enough
- Who has the responsibility to fix broken models?
- Do models follow a set of rules?
 - Logically, relationally, or operationally.

Awareness

- In order for entity A to be aware of entity B, entity A must have a model of entity B.
- Entity B need not have a model of entity A.
- Being aware does not mean having complete knowledge of another.

Levels of Abstraction

- Any massively complex system has to be viewed at an appropriate level of complexity
 - Information with **right** degree of detail
 - Only relationships of **interest** and their connections of interest are retained

Planning

- Requires knowledge about future
 - Using Models
 - Estimates
 - Accuracy
 - Confidence
- Knowledge of Dynamics
 - Expected changes over time

Example – Mutual Exclusion Problem

- N Agents - Cooperative
- Any agent can enter its CS if nobody else is in its CS
- Check if anybody is in its CS
 - If not – enter
 - If yes – wait and try again
- Each action takes time
 - State of agents can change in that time

Entry

CS

Exit

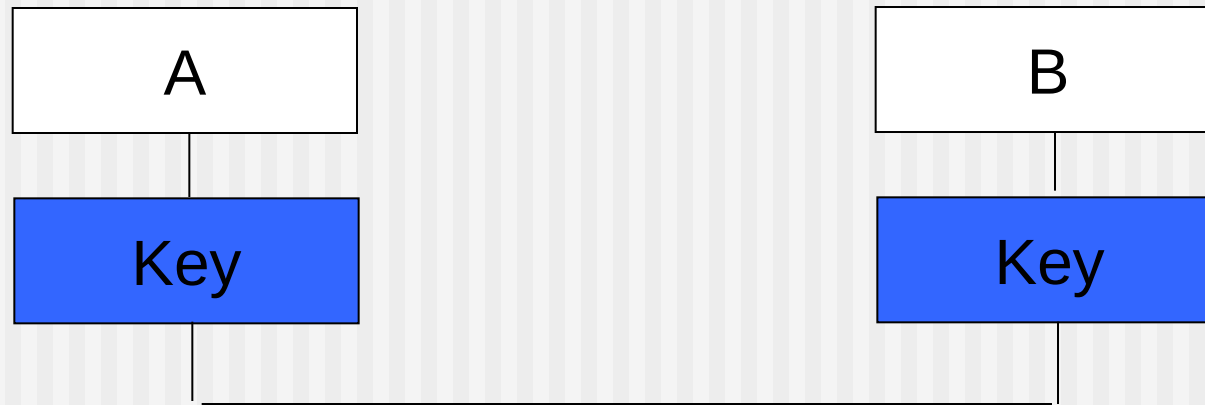
Non – CS

LOOP

Mutual Exclusion Problem

- How to know the state of all other agents
 - Shared memory model
 - Distributed –
 - through messages
- Shared Memory Model
 - Set up a mechanism for sharing of state information
 - Semaphore
 - Delay
 - Atomic action
 - Define checking mechanism
- Distributed
 - Messages
- Algorithms vary in terms of the implications of messages and their meaning
- Simplest – Ask everybody for permission and enter when received from everybody
- How to process a permission request?

Example - Security



- Key – part of “perceived reality”
- How does B know which key to use?
- Public Key encryption

Example – Link State Routing

- Each node measures delays
- Periodically send the measured delay to every other node
- Determine route as the minimum delay path from source to destination
- Need delay when packet gets there not what it was
- Estimate of future delay rapidly moves towards the steady state values
- IF Steady State values are known
 - Reduce communication
 - Improve routing
- Demonstrated through implementation/simulation

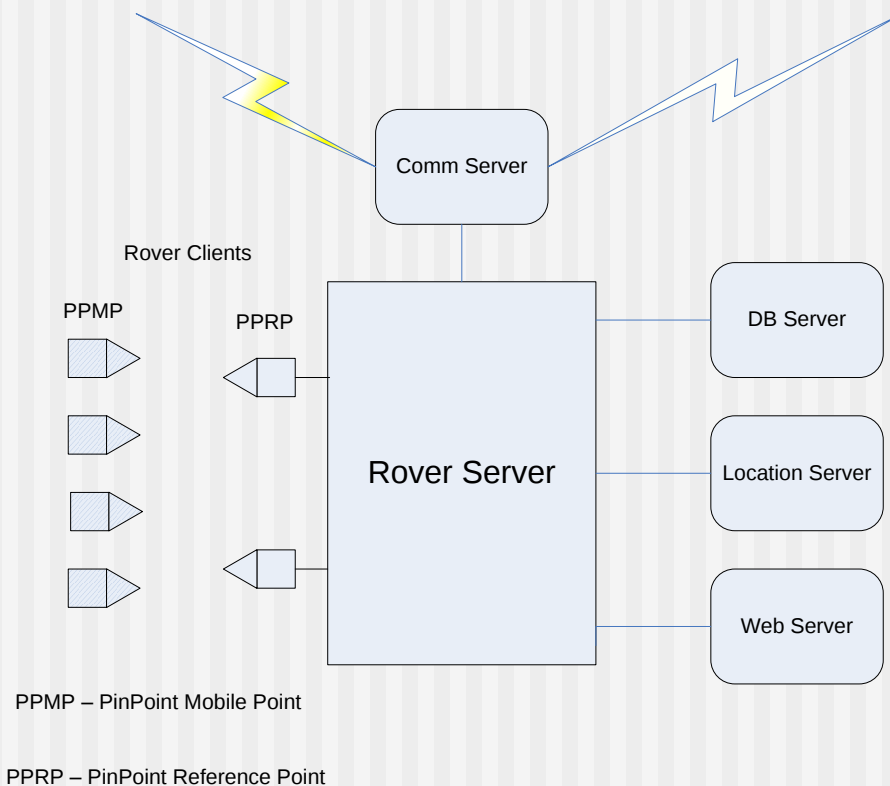
Information-centric Design

- Having right information at the right place at the right time
- Explicitly take into account the time dependent aspect of information
- Explicitly take into account the value of information
- Explicitly take into account implicit information
- Organize/design system based on the dynamics of information requirements

Rover Technology

- Context-aware computing platform
 - Location
 - Time
- Self-describing Information Representations
- Services/actions depend on context

Rover Technology



Rover Technology

- Designed to address issues in
 - Enterprise Applications
 - Command and Control Applications
 - Pervasive Computing
 - Sensor Networks
 - ...

Rover Network Diagram



UMD Wireless Network
AV Williams Building, 3rd and 4th Floors
Unit 1
Unit 2

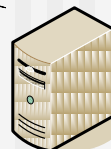
Units inform their position, performs tagging operations, and utilizes other services.



Watcher 1

MINDLab Network
8400 Baltimore Avenue
Watcher 1

Listens for position activity, performs tagging operations, and utilizes other services.

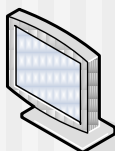


Server

UMD/CS Unsupported Public Network
AV Williams Building, Room 4160

Mitigates Rover Services Between
Rover Clients Including:

User Position Notification
Map Tagging
Text Chat
Internet Services



Watcher 2

UMD/CS Unsupported Private Network
AV Williams Building, Room 4160
Watcher 2

Listens for position activity, performs tagging operations, and utilizes other services.



The Internet

Rover Server accesses internet services as a proxy for Rover Clients, with Services including (with support for caching):

Yahoo! News and Web Searches via REST
Yahoo! Weather RSS Feeds

Uses of Information Dynamics

- Framework for
 - Approaching system designs
 - System Analysis
 - Given a design determine
 - All Information Dynamics – Explicit and Implicit
 - Decision Structure
 - Actions
 - System Synthesis
 - Outcome required
 - Processing/Action needed
 - Information needed

Questions???



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The Maryland Information and Network Dynamics Lab