System Architecture
Tutorial on Object Process Modeling

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Outline

- Objects, processes and their links
- Objects and their links
- Processes
A Tutorial: Object-Process Methodology (OPM)

- OPM is a system development methodology that integrates many system attributes in one model
- In particular, explicitly represents objects, processes and their links
- Gives us a framework for rigorous qualitative system thinking, and perhaps quantitative modeling and analysis
- Developed by Dr. Dov Dori, modified for System Architecture
- A way to think, not the way to think
The world is composed of things (physical/informational) which consist of objects and processes
Objects

- Defined: An **object** is that which has the potential of stable, unconditional existence for some positive duration of time
- Can be physical: visible or tangible and stable in form
- Can be informational: anything that can be apprehended intellectually
- Objects have states (which can be changed by processes)
- Objects are linked to nouns
Processes

- Defined: A **process** is the pattern of transformation applied to one or more objects
- Cannot hold or touch a process - it is fleeting
- Generally creation, change, or destruction
- A process relies on at least one object in the pre-process set
- A process transforms at least one object in the pre-process set
- A process takes place along a time line
- A process is associated with a verb
Object and its States

- **State** is a situation at which the object can exist for some positive duration of time (and implicitly can change).
- Processes change the state of a particular object(s), the operand(s)
- For simple objects, the state can be represented by a rounded rectangle within the rectangle representing the object

Examples:
- When thinking about transportation, a person:
  - Person
    - Here
    - There

- When thinking about heating, a home
  - Home
    - Cold
    - Warm

- When thinking about assigning, an array
  - Array
    - Unsorted
    - Sorted
Thought Exercise

- Look at things and decide if they are objects or processes - have states or change states
Process and its Links

- A process is associated with a verb and stateless
- There are a family of about 5 types of links from process to object
- A process changes the states of its operand(s) through input and output links

*Transporting changes a person from here to there*
Effect Links

- The input, output and states can be suppressed for simplification to an effect link

Transporting affects person
Consumption and Result Links

- Special cases of input and output links are consumption and result
- Consumption links connects a process with an object which is consumed
  - A whole and its parts
- Result link connects a process with an object which results

Transporting consumes energy

Transporting yields entropy
Enablers

- Defined: Enablers of a process is an object that must be present for that process to occur, but does not change as a result of the occurrence of the process.

- Defined: Agent is an intelligent enabler
  - A human or organization of humans
  - Autonomous devices (animals, real-time computing services)

- Defined: Instruments is a non-agent enabler

Transporting requires skateboard

Skateboard is handled by operator
Conditional Link

- Defined: Conditions are state that must be achieved before a process will execute

- Could be agent or instrument

\[
\begin{align*}
\text{Money} & \quad \text{Enough} \\
\text{None} & \quad \text{Purchasing}
\end{align*}
\]

*Purchasing occurs if Money is enough*
Invocation Links

- While almost all process produce outputs that lead to other processes (i.e. there is an object between processes), sometimes it is more convenient to represent a direct causal link from one process to another.
- This is called an invocation link.
- Can occur between physical processes (skidding invokes spinning) or informational (if command invokes contained instructions).

Sometimes a double headed arrow
OPM Process Links

- P changes O (from state A to B).
- P affects O
- P yields or creates O
- P consumes or destroys O
- O is an agent of P (agent)
- O is an instrument of P
- P occurs if O is in state A
- P1 invokes P2 directly
Forks in Object Process Links

- If two links leave from different point on a process, it implies that both paths occur.
- If two links leave from the same path on the process oval, it implies an exclusive or, one or the other path occurs.
- Similarly for inputs and instruments of processes.
OPM of a Whole Product System (Mechanical - Skateboard)

- OPM Def: The whole system is the array of objects necessary to deliver the externally delivered process to the operand(s).
OPM of an Information System (Bubble Sort)
OPM of a Fundamental Physical Process

Generally, in detailed technical systems, equations represent processes, and variable represent the state of the objects.
OPM of a Social System

Decision

Goals

Values

Information

Leader

Participants

No product

unmade

made
Defined: A structural link is the symbol that represents a binary relationship between two objects.

There is also a backward direction relation.

Usually it is only necessary to show one, and the other is implicit.
Structural Link Examples

- Chair → Table: Is under
- Data → Array: Is stored in \( n \)
- Disk → Blades: contacts 25
- Wheels → Axel: are bolted to
- Capacitor → Resistor: Is connected to

Spatial (under)
Topological (within)
Topological (touching)
Implementation
Implementation
Forks

- Some times there are two or more structural links with the same label, and one common end point

- Can be replaced with a Fork
Logical/Relational Structural Links
Decomposition

- These 4 are a set of very commonly used logical/relational links, and therefore have special symbols.
- Decomposition/Aggregation
  - A whole and its parts

```
Skateboard
  └── Deck
  └── Suspension Assembly
      ├── 2
      └── Wheel Assembly
  └── Wheel Assembly
      └── 4

A
  └── B

A
decomposes to

B
aggregates to
```
Characterization

- Characterization/Exhibition
  - The relation between an object and its features or attributes
  - Some attributes are states (which ones?)
State

- Defined: **State** is a situation in which the object can exist for some positive duration of time.
- The combination of all the states describes the possible configuration of the system throughout the operational time.
- The states can be shown with the object, or alternatively within an attribute object.
Specialization

- Specialization/Generalization
  - The relationship between a general object and its specialized forms
Instantiation

- The relationship between a class of things and instances of the class
Relational Structural Links- Summary

- Logical/Relational links

  - “Is a”, is the same as

  - A code, surrogate, address of symbol for

  - Decomposes to, aggregates to

  - Is characterized by, exhibits

  - Specializes to, generalizes to

  - Instantiated to, belongs to the class of
Summary- OPM Objects

- An object is that which has the potential stable circumstantial existence for some period
- An object has states, which can change
- An object can be linked to another object
- Objects are often linked to other objects special by logical/relational links:
  - Equivalence,
  - Decomposition,
  - Characterization,
  - Specialization and
  - Instantiation
Processes

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Zooming

- Process zooms into sub-processes

Process zooms to sub-process #1 and sub-process #2
Process emerges from sub-process #1 and sub-process #2
Object-process arrows can move to sub-processes
Sub-process #1 invokes Sub-process #2 (a rarely used symbol that suppresses the intermediate object between processes)
Emergence

- A process can be zoomed into sub-processes
- A process **emerges** from sub-processes
- The process and sub-processes are not linked in any explicit manner, as the object decomposes into parts
- Emergence is a powerful feature of systems - parts and sub-processes can come together to cause a process to emerge
- Emergence sometimes yields the anticipated processes, sometimes *does not* yield the anticipated process and sometimes *unanticipated* processes
Some OPM Process Notes

- When a process is zoomed, affect, instrument and agent links move from the boundary of the process to the boundary of the sub-process they are actually connected to (it could be more than one sub-process).

- If one sub-process is followed by a second without any explicit object between, the invocation link is used (only from process to process).

- In reverse engineering, objects may “dangle”. This indicates all functions have not yet been identified.

- Sometimes it is more convenient in an OPM to use the decomposition symbol rather than the zooming “Venn diagram” but if you do so, remember that this is just a convenience - processes don’t decompose in any linear manner.
Objects and Processes in Natural Language

- Objects are nouns: subjects (agents and instruments) and predicates (operands)
- Processes are verbs
- All human languages are in one of two patterns: NNV or NVN
- Read down for passive voice, up for active

Engineers tend to focus on product/systems objects, and neglect the associated processes and operands, and hence the link to value
Summary - OPM

- OPM is *a* means (not *the* means) of representing systems. It is conceptually able to represent a wide range of system nature and complexity.
- OPM represents in one graphical model the objects, the processes and their interrelationships.
- Objects sum to form, and have interrelationships - structure.
- Processes, together with operand objects, yield function, and have interrelationships - emergence.
- Objects are related to processes through a small number of types of links.