Possibilities and limitations of formal methods for business process analysis and design

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Outline

- **Preliminaries**
  - Background Information
- **Formal Methods**
  - Introductory Notes
- **Ψ-Theory Introduction**
  - Managing complexity
- **Conceptualization**
  - Capturing business processes
- **Conclusion**

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Enterprise Engineering

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Preliminaries

- **Enterprise Engineering Institute**
- **Enterprise engineering community**
  - Many universities and HSE
- **Conference/Publications/Prof Organization:**
  - Enterprise Engineering Working Conference
  - International Workshop on **E**nterprise & **O**rganizational **M**odeling **A**nd **S**imulation (EOMAS) http://www.EOMAS.org
  - LNBIP series – advances in EE
  - Dietz, J.… Babkin, E.…Barjis, J., … (2013). The discipline of enterprise engineering. Int. J. Organisational Design and Engineering, Vol. 3, No.
  - CIAO! Network: http://ciaonetwork.org
  - Special Interest Group on Modeling And Simulation: http://www.AIS-SIGMAS.org

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Preliminaries…

The mission of Enterprise Engineering

The mission of the discipline of Enterprise Engineering is to combine (relevant parts from) the traditional organizational sciences, information systems sciences, and systems engineering, and to develop emerging theories and associated methodologies for the analysis, design, engineering, and implementation of future enterprises.

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Enterprise Engineering Discipline

- **Several fundamental notions (sub-disciplines) have already emerged, and seem to be indispensable for accomplishing this mission:**
  - Enterprise Ontology
  - Enterprise Architecture
  - Enterprise Governance

- **Today, we focus on Enterprise Ontology based on a formal theory – Ψ Theory**

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Formal Methods

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Formal Methods: General

- **Formal methods are mathematically based techniques for analysis, specification, verification of systems**
- **Application of formal methods is motivated by the expectation that performing appropriate mathematical analysis can contribute to the reliability and robustness of a design**
  - Railway engineering and aerospace engineering widely used methods
  - Followed by software engineering and hardware engineering
  - Now, we explore their application in business processes

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Formal Methods: Business Processes

- **Compare and contrast**
  - design and redesign alternatives in search of optimal solution
- **Business process transformation**
  - (change) implies a complex optimization based on input output entities of resources, cost, production time, quality, efficiency
- **Effects of change**
  - For knowing beforehand whether the effect of a change is positive or negative and how it impacts each entity (cost, time, quality,…) we use formal methods to get reliable estimates

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Formal Methods: Business Processes…

- **Qualitative and quantitative techniques - two different categories of formal analysis techniques**
- **Qualitative techniques – investigate if design meets a specific property**
  - Authorized access to patients medical records
- **Quantitative techniques – calculate size of a specific property**
  - Patients waiting time before service and during service

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Formal Methods: Quantitative Techniques

- **Simulation - an approximation technique**
  - E.g.: on arrival of a patient, the model allocates a free resource or entity waits based on the specified interaction of the model components
- **Analytical techniques – exact technique**
  - E.g.: patient flow modeled as a network of nodes connected to each other by arcs, expressing precedence relations to find the shortest path from arrival to service delivery can be calculated
  - Formalisms and mathematical theories: Process calculi, CSP, π-calculus, Petri nets, GERT, queuing theory, Markov chains, CPM, PERT…

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Formal Methods: Quantitative Techniques…

- **Complexity of business processes may necessitate simulation as the only feasible means of analysis**
- **If synchronization structures within a process and behavior of resources is too complex, no known general analytical techniques are available to determine the throughput patterns of a process**
- **Simulation is a flexible technique suited to investigate almost any type of business process**
- **Requires efforts to model, set experiments (many lengthy simulation runs) to obtain reliable results**

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Formal Methods: Summary

- **Benefits:**
  - Automatic model transformation, automatic execution, automatic code generation, formal verification
- **Downsides:**
  - Expressiveness
    - Rich informal world to be translated it into formal - expressivity is low
  - Communication
    - Model is communication medium for knowledge sharing and understanding
  - Steep learning curve
    - Non-technical users (managers), easy to learn UML but not PN
  - Conceptualization

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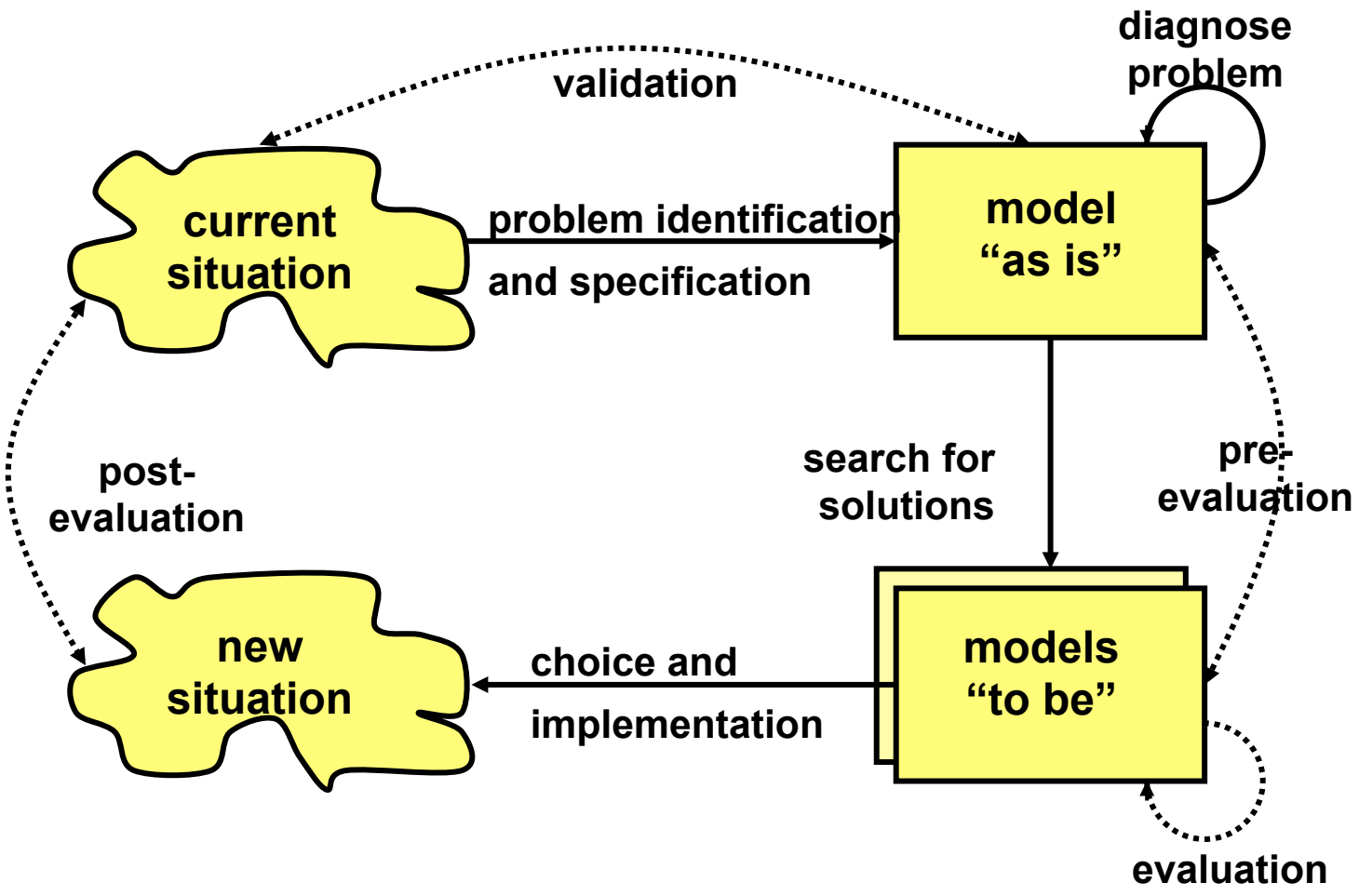
Using Models For Problem Solving



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Ψ-Theory

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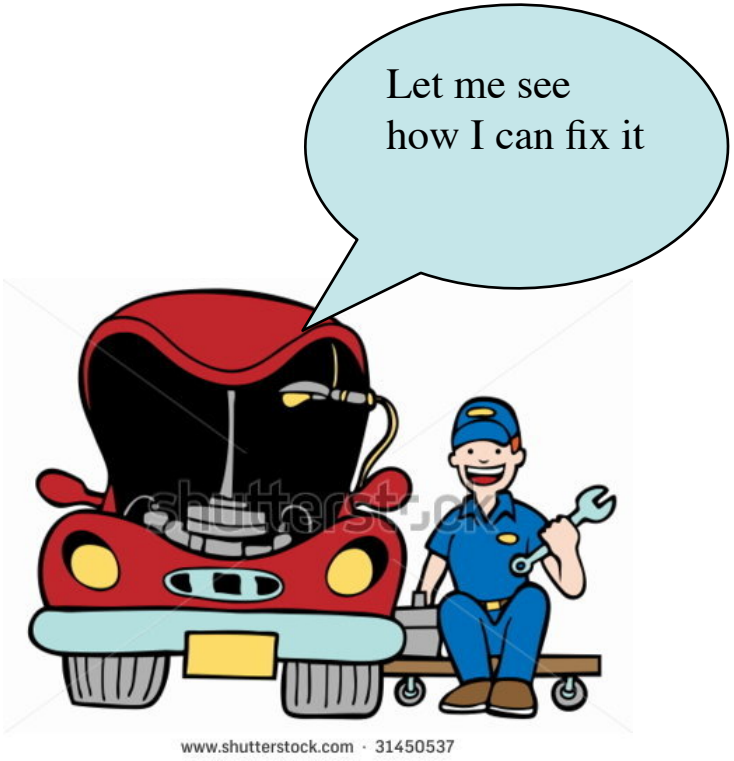
Functional vs Constructional Thinking



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Ψ-Theory

- **EO is concerned with the study of the operation of an enterprise and its construction**
- **The theory underlying EO is Ψ-Theory or PSI (Performance in Social Interaction)**
  - Roots in communicative acts; language-action perspective; speech act theory
- **This theory consists of:**
  - Organization theorem
  - Distinction axiom
  - Transaction axiom
  - Operation axiom
  - Decomposition axiom

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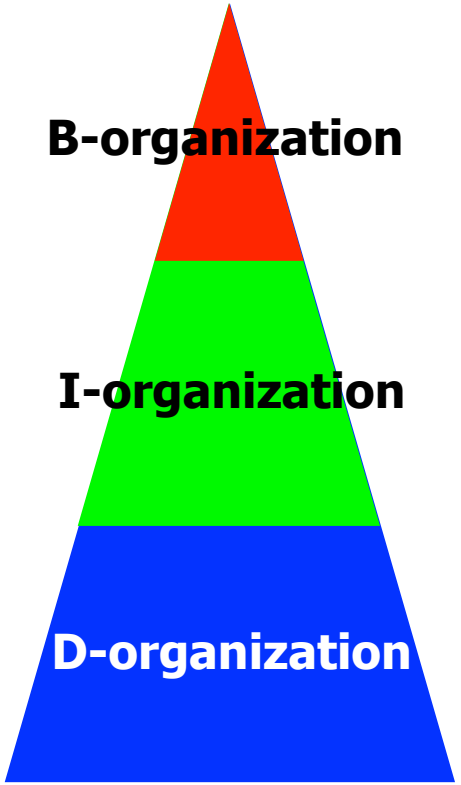
Ψ-Theory: Organization Theorem

❖ **The organization of every enterprise can be conceived as a layered nesting of three parts, called *aspect organizations*:**

- **B-organization** ("B" from business), the *business* actions take place.
  - It consists of **B-actors** and **B-transactions**.
- **I-organization** ("I" from information and intellect) supporting *infological* actions take place.
- **D-organization** ("D" from data and document) supporting *datalogical* actions take place.
  - The **integration** of the three aspect organizations is established through the **unity** of the human actor (subject).



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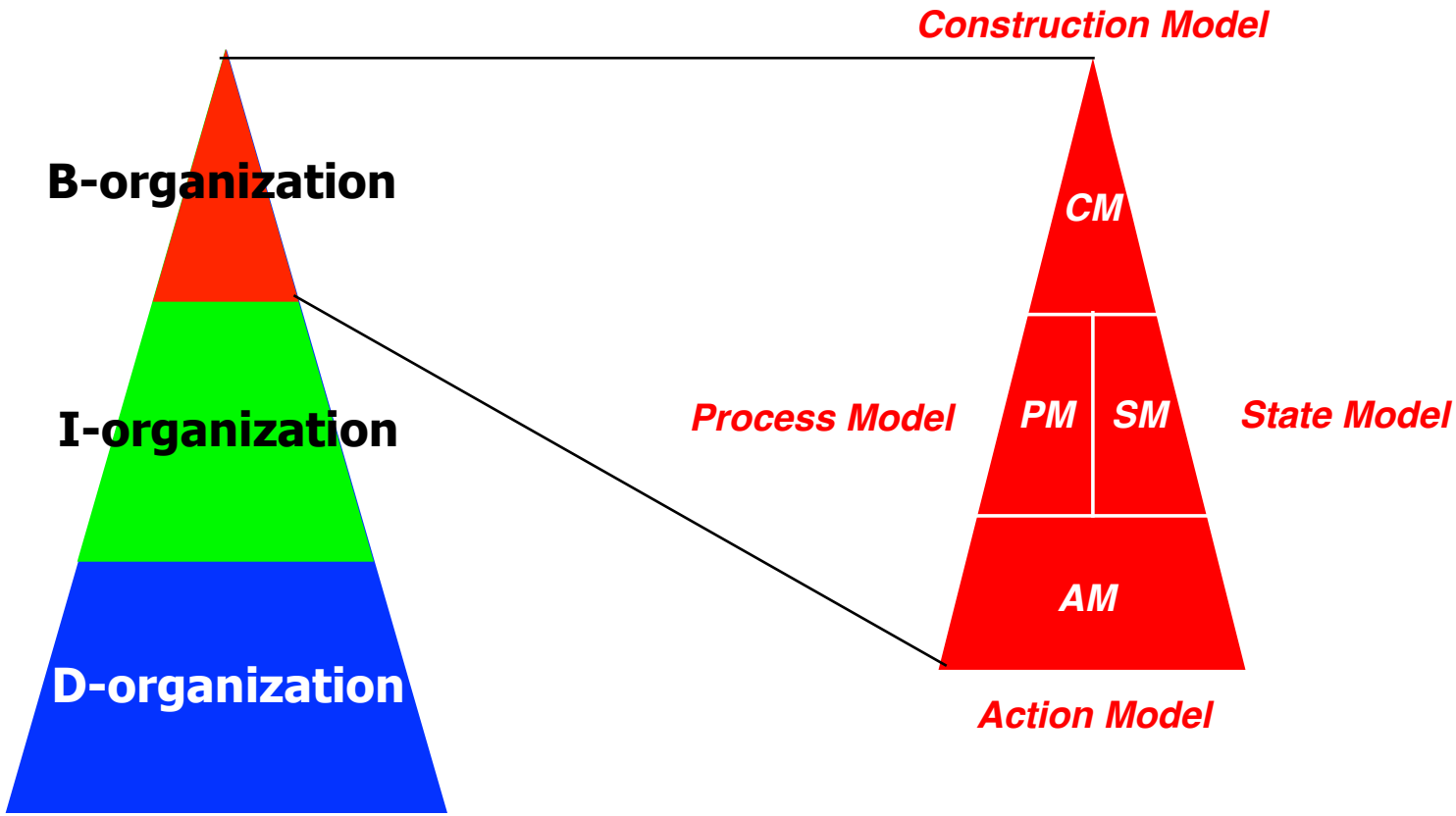
Ontological Aspect Models



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Ψ-Theory: Distinction Axiom

- **Actions in organizations can be classified as either datalogical, infological, or ontological**

- **Furthermore, distinction is made between production acts and coordination acts**

Ψ-Theory: Distinction Axiom…

- **A datalogical production act is an act in which one manipulates the form of information, commonly referred to as data, so without being concerned about its content**
- **Acts like copying, storing, and transmitting data are typical datalogical production acts**
  - E.g., the act of recording a student application for enrollment in the system is considered to be a datalogical act
  - speaking, listening, writing, and reading are typical datalogical coordination acts

Ψ-Theory: Distinction Axiom…

- **An infological production act is an act which is not concerned about the form but, instead, about the content of information only**
- **Typical infological acts are inquiring, calculating, and reasoning**
  - E.g., calculating student GPA is considered an infological act
  - Regarding the coordination between people, formulating thoughts (in written or spoken sentences) and interpreting perceived (through listening or reading) sentences are typical infological coordination acts

Ψ-Theory: Distinction Axiom…

- **An ontological act is an act in which new original things are brought about**
- **Deciding and judging are typical ontological production acts.**
  - E.g., deciding about enrollment in college is an ontological act
  - Regarding the coordination between people, typical ontological acts are requesting and promising
- **Coordination acts appear to occur in a particular pattern, called the transaction**

Ψ-Theory: Transaction Axiom

- **Ψ-Theory: a social individual is capable of two kinds of acts:**
  - C-Act: coordination act
    - Coordinate, negotiate, commit
  - P-Act: production act
    - Produce goods or service, judge, decide
- **C-Act and P-Act appear in a generic pattern called Ontological Transaction**

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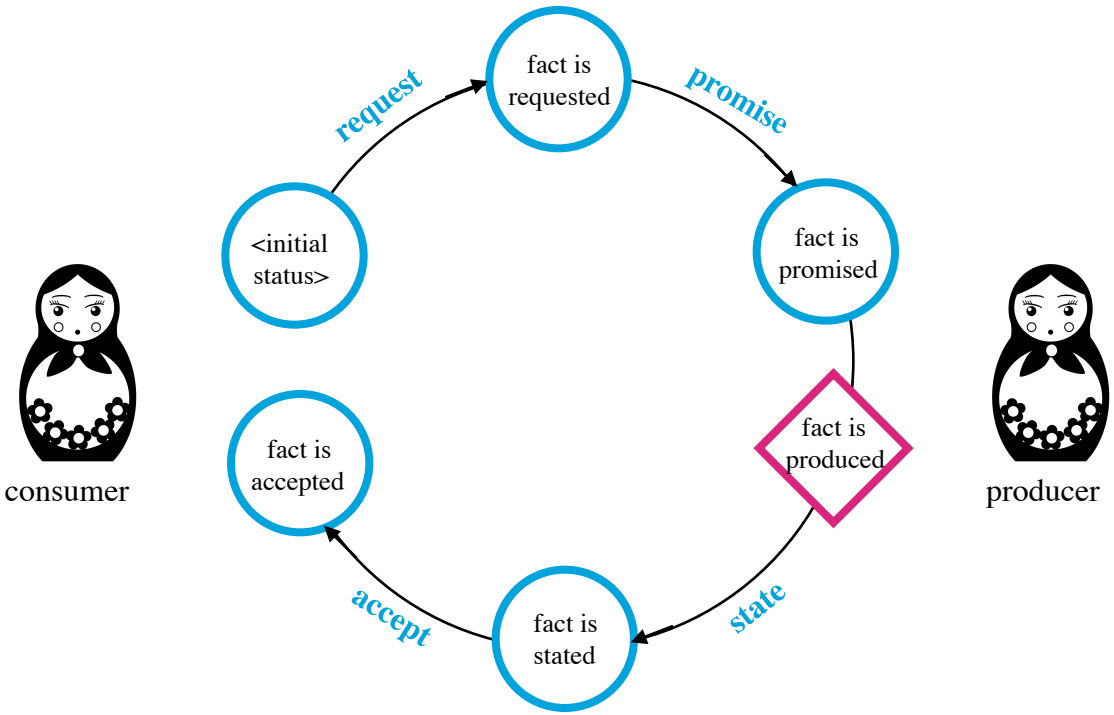
Basic transaction pattern (happy path)

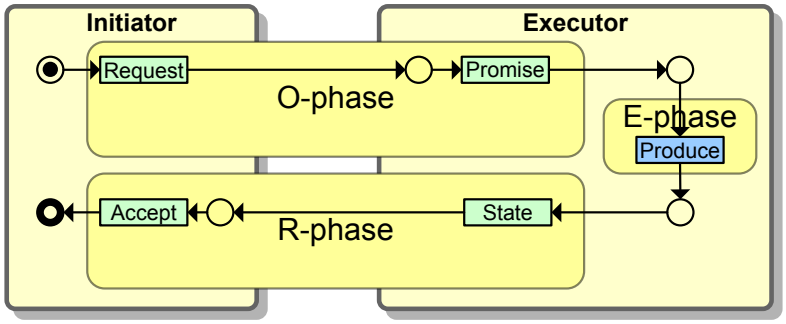


Ψ-Theory: Transaction Axiom…

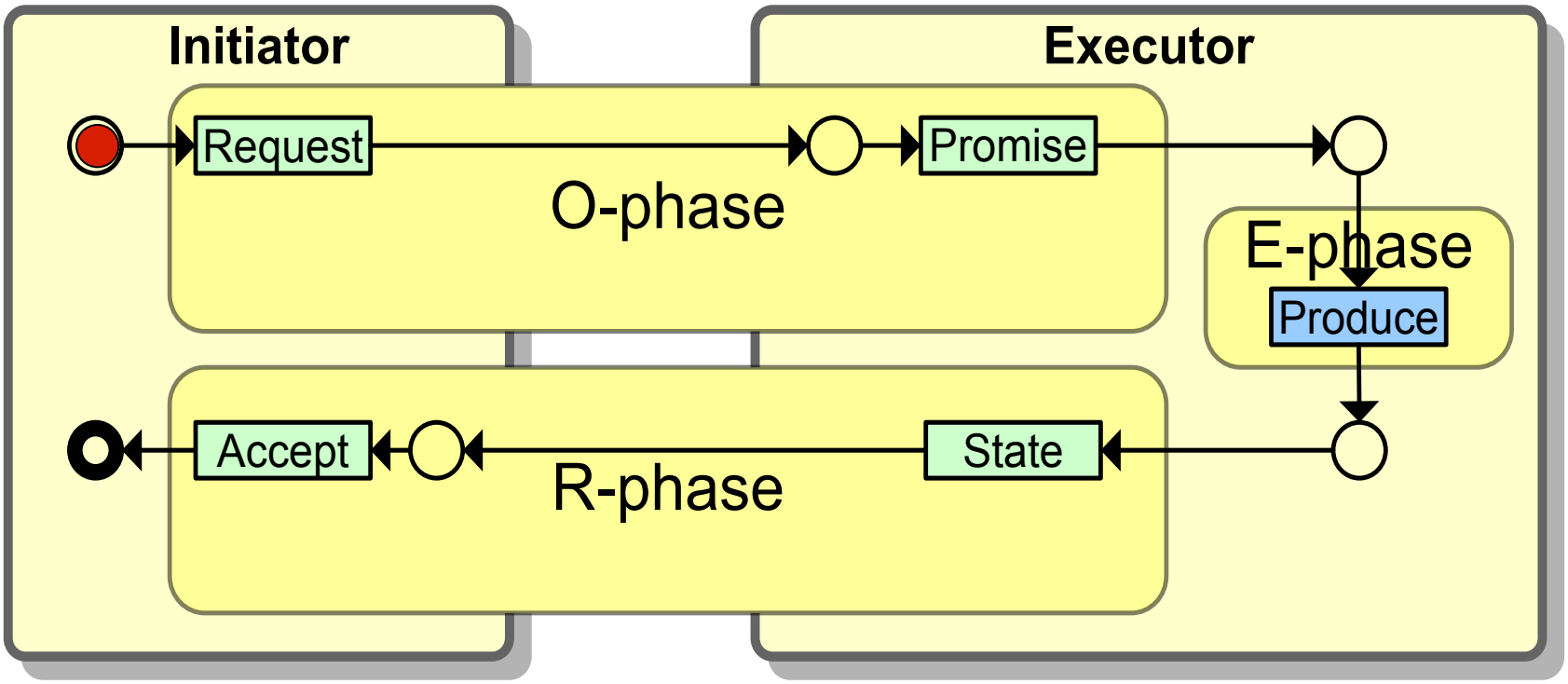
- **Examples of coordination acts (C-Acts):**
  - A surgeon requests a scheduler for an OR scheduling
  - An admission nurse promises to patient admission to hospital
  - A technician states to patient the results of lab works
- **Examples of production acts (P-Acts):**
  - The scheduler schedules an OR
  - The nurse admits the patient to the hospital
  - The technician conducts lab analysis of the patient
- **Ontological Transaction (C-Acts+P-Act):**
  - Scheduling an operating room
  - Admitting to a hospital
  - Conducting lab analysis

Ψ-Theory: Transaction Axiom…

- **Ontological transaction – an atomic process involving two actor roles**
  - Initiator and Executor
- **It consists of three phases:**
  - Order phase (O)
    - an actor makes a ‘request’ towards another actor, the other actor makes a commitment
  - Execution phase (E)
    - the other actor fulfills its commitment
  - Result phase (R)
    - the other actor does ‘present’ the result to the first actor



Ψ-Theory: Transaction Axiom…



Ontological Transaction

- **An ontological transaction is a generic pattern of coordination and production acts, carried out by two actor-roles, that create an original fact (result) in the process of three phases: order phase, execution phase, and result phase**

Transaction (e.g., T01)	Activity (e.g., designing a new product)
Initiator	Name of the role that initiates the transaction (e.g., *customer)*
Executor	Name of the role that executes the transaction (e.g., *designer)*
Result	The result created as the transaction is carried out (e.g., *a new product is designed)*

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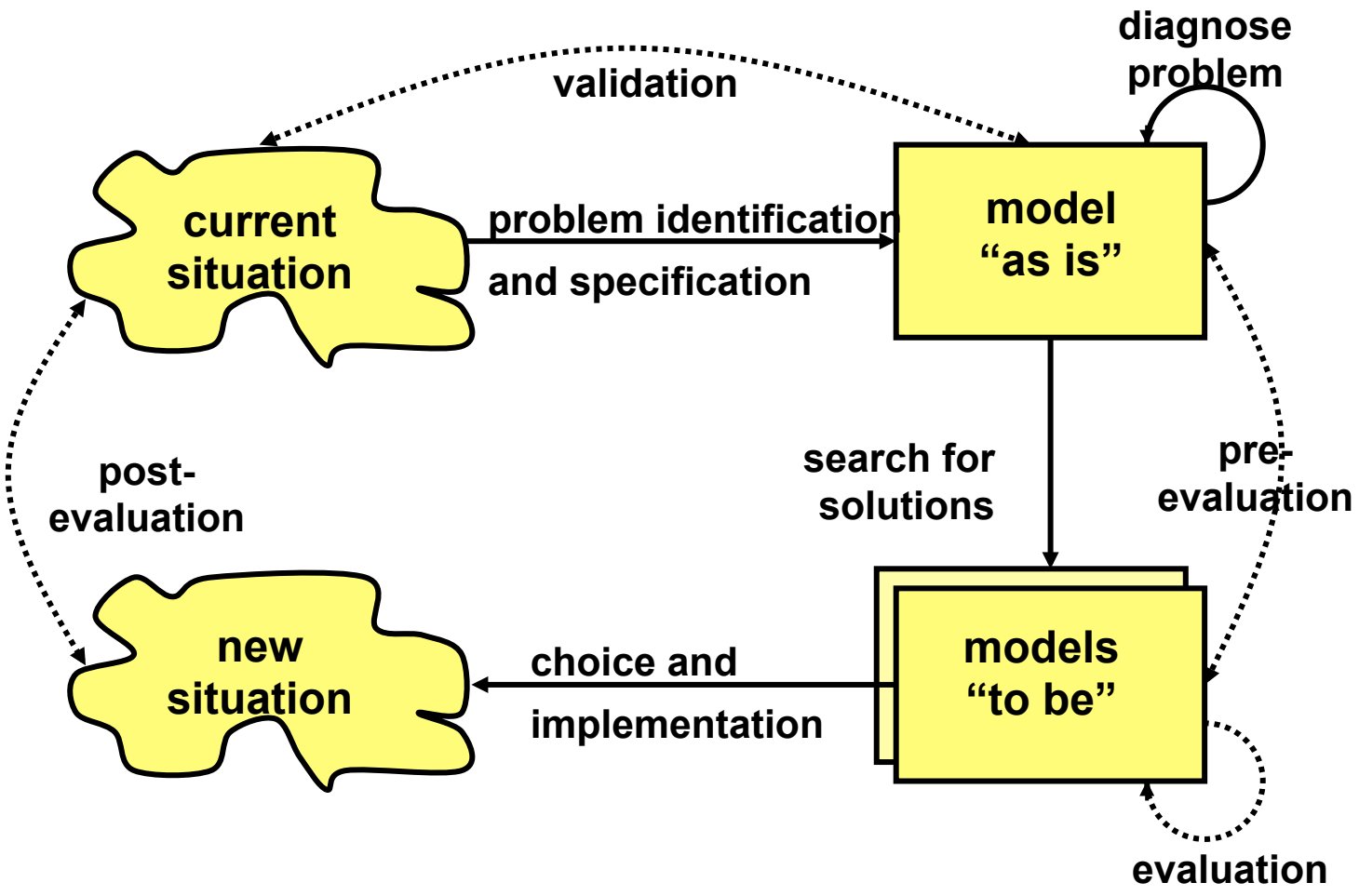
Using Models For Problem Solving



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Conceptualization

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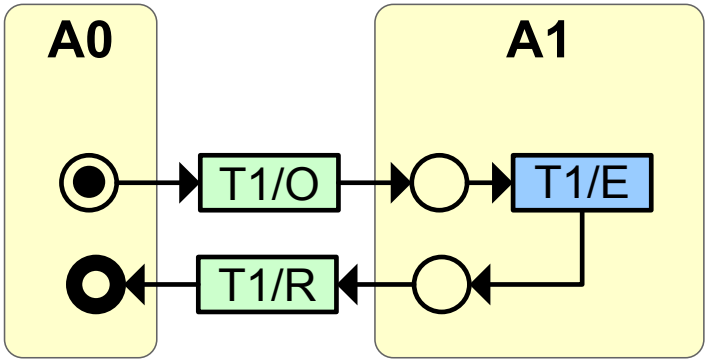
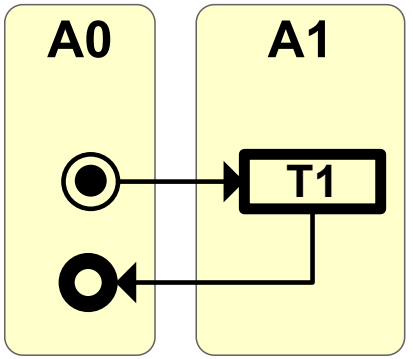
Modeling Constructs

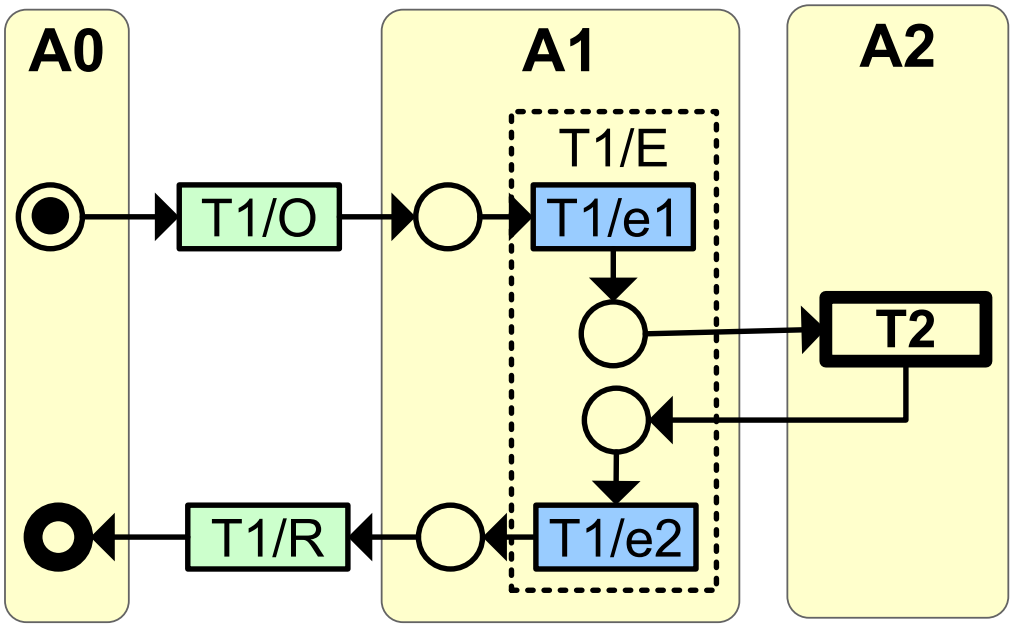
- **The following slides introduce you to a series of modeling constructs (mini-models) using:**
  - Ontological Transaction concept
  - Using Petri Net notations

Atomic (simple) Process

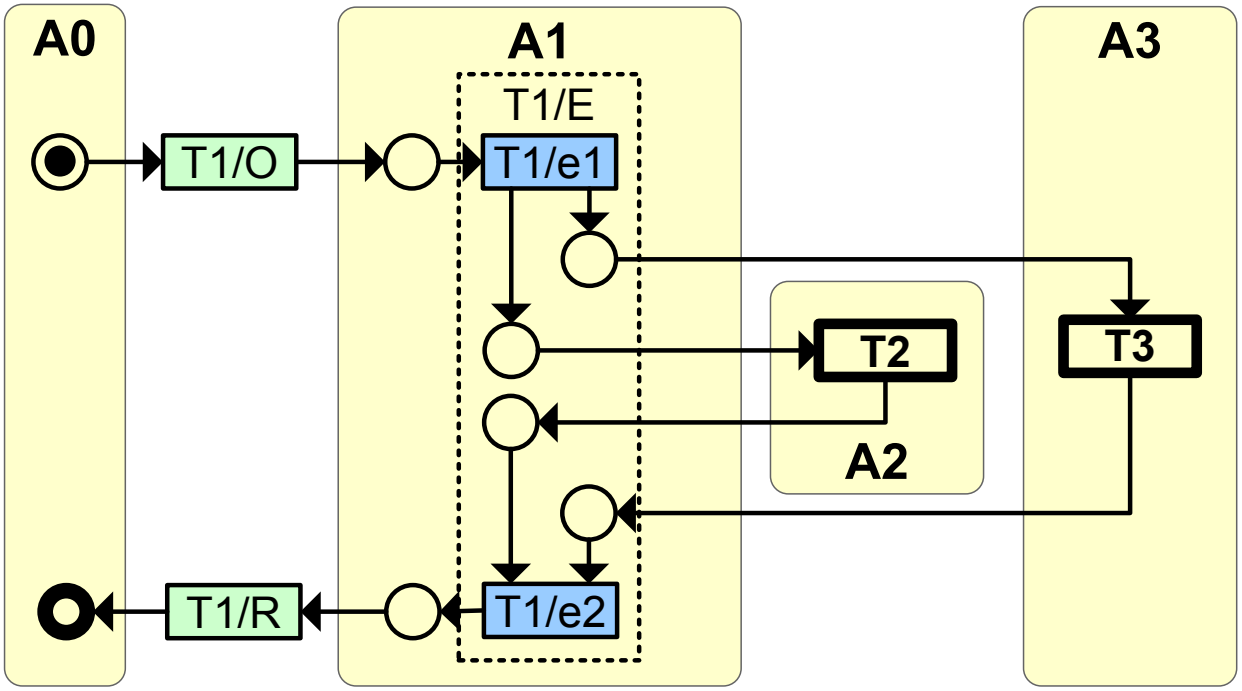




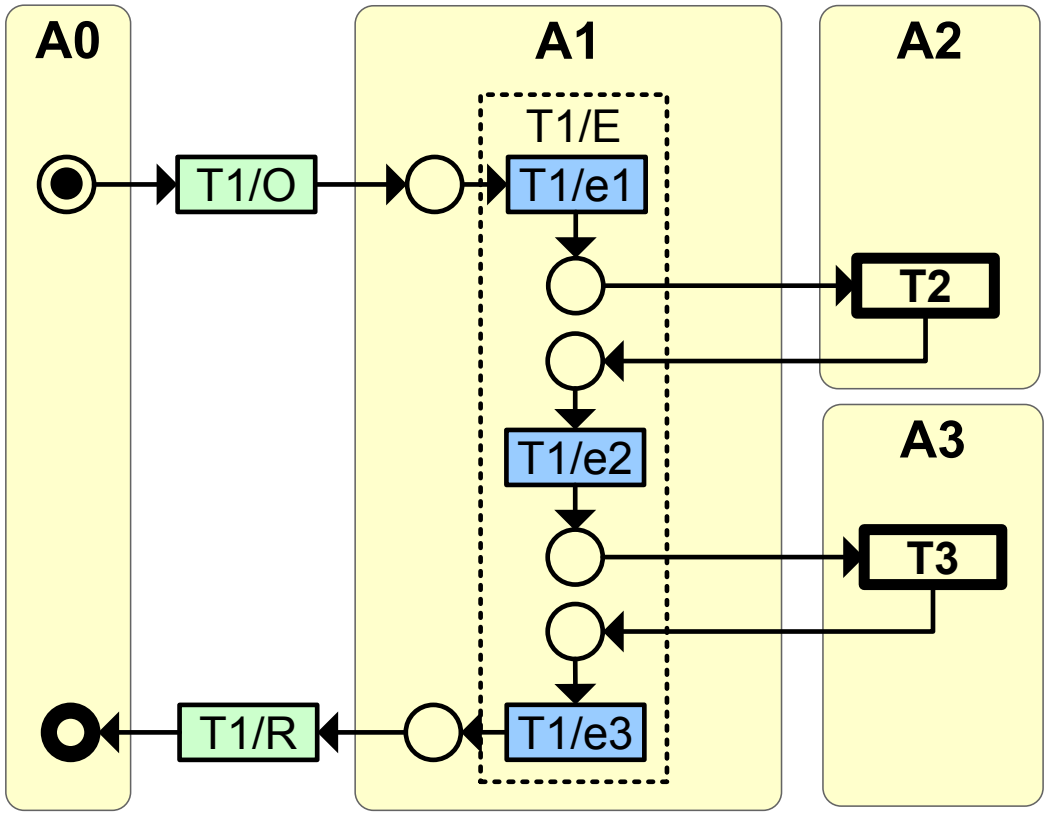
Shallow Nested Process



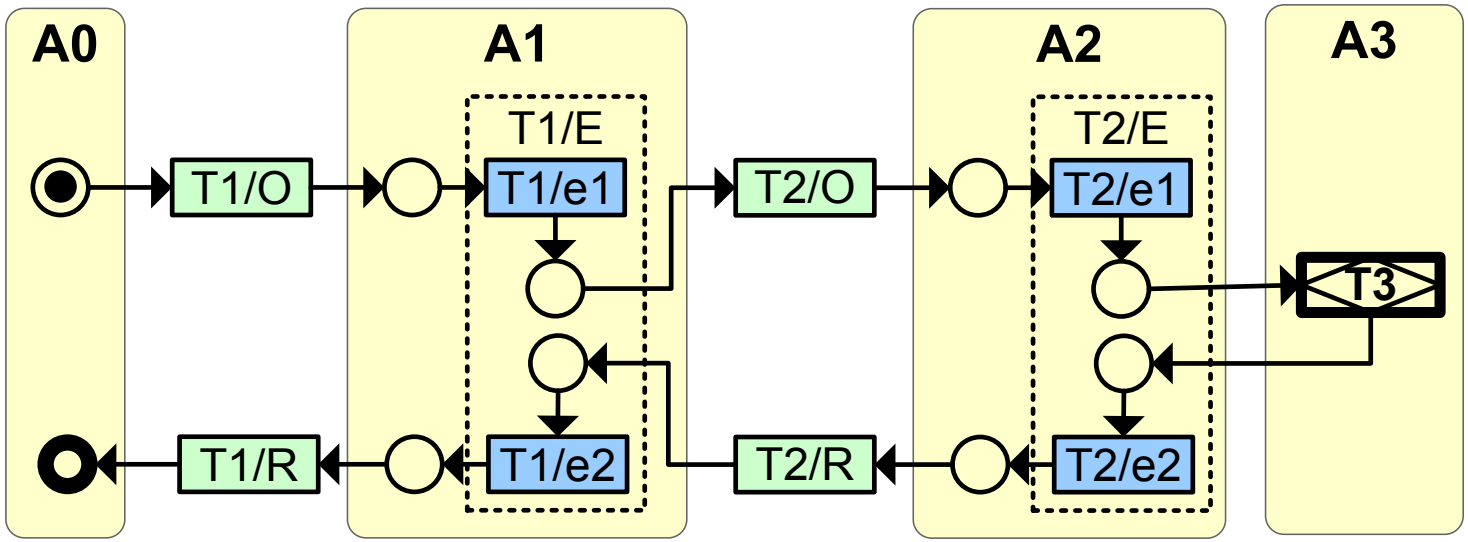
Parallel Processes



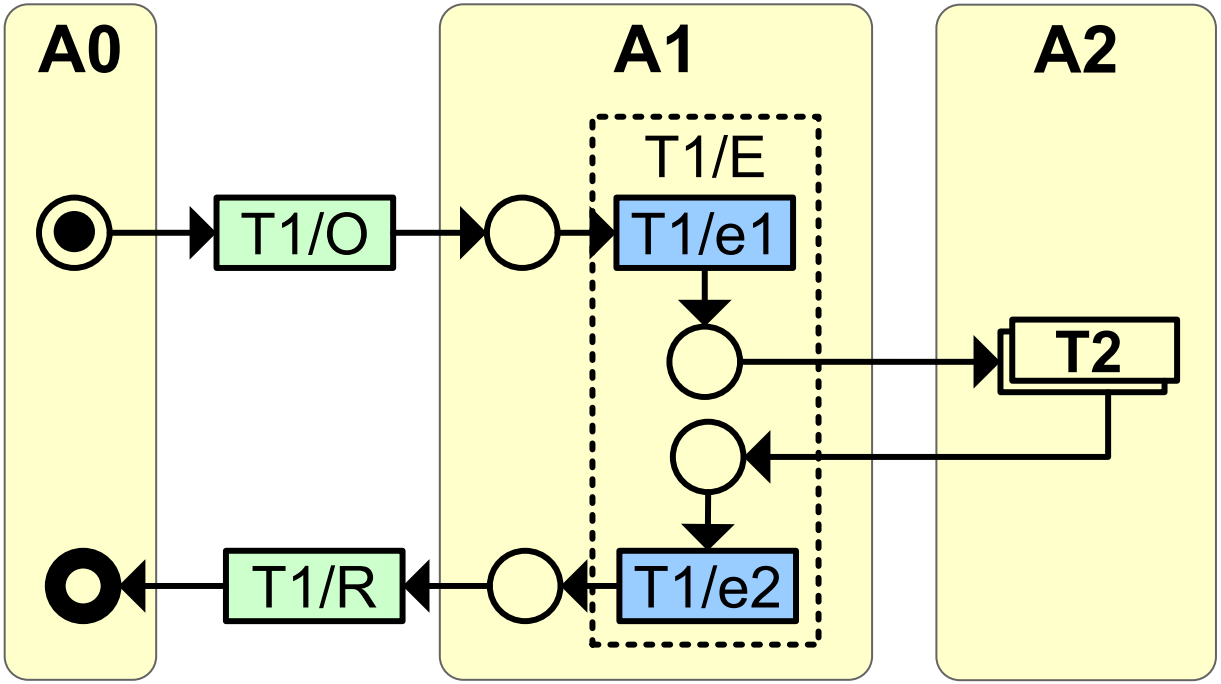
Sequential Processes



Deep Nested Process



Composite Process



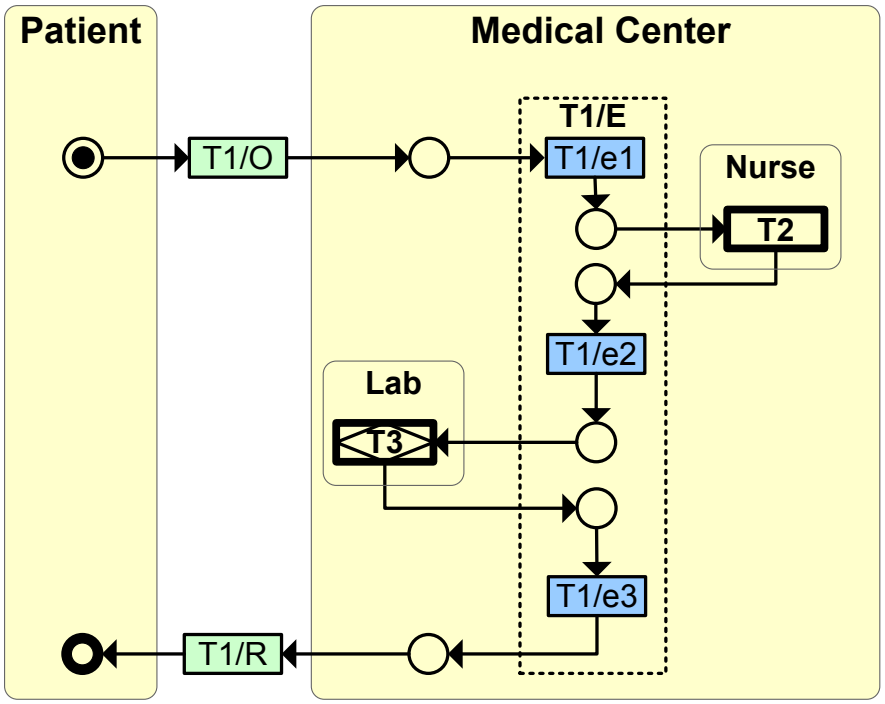
Family Healthcare Center (FHCC): Patient Examination

- **In this process, there are only three ontological transactions identified**
- **The process starts with a patient applying for medical treatment to a physician**
  - We denote this transaction as T1
- **T1 seems to be a composite transaction as it nests at least two further transactions (T2, T3)**
- **When the treatment starts, a nurse should conduct a complete general check up**
  - We denote this second transaction as T2
- **The treatment process might require the patient to do some basic lab tests (e.g., ECG) as part of the treatment while in the doctor's office**
  - We denote this third transaction as T3

FHCC: Ontological Transactions

Ontological Transactions	
T1: Initiator Executor Fact	deliver healthcare patient physician patient is treated
T2: Initiator Executor Fact	do general checkup physician nurse general checkup done
T3: Initiator Executor Fact	perform lab test physician lab technician lab tests done

FHCC: Ontological Model



Conclusion

- **Modern enterprises and their business processes are growingly complex**
  - Qualitative and quantitative techniques
  - Simulation and analytical techniques
- **Conceptualization is the far most challenging step**
  - Formal theory
  - Sound modeling methods and languages

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