Refinement – formal design with sequence diagrams

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September 19, 2008

Overview

- Obligatory Exercise No. 1
- Motivation
  - How can we incrementally develop UML specifications
- Requirements to STAIRS
  - What should we require from a stepwise method for developing UML specifications
- Explanation through an example
  - A Dinner Restaurant
- Refinement
  - Comparison with traditional pre-post paradigm

Obligatory Exercise No. 1

- Should be solved individually by each student
- Will be made available today
- Refinement exam from last year

- The deadline is **October 13, 0900 AM**

- There will be a place where you will upload your exercise and that place will be closed at 0900.

- October 20:
  - The assistant teachers will walk through the obligatory exercise 1 and return the individual solutions
  - Some selected individuals will have to explain their solutions orally to the teachers

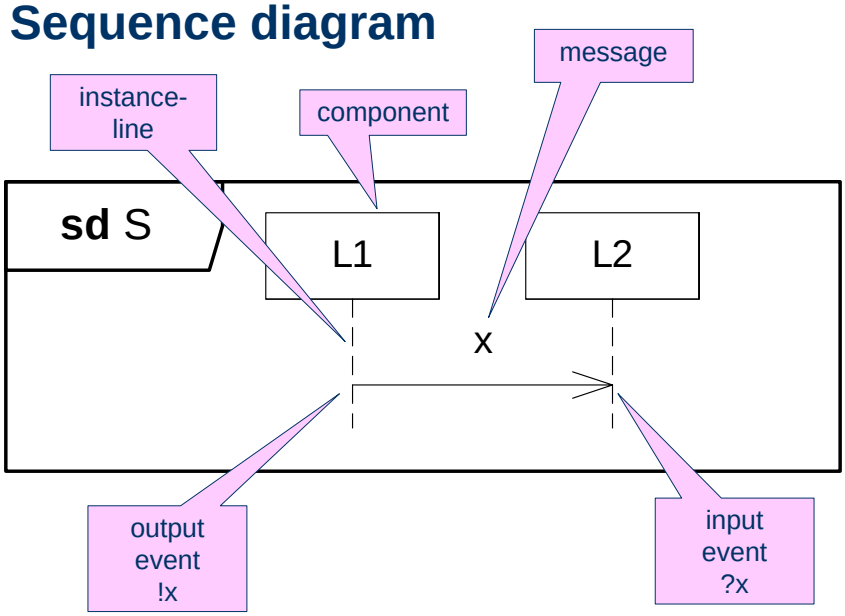
Motivation

- Exploit classical theory of refinement in a practical UML setting
  - From theory to practice, and not the other way around
- Briefly summarized: we aim to explain how classical theory of refinement can be applied to refine specifications expressed with the help of sequence diagrams
- Sequence diagrams can be used to capture the meaning of other UML description techniques for behavior
- By defining refinement for sequence diagrams we therefore implicitly define refinement for UML

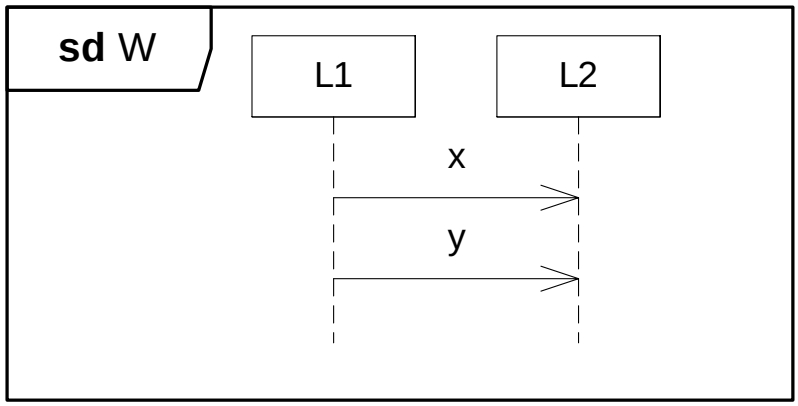
Requirements to STAIRS

- Should allow specification of potential behavior
  - Support for under-specification
- Should allow specification of mandatory behavior
  - Support for information hiding (inherent non-determinism, unpredictability)
- Should allow specification of negative behavior in addition to positive behavior
  - Support for threat modeling
- Should capture the notion of refinement
- Should formalize incremental development
- Should support compositional analysis, verification and testing

Sequence diagram



Weak sequencing



<!x,?x,!y,?y>
<!x,!y,?x,?y>

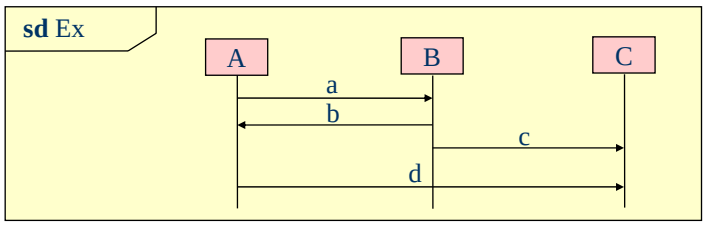
Traces

- Traces are used to capture executions (behaviors) semantically
- Within the field of formal methods there are many variants of traces
- In STAIRS traces are sequences of events

<e1, e2, e3, e4, e4, e1, e2, e5, ……>

- An event represent either the transmission or reception of messages
  - ?m - reception of message m
  - !m - transmission of message m
- Events are instantaneous
- A trace may be finite
  - termination, deadlock, infinite waiting, crash
- A trace may also be infinite
  - infinite loop, intended non termination

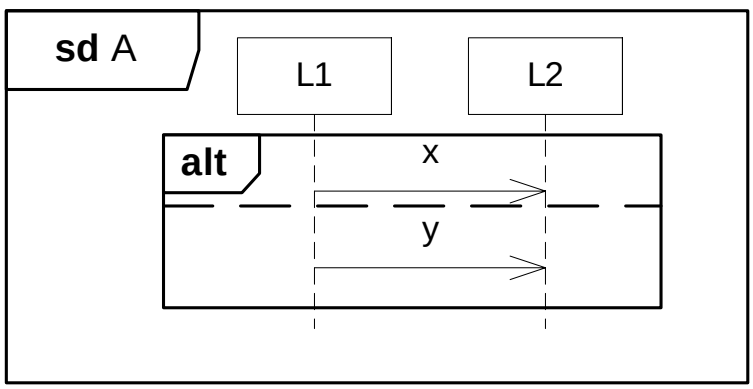
Example



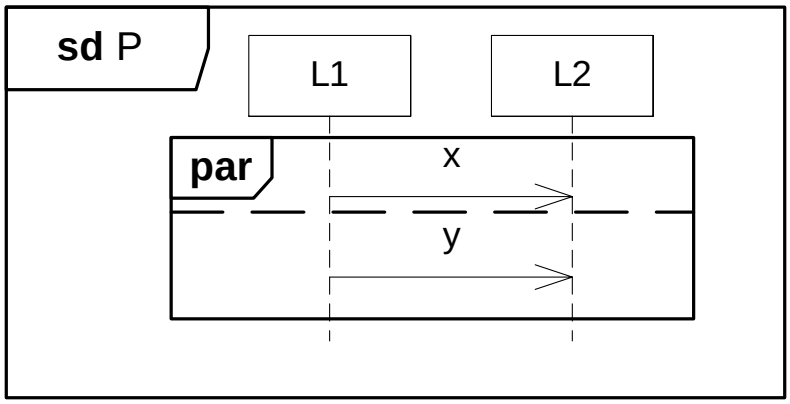
This sequence diagram has six traces:

<!a, ?a, !b, ?b, !c, ?c, !d, ?d>
<!a, ?a, !b, ?b, !c, !d, ?c, ?d>
<!a, ?a, !b, ?b, !d, !c, ?c, ?d>
<!a, ?a, !b, !c, ?b, ?c, !d, ?d>
<!a, ?a, !b, !c, ?b, !d, ?c, ?d>
<!a, ?a, !b, !c, ?c, ?b, !d, ?d>

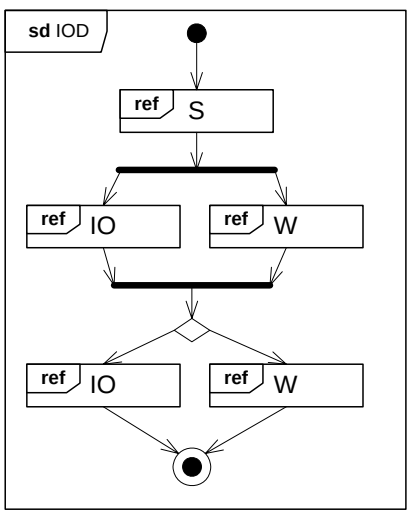
Alternative



Parallel execution

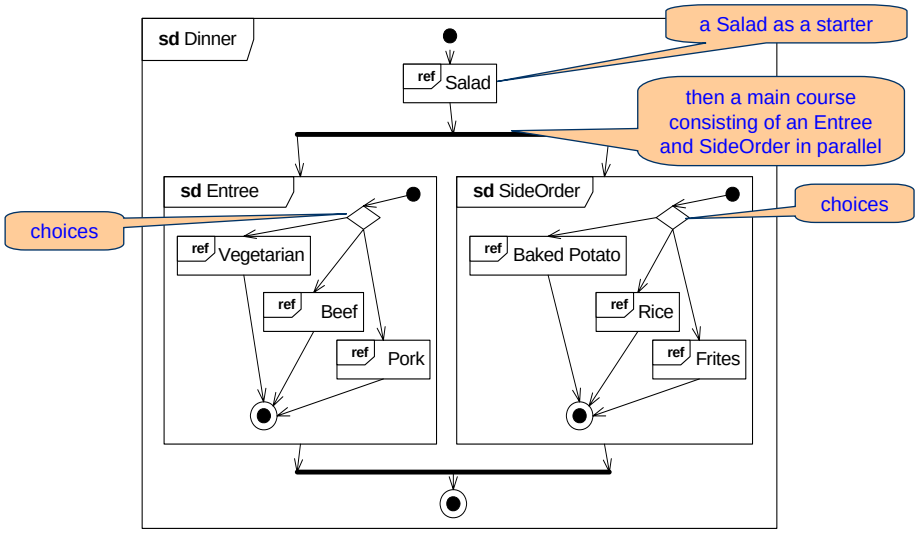


Interaction overview diagram

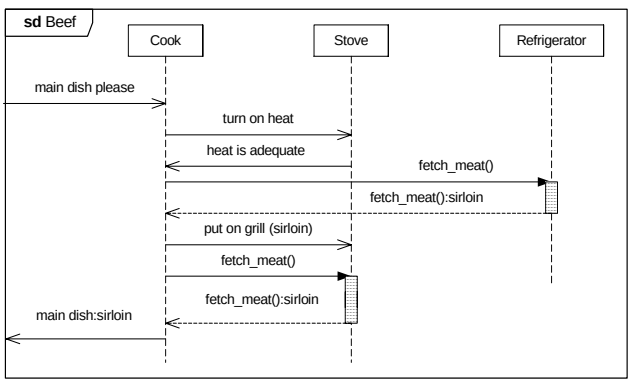


S **seq** (IO **par** W) **seq** (IO **alt** W)

Dinner

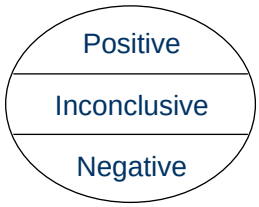


Some potential positive traces of Beef



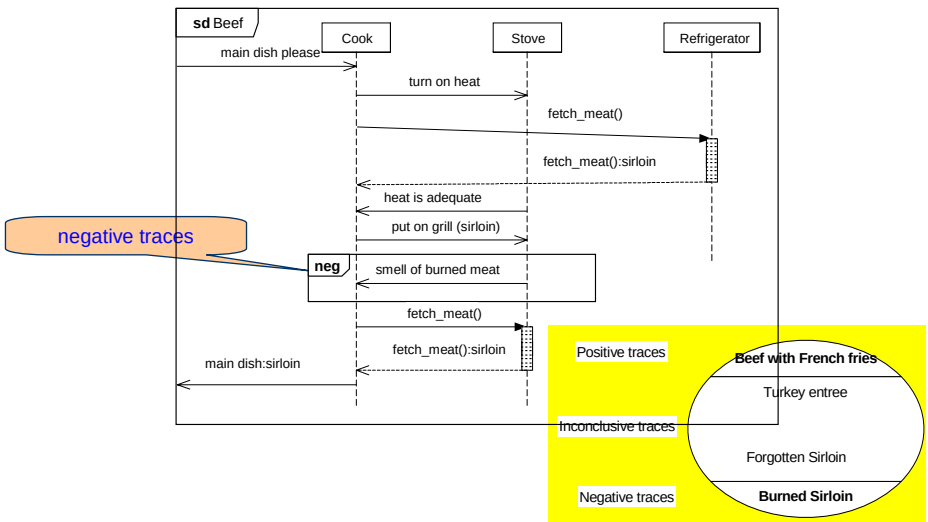
STAIRS semantics: simple case

- Each positive execution is represented by a trace
- Each negative execution is represented by a trace
- The semantics of a sequence diagram is a pair of sets of traces (Positive, Negative)



- All other traces over the actual alphabet of events are inconclusive

Potential negative Beef experiences



Pre-post specifications

Pre-post specifications are based on the assumption-guarantee paradigm

Integer division

var dividend, divisor, quotient, rest : Nat

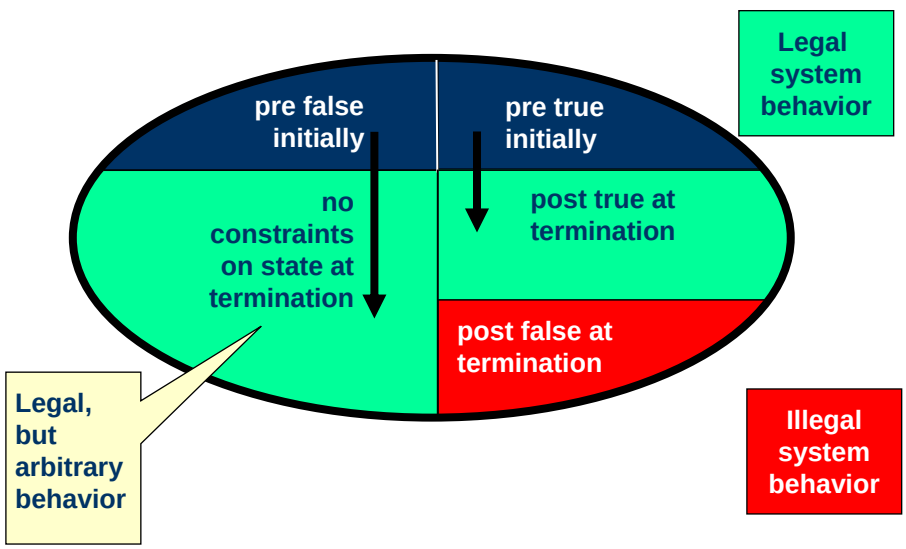
pre divisor ≠ 0

Assumption about the state at the moment the execution is initiated

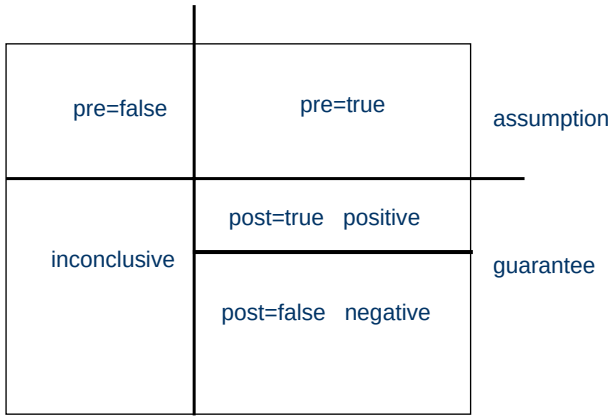
post (dividend = (quotient' * divisor) + rest') &
rest' < divisor

Guarantee with respect to the state at the moment of termination

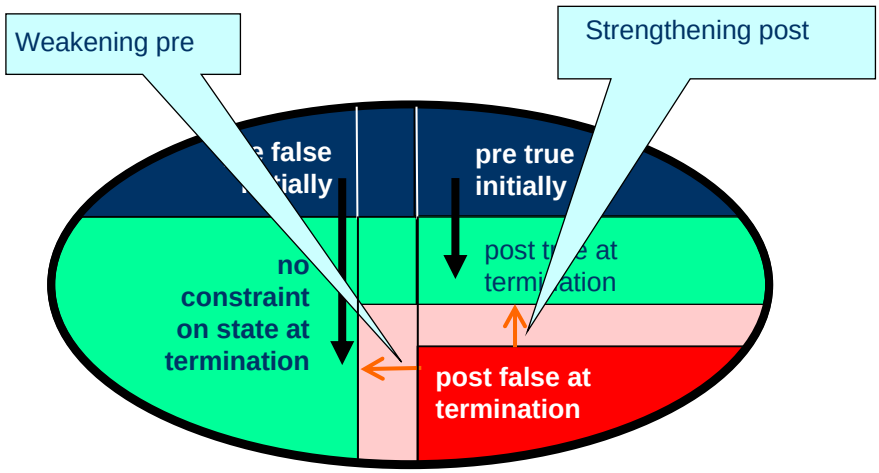
Semantics of pre-post specifications



Comparing STAIRS with pre-post

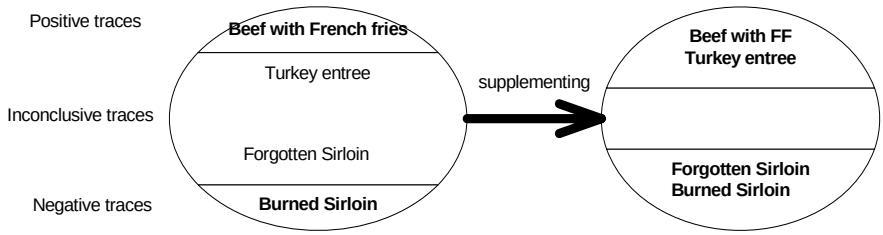


Refinement in pre-post

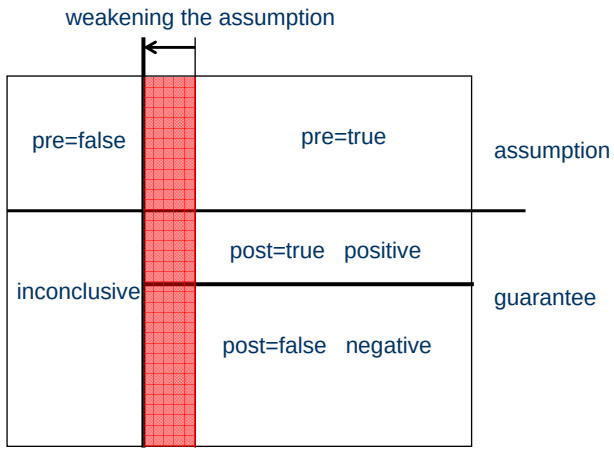


STAIRS: supplementing

- Supplementing involves reducing the set of inconclusive traces by redefining inconclusive traces as either positive or negative
- Positive trace remains positive
- Negative trace remains negative

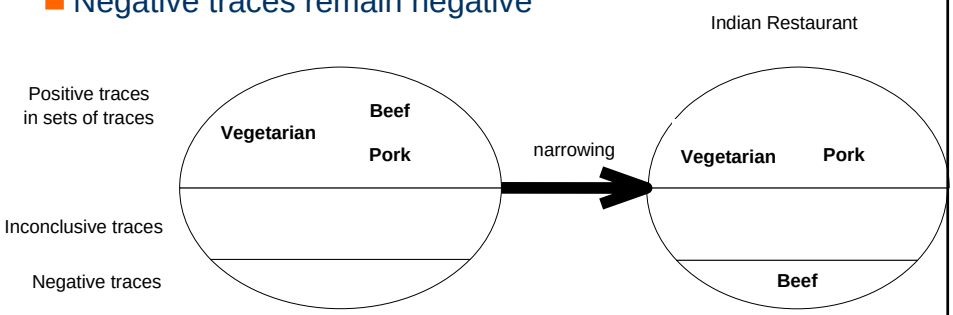


Supplementing in pre-post

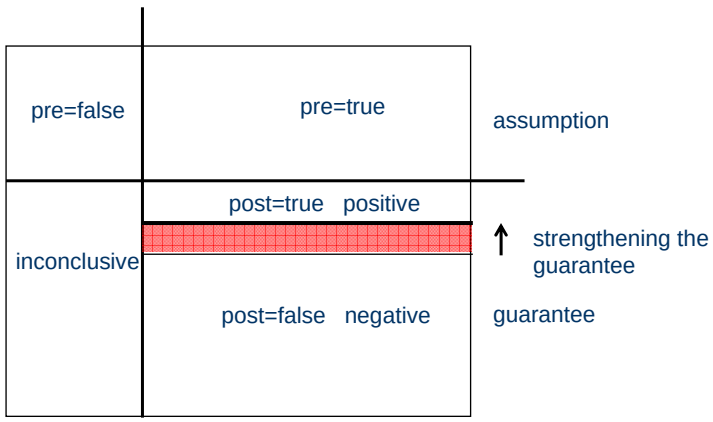


STAIRS: narrowing

- Narrowing involves reducing the set of positive traces by redefining them as negative
- Inconclusive traces remain inconclusive
- Negative traces remain negative



Narrowing in pre-post



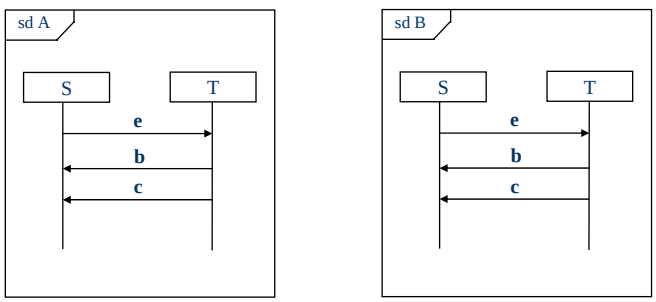
Indirect definition: Refinement in STAIRS

- A sequence diagram B is a general refinement of a sequence diagram A if
  - A and B are semantically identical
  - B can be obtained from A by supplementing
  - B can be obtained from A by narrowing
  - B can be obtained from A by a finite number of steps

    A -> C1 -> C2 -> …. ->Cn->B

    each of which is either a supplementing or a narrowing

Is B a refinement of A?



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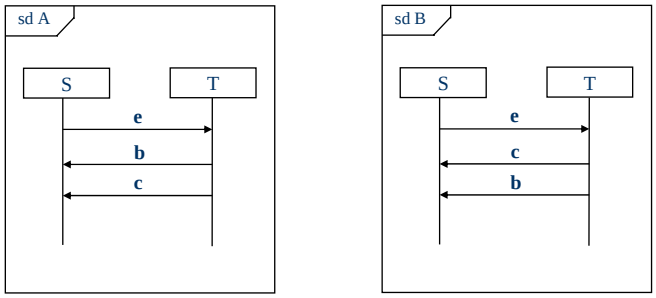
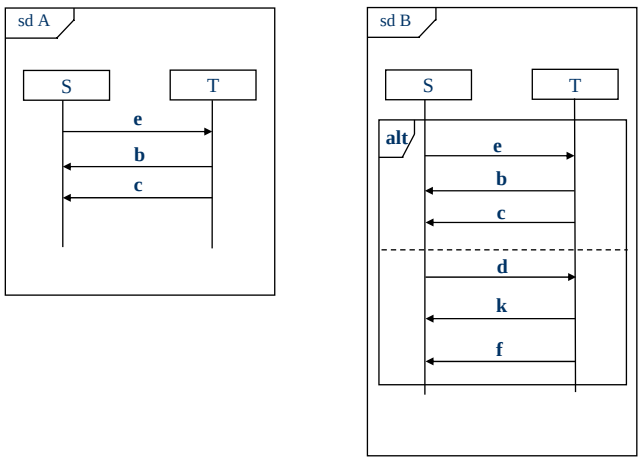
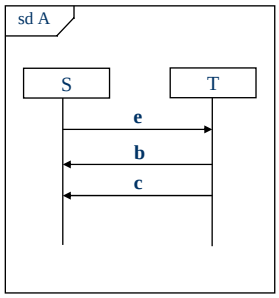
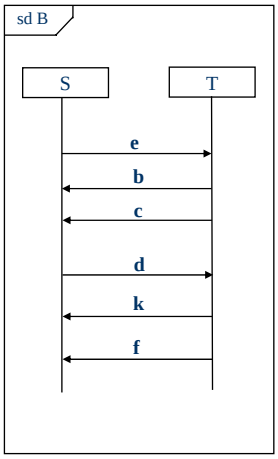


Is B a refinement of A?

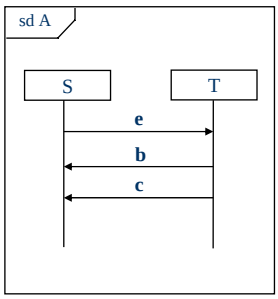


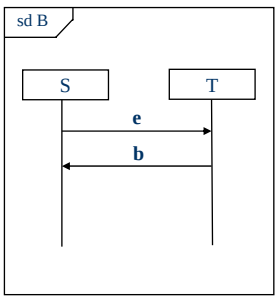
Is B a refinement A?





Is B a refinement of A?

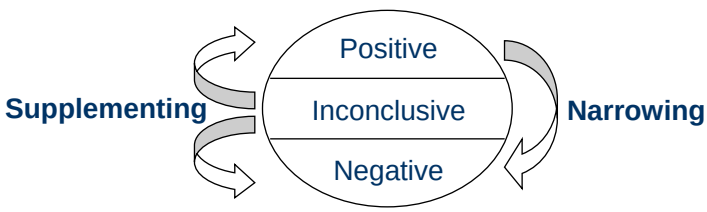




DIRECT DEFINITION: Refinement in STAIRS

- A sequence diagram B is a refinement of a sequence diagram A if
  - every trace classified as negative by A is also classified as negative by B
  - every trace classified as positive by A is classified as either positive or negative by B

Refinement in STAIRS



- An interaction obligation o'=(p',n') is a refinement of an interaction obligation o=(p,n) iff
  - $n \subseteq n'$
  - $p \subseteq p' \cup n'$

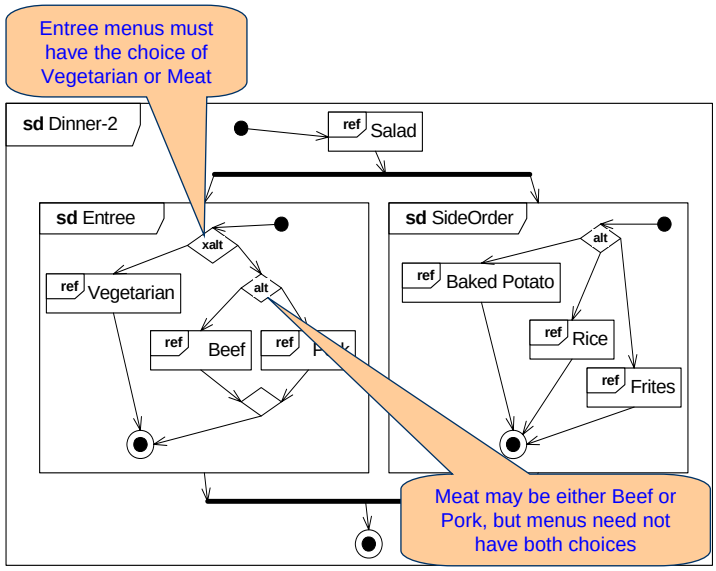
Underspecification and non-determinism

- Underspecification: Several alternative behaviours are considered equivalent (serve the same purpose).
- Inherent non-determinism: Alternative behaviours that must all be possible for the implementation.
- These two should be described differently!

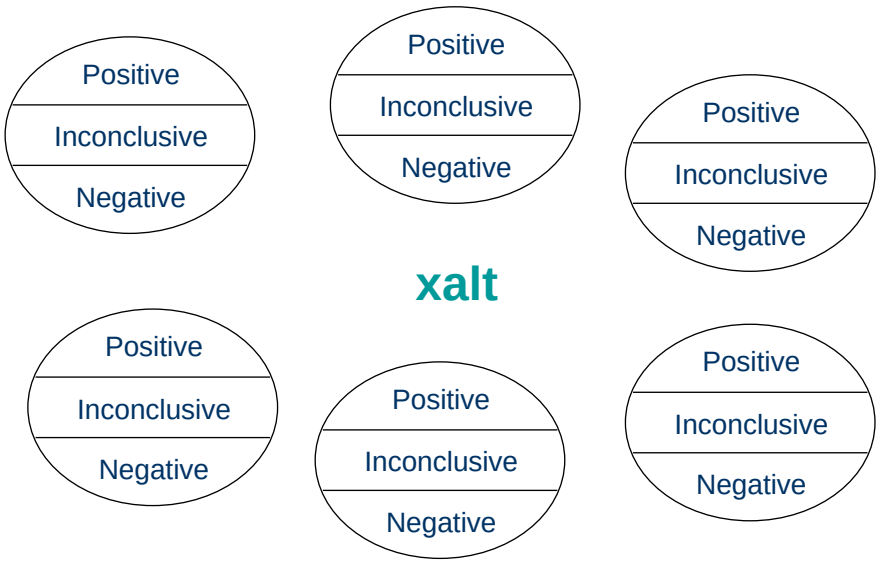
The need for both *alt* and *xalt*

- Potential non-determinism captured by alt allows abstraction and inessential non-determinism
  - Under-specification
  - Non-critical design decisions may be postponed
- Mandatory non-determinism captured by xalt characterizes non-determinism that must be reflected in every correct implementation
  - Makes it possible to specify games
  - Important in relation to security
  - Also helpful as a means of abstraction

Restaurant example with both alt and xalt

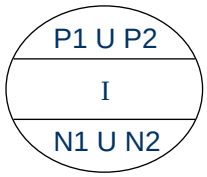


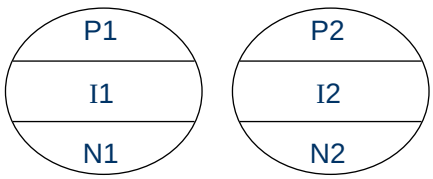
STAIRS



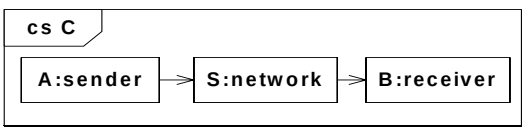
alt vs xalt

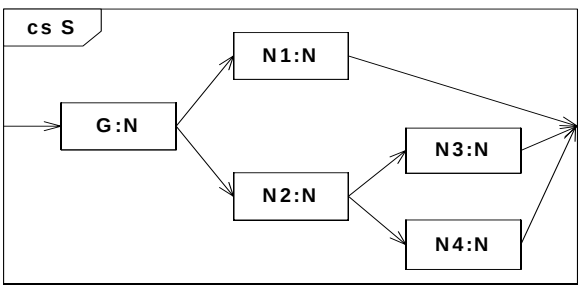
- Assume
  [[d1]] = {(p1,n1)} [[d2]] = {(p2,n2)}
- alt specifies potential behaviour:
  [[d1 alt d2]]
  = [[d1]] + [[d2]]
  = {(p1 U p2, n1 U n2)}
- xalt specifies mandatory behaviour:
  [[d1 xalt d2]]
  = [[d1]] U [[d2]]
  = {(p1,n1)} U {(p2,n2)}



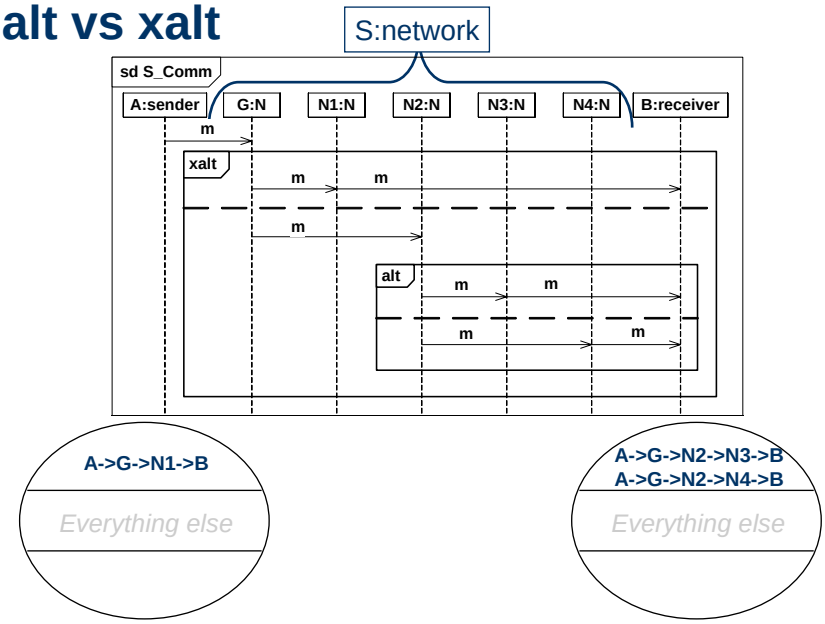


Example: Network communication





alt vs xalt



Mandatory requirements STAIRS

- Haugen, Husa, Runde, Stølen: *STAIRS towards formal design with sequence diagrams*, 2005. SoSyM, Springer.
- Runde, Haugen, Stølen: *The Pragmatics of STAIRS*, 2006. Springer-Verlag. LNCS 4111.

NOTE:

- Next Friday: Agile modeling 1 with Haugen
- Last lecture on STAIRS: October 3 with Brændeland