Network-like System Relations and Their Meaning for IT-System Architecture

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To be semantic or not to be?

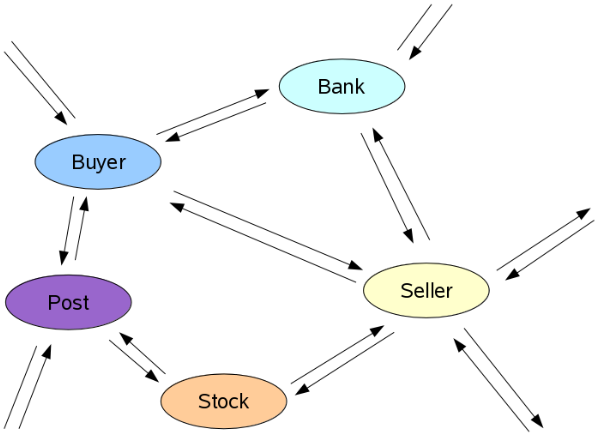
Claude E. Shannon (1948): A Mathematical Theory of Communication

> *"The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point. Frequently the messages have meaning; that is they refer to or are correlated according to some system with certain physical or conceptual entities.* **These semantic aspects of communication are irrelevant to the engineering problem***."*

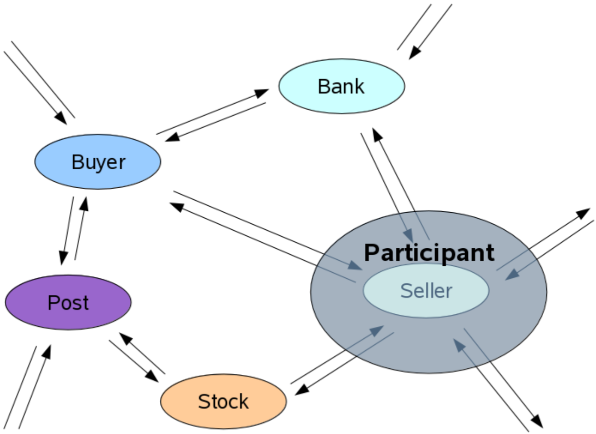
Frege Principle of Semantics

Two components are semantically equivalent if they can be exchanged.

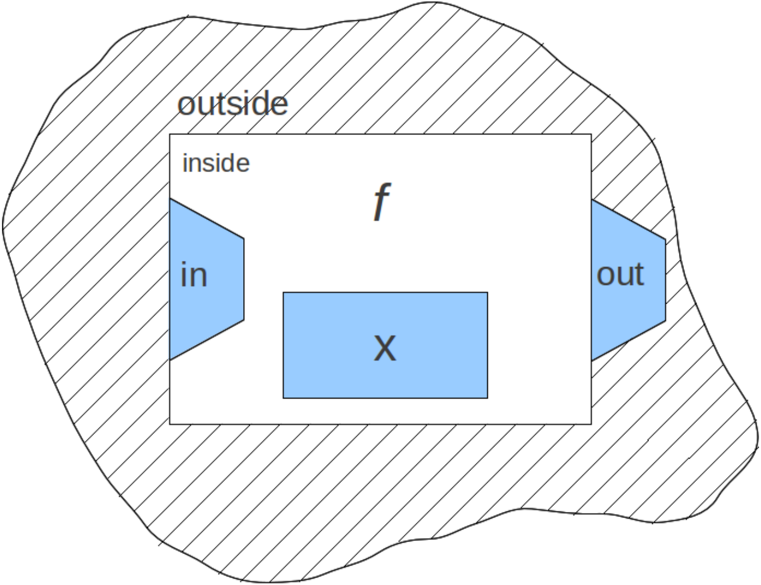
We are living in an open world of network-like relations between systems



We are living in an open world of network-like relations between systems: Focus on processes



Systems



Two Simple Example Systems

A simple multiplier

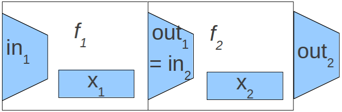
No internal state
Input state: $x, y \in \{-2^{31} \ldots 2^{31} - 1\}$
Output state: $z \in \{-2^{31} \ldots 2^{31} - 1\}$
System function: $z' = f(x, y) = x * y$ // watch for overflow!

A simple counter

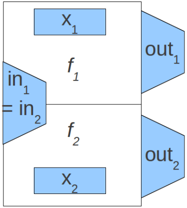
No input and no internal state
Output state: $z \in \{0 \ldots 2^{32} - 1\}$,
System function: $z' = f(z) = z + 1$, // watch for overflow!

System Composition/Super System Formation

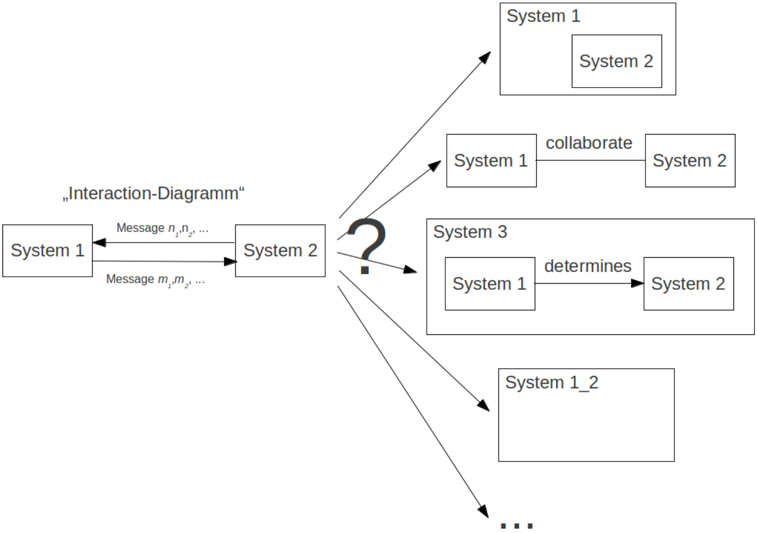
Sequential Composition ($\mathcal{S}_2 \circ \mathcal{S}_1$)



Parallel composition ($\mathcal{S}_2 || \mathcal{S}_1$)



Richer Interaction Semantics



Recursive System Relations

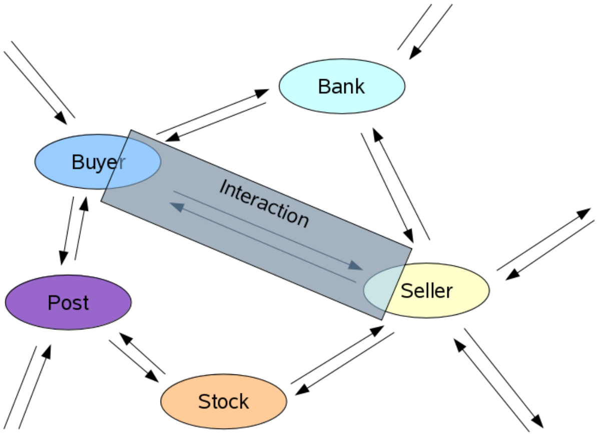
System $\mathcal{U}_1$

```
int fac1(int i) {
  if (i==0)
    return 1;
  else
    return i*fac2(i-1);
}
```

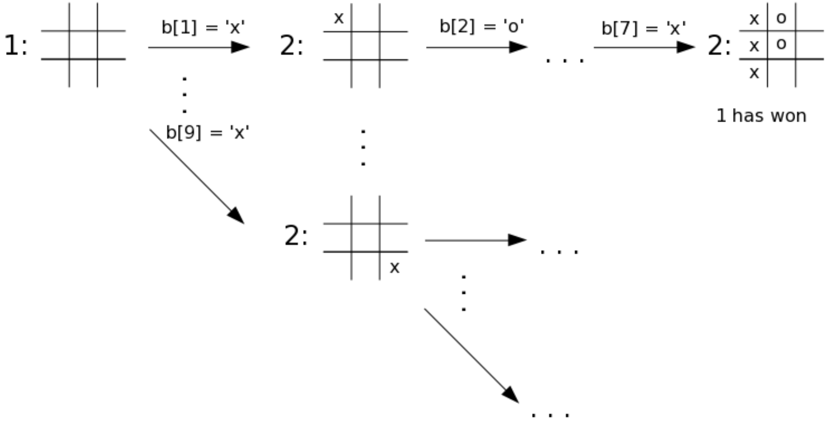
System $\mathcal{U}_2$

```
int fac2(int i) {
  if (i==0)
    return 1;
  else
    return i*fac1(i-1);
}
```

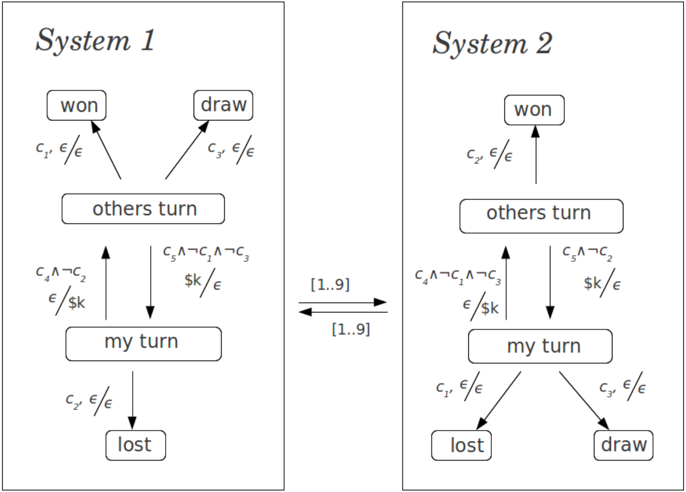
We are living in an open world of network-like relations between systems: Focus on interactions



Tic tac toe as an extensive form game



Tic tac toe as an interaction


System 1
won
draw
c_1, ϵ/ϵ
c_3, ϵ/ϵ
others turn
$c_4 \wedge \neg c_2$
$\epsilon/\$k$
$c_5 \wedge \neg c_1 \wedge \neg c_3$
$\$k/\epsilon$
my turn
c_2, ϵ/ϵ
lost
[1..9]
[1..9]
System 2
won
c_2, ϵ/ϵ
others turn
$c_4 \wedge \neg c_1 \wedge \neg c_3$
$\epsilon/\$k$
$c_5 \wedge \neg c_2$
$\$k/\epsilon$
my turn
c_1, ϵ/ϵ
c_3, ϵ/ϵ
lost
draw

c_1 if player 1 wins.
c_2 if player 2 wins.
c_3 if it is a draw.
c_4 if the k-th position is empty.
c_5 if the '$k'-th position is empty.

Two systems playing tic tac toe. System 1 makes the initial move.

Games and Protocols/Processes

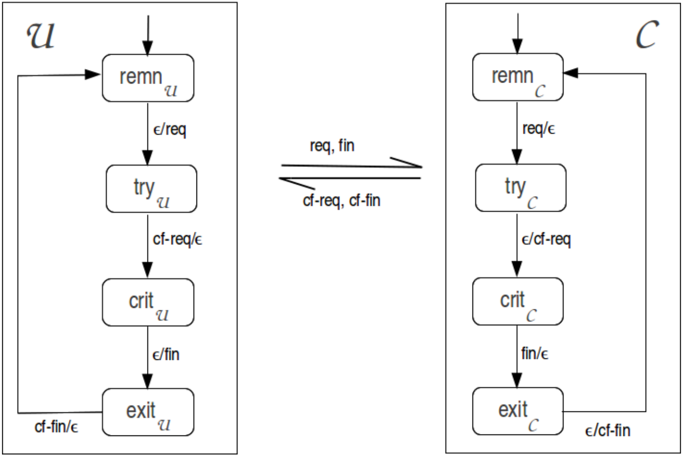
Relation between Games and Protocols

Protocols + Decisions = Games - Payoff

Consequences

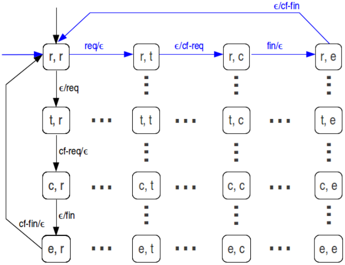
- Game theory and protocol/process theory should use the same interaction model!
- Processes [in game-like interactions] interact via shared states (Shannon-channels).
- Prozesses [in game-like interactions] interact statefully.

Example: the Protocol of Mutual Exclusion

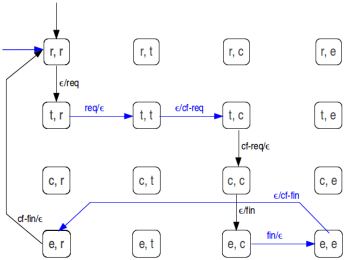

$\mathcal{U}$
$\text{remn}_{\mathcal{U}}$
ϵ/req
$\text{try}_{\mathcal{U}}$
cf-req/ϵ
$\text{crit}_{\mathcal{U}}$
ϵ/fin
$\text{exit}_{\mathcal{U}}$
cf-fin/ϵ
req, fin
cf-req, cf-fin
$\mathcal{C}$
$\text{remn}_{\mathcal{C}}$
req/ϵ
$\text{try}_{\mathcal{C}}$
ϵ/cf-req
$\text{crit}_{\mathcal{C}}$
fin/ϵ
$\text{exit}_{\mathcal{C}}$
ϵ/cf-fin

Causal Relation Between Output and Input of Different Systems - Channel Based Restriction

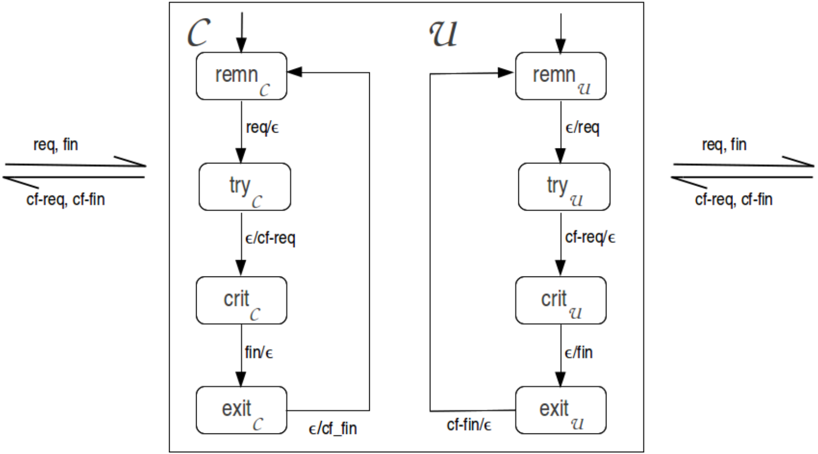
Weakly synchronized product



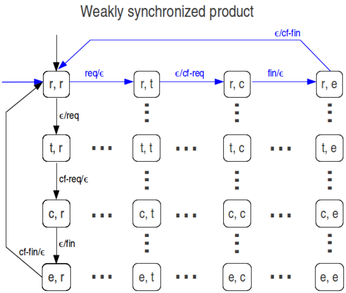
Channel based restricted product

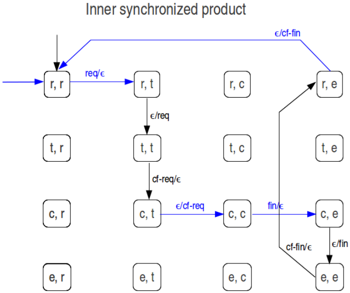


Example: Man in the Middle of the Protocol of Mutual Exclusion


req, fin
cf-req, cf-fin
$\mathcal{C}$
$\text{remn}_{\mathcal{C}}$
req/ϵ
$\text{try}_{\mathcal{C}}$
ϵ/cf-req
$\text{crit}_{\mathcal{C}}$
fin/ϵ
$\text{exit}_{\mathcal{C}}$
ϵ/cf_fin
$\mathcal{U}$
$\text{remn}_{\mathcal{U}}$
ϵ/req
$\text{try}_{\mathcal{U}}$
cf-req/ϵ
$\text{crit}_{\mathcal{U}}$
ϵ/fin
$\text{exit}_{\mathcal{U}}$
cf-fin/ϵ
req, fin
cf-req, cf-fin

Causal Relation Between Input and Output of the Same System - Condition Based Restriction


Weakly synchronized product


Inner synchronized product

Semantic is key!

Common phrases and what the imply . . .

- "The process is in the objects"
- "message exchange patterns"
- "communication is about sending data from one system to another"
- "message based integration"
- "loose coupling is just asynchronous message exchange"
- "process interactions should be based on idempotent, stateless methods with no side effects"
- "the actual meaning of an interface is independent of its implementation"
- "for integration, write services, expose your object model!"

Architectural Principles

A process oriented application architecture is based on

- Clear system borders, clear layering
- A dedicated top process layer - separating reusable from non-reusable parts
- An internal event model - formalizing upward communication
- Sending/receiving documents - the basis for non-deterministic interactions
- Roles implementing protocols
- An adequate component model with protocol signatures

A process oriented application architecture simplifies

- Integration
- Reuse
- Security

Thank You!

Any questions?

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Literature

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