A Vision of Large-scale Software Design

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9th April, 2010
Cachan, France

Mesdames et messieurs

C'est un grand honneur pour moi de recevoir le Doctorat Honoris Causa de cette prestigieuse institution.

Et c'est un plaisir et un privilège de prendre la parole devant cet auditoire distinguè.

A Little Problem

- An office assistant contacts the visitor.
- The visitor sends the date of her visit.
- The assistant contacts two airlines and a hotel for reservation.
- After hearing from an airline and the hotel: she informs the visitor.
- The visitor sends a confirmation which the assistant notes.
- The assistant reserves a room for the lecture.
- She announces the lecture by posting at a web site.
- She emails a technician to check equipment in the lecture hall before the talk.

Another Little Problem

- Contact two airlines simultaneously for price quotes.

- Buy ticket from either airline if its quote is at most 300 Euros.

- Buy the cheapest ticket if both quotes are above 300 Euros.

- Buy any ticket if the other airline does not provide a timely quote.

- Notify client if neither airline provides a timely quote.

A Not So Little Problem:
Coordination in Earthquake Recovery

- Accept inputs from the medical staff, firemen and the police.

- Direct them by sending commands and information to their hand-held devices.

- And,
  - send announcements,
  - make reservations in the local hospitals,
  - block certain roads to traffic to let emergency vehicles pass, $\cdots$

Why Consider Such Problems?

- Problems seem related in some abstract sense.

- Any general approach will yield insight for designs of many similar large systems.

- Generality vs. Simplicity in solutions:
  If it is not general, no one will use it.
  If it is not simple, no one will use it.

A Quote

In their capacity as a tool, computers will be but a ripple on the surface of our culture. In their capacity as intellectual challenge, they are without precedent in the cultural history of mankind.

– Edsger W. Dijkstra, 1972

An intellectual challenge posed by computers

- Large-scale mathematical engineering: Designs of large, complex artifacts.

- Computer systems are among the most complex of human creations.

- Imagine a symbol to weigh 1 gram.
  Some software systems weigh in thousands of metric tonnes!

Inspiration from Nature and Society in System Design

- Natural systems have hierarchy:
  Atoms, Molecules, Compounds, Genome, Protein, Organisms.

- Society is hierarchical:
  Individuals, Towns, States, Nation.

- Organizations are hierarchical:
  Military, Bureaucracies, $\cdots$

Hierarchical System Design

- System consists of components.

- Each component is a system, having subcomponents.

- Lowest level components are easy to design.

Advantages of Hierarchical System Design

- Components can be undestood individually.

- Different people/groups can work on different components.

- A component can be replaced by a better one.

- Components can be tested/verified individually.

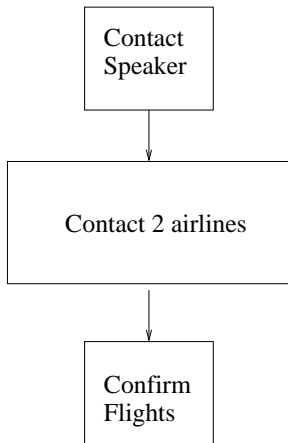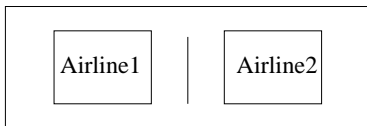# Back to our Little Problem: Speaker's visit

Figure: Structuring Visitor contact: Sequential Flow

Refining the solution of Airlines

Contact 2 Airlines

Figure: Structuring Airlines: Parallel Flow

A line of program

Contact ≫ (*Airline*1 | *Airline*2) ≫ *Confirm*

Similar to the arithmetic expression

$3 \times (5 + 6)$

External Services

- Some of the components are not divided, because their solutions are available.
  Airline databases, email

- Web services, specialized programs, $\cdots$

- Very few restrictions on boxes.

Combinators

- How to combine services?

- How to achieve all manners of communication/synchronization using a few combinators?

- What are the theoretical properties of the combinators?

Little student Projects

- Smart Phone application: interesting things around you.

- Add music events to calendar

- Trip Advisor

- Meeting Planner

Larger Application Developments

- Telecommunication Service Level Agreement

- Supply chain logistics

- eHealth applications

- Multimedia control with mobile devices

- Large-scale simulations, Adaptive workflow, Secure Information Flow

The Larger Vision

- Society depends on large software systems.

- These have many interacting components.

- Their communication patterns are complex.

- Time-sensitive behavior.

- Prone to failures.

A mathematical foundation for study of combinators.

Thanks

- Ecole Normale Supérieure, Cachan

- My collaborators and students

- You, the patient audience.