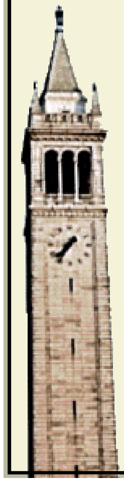
Giotto: A Time-triggered Language for Control Programming



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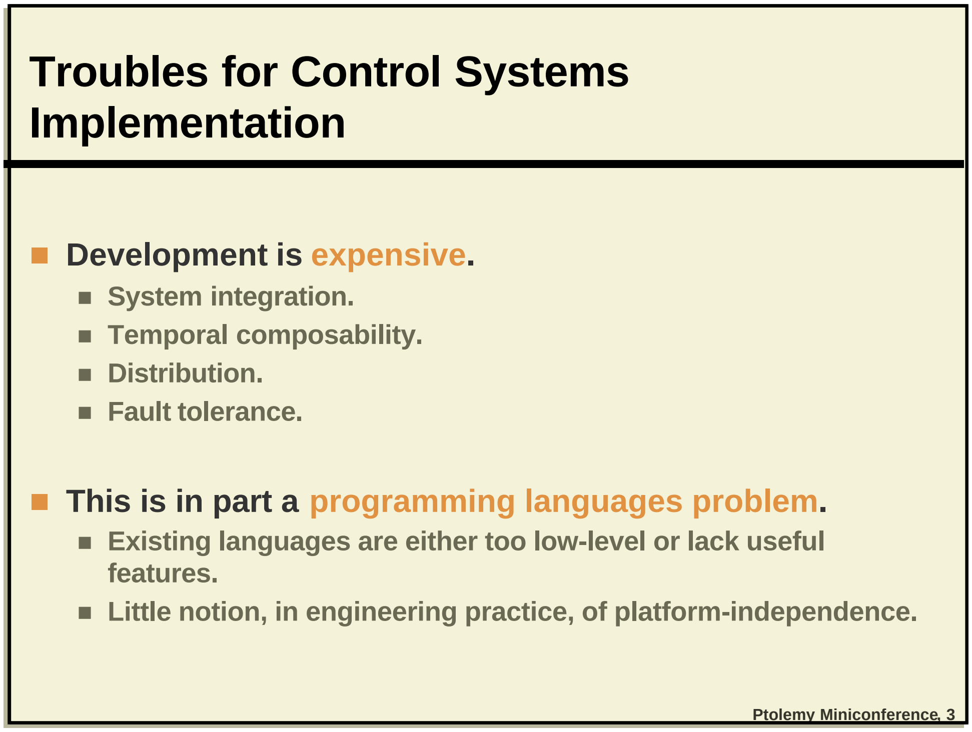
4th Biennial Ptolemy Miniconference
March 22-23, 2001, Berkeley, CA

What is Giotto?

- A time-triggered, platform independent programming language + compiler + runtime library.
- For hard real-time, safety-critical control applications on distributed platforms.

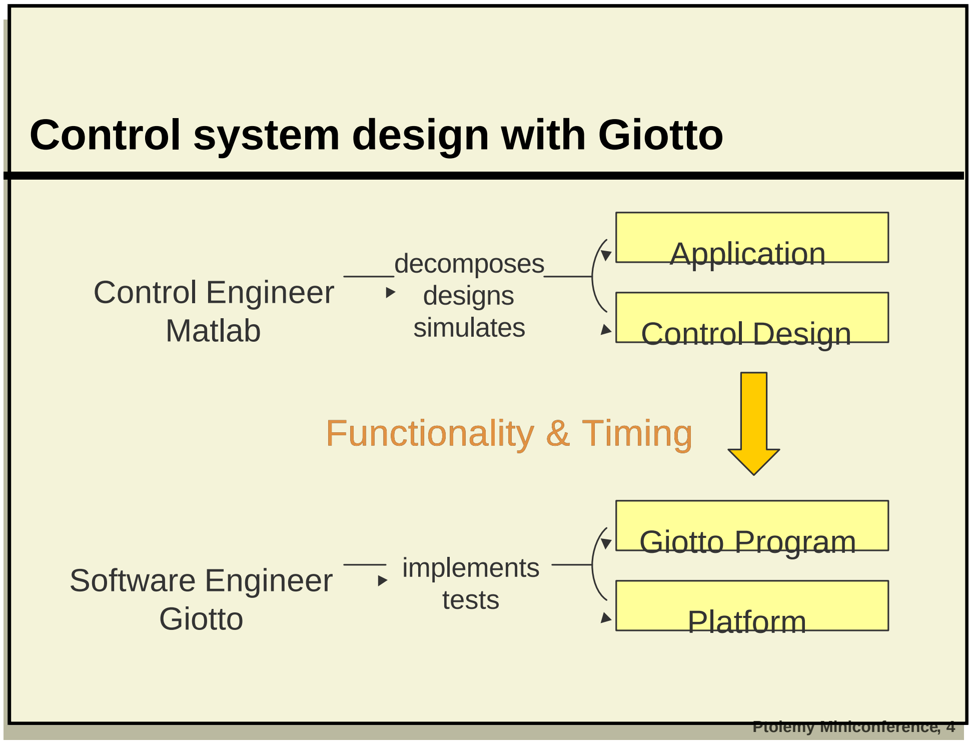
- Abstract programming model for control system development.

- VxWorks runtime library.
- Ptolemy II domain.



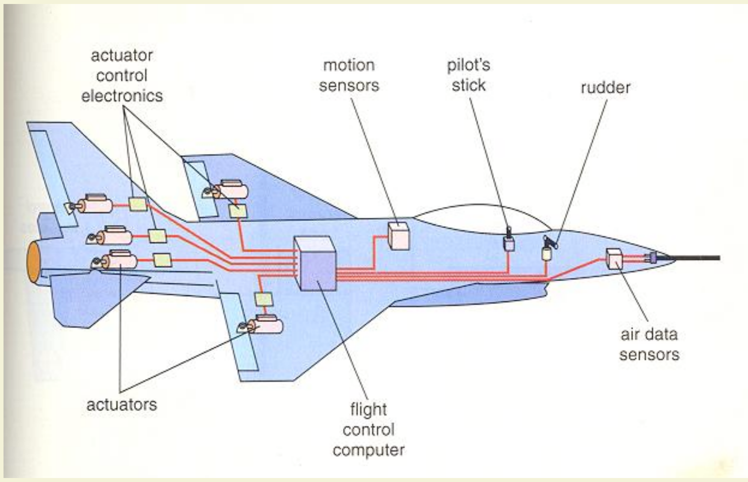
Troubles for Control Systems Implementation

- Development is expensive.
  - System integration.
  - Temporal composability.
  - Distribution.
  - Fault tolerance.
- This is in part a programming languages problem.
  - Existing languages are either too low-level or lack useful features.
  - Little notion, in engineering practice, of platform-independence.



Control system design with Giotto

Motivating Example: Fly-by-wire Flight Control

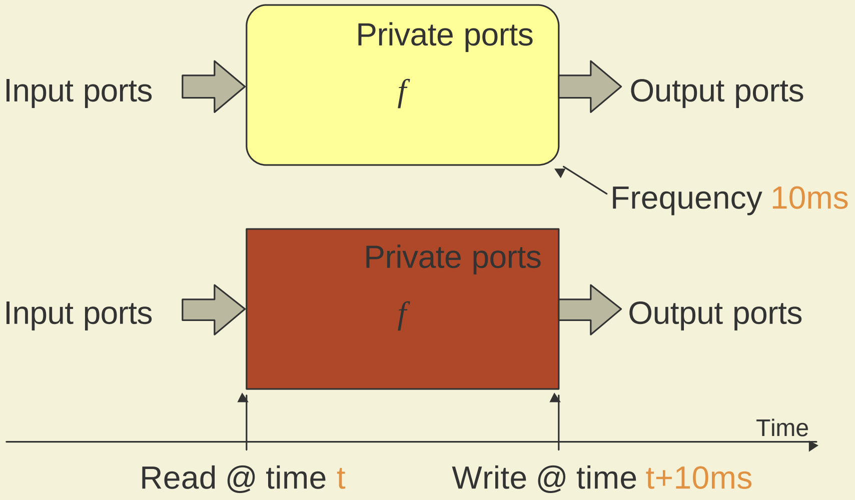


Requirements for Control Programming Language

- Talk about time:
  - Periodic computation and IO.
- Operational modes:
  - Take off, cruise, land.
  - Different control laws needed in each mode.
- Easy to distribute:
  - For performance…
  - …or fault tolerance.
- Encapsulate existing (legacy) code.
  - Or output of tools such as Matlab.

- Deterministic, platform independent, simple.

A Single Giotto Task



Private ports

f

Input ports

Output ports

Frequency 10ms

Private ports

f

Input ports

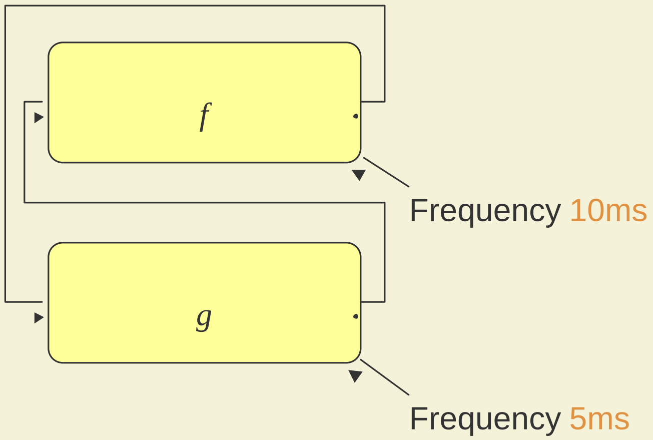
Output ports

Time

Read @ time t

Write @ time t+10ms

Two Communicating Giotto Tasks



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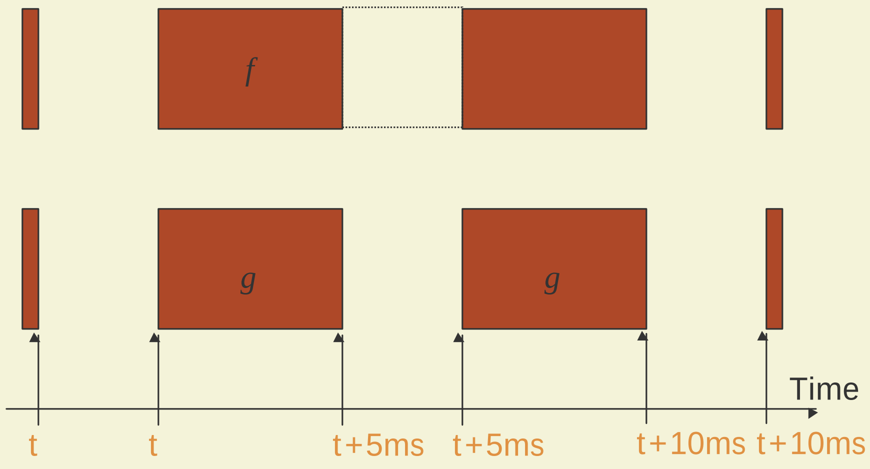
Frequency 10ms

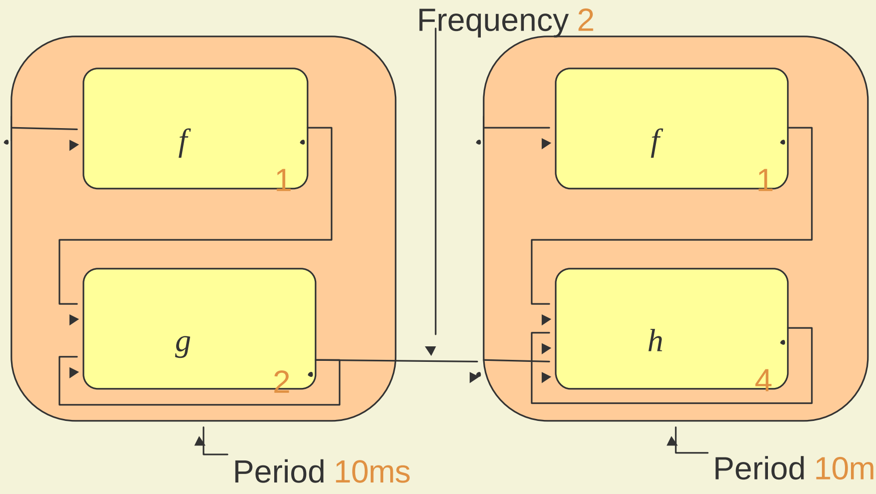
g

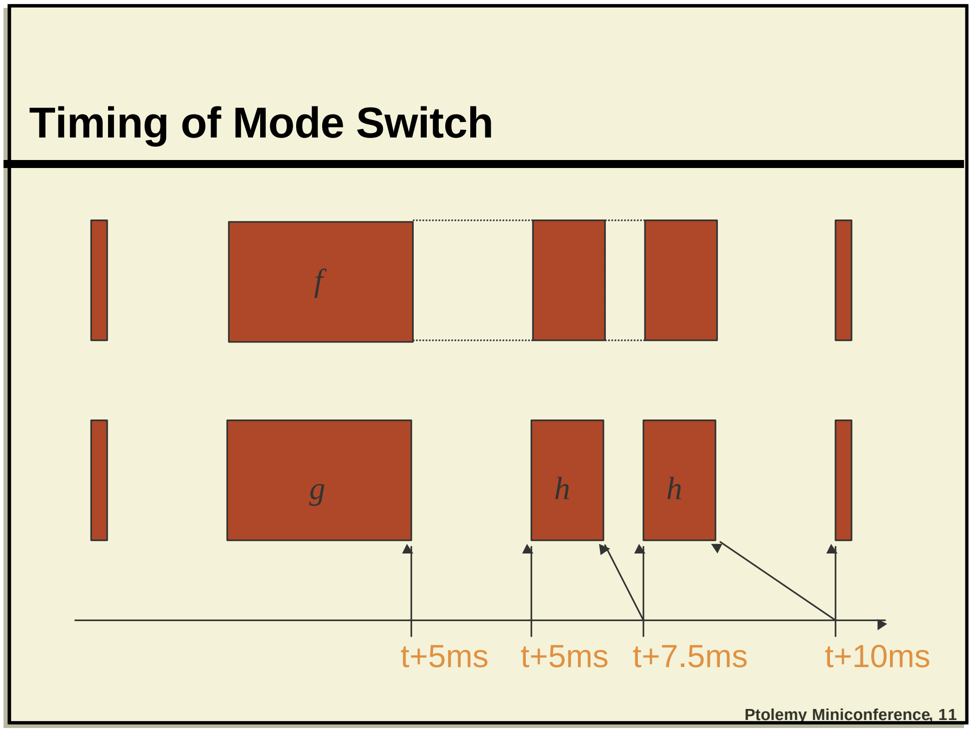
Frequency 5ms

Timing of Two Communicating Tasks

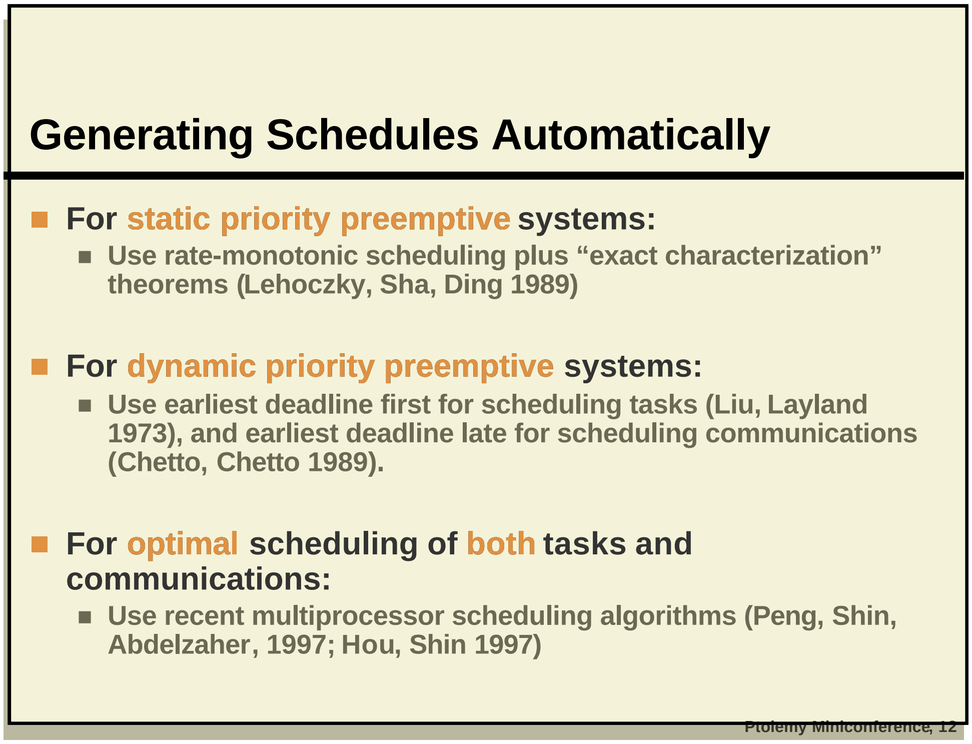


Mode Switches in Giotto



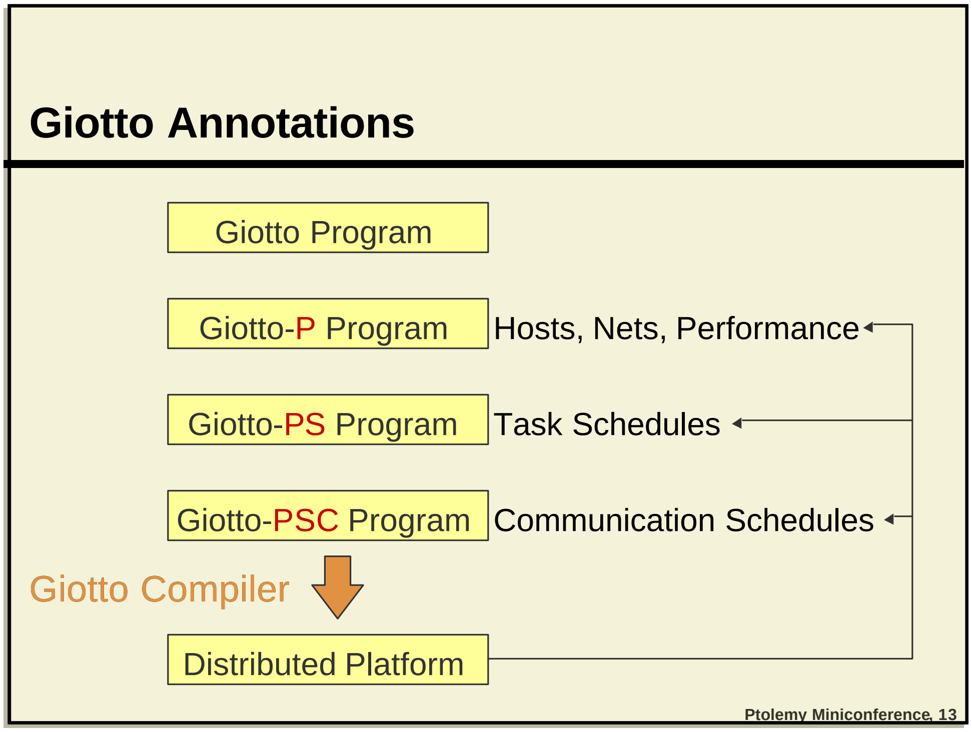


Timing of Mode Switch

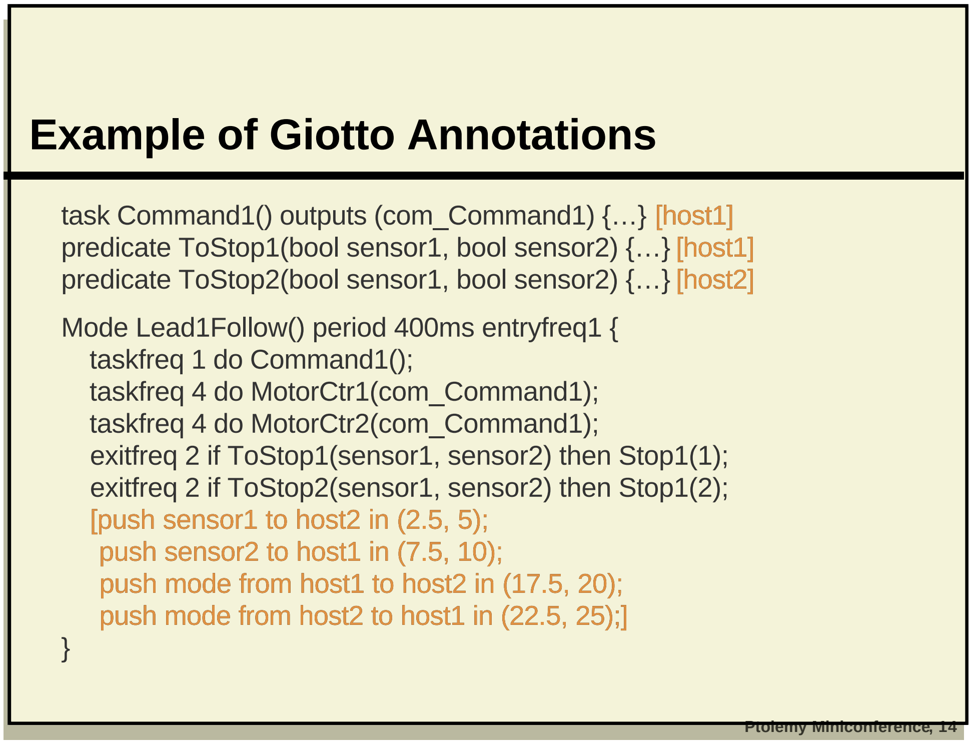


Generating Schedules Automatically

- For **static priority preemptive** systems:
  - Use rate-monotonic scheduling plus “exact characterization” theorems (Lehoczky, Sha, Ding 1989)
- For **dynamic priority preemptive** systems:
  - Use earliest deadline first for scheduling tasks (Liu, Layland 1973), and earliest deadline late for scheduling communications (Chetto, Chetto 1989).
- For **optimal** scheduling of **both** tasks and communications:
  - Use recent multiprocessor scheduling algorithms (Peng, Shin, Abdelzaher, 1997; Hou, Shin 1997)



Giotto Annotations



Example of Giotto Annotations

```
task Command1() outputs (com_Command1) {…} [host1]
predicate ToStop1(bool sensor1, bool sensor2) {…} [host1]
predicate ToStop2(bool sensor1, bool sensor2) {…} [host2]

Mode Lead1Follow() period 400ms entryfreq1 {
   taskfreq 1 do Command1();
   taskfreq 4 do MotorCtr1(com_Command1);
   taskfreq 4 do MotorCtr2(com_Command1);
   exitfreq 2 if ToStop1(sensor1, sensor2) then Stop1(1);
   exitfreq 2 if ToStop2(sensor1, sensor2) then Stop1(2);
   [push sensor1 to host2 in (2.5, 5);
    push sensor2 to host1 in (7.5, 10);
    push mode from host1 to host2 in (17.5, 20);
    push mode from host2 to host1 in (22.5, 25);]
}
```

Comparison with Synchronous Languages

- In spirit, Giotto is similar – allowing a precise semantic description of programs…
- …However:
  - Giotto is more of a “glue” language.
  - Giotto has more restricted scope (periodic tasks, flat mode structure).
  - But Giotto can better leverage real-time scheduling theory.
- Disadvantages of synchronous languages:
  - Esterel tasking mechanisms make it difficult to prove that Esterel programs meets their deadlines.
  - Lustre programs often underutilize CPU (lots of activity around tick, idle otherwise).

Comparison with Architecture Description Languages (ADLs)

- ADLs shift programmer’s perspective from small- to large-grained features.
- ADLs allow the automatic generation of code for task communication and scheduling.
- Giotto is particularly similar with MetaH (Vestal 1997):
  - Periodic tasks, multi-modal control, distributed and real-time implementations.
- Mode switches in Giotto are handled more cleanly than in MetaH.
- Giotto has an abstract semantics:
  - Does not constrain choice of scheduler.
  - Allows for optimal real-time scheduling.

For More Information…

- Visit http://www-cad.eecs.berkeley.edu/fresco/~giotto/
- … Or contact:
  - Ben Horowitz (bhorowit@cs.berkeley.edu)
  - Tom Henzinger (tah@eecs.berkeley.edu)
  - Christoph Meyer Kirsch (cm@eecs.berkeley.edu)
- … Or read:
  - Giotto: A Time-Triggered Language for Embedded Programming
  - Embedded Control Systems Development with Giotto.
    - (All papers are available at the above URL.)