Implementing Mixed Discrete-Continuous Models into Realtime Environments

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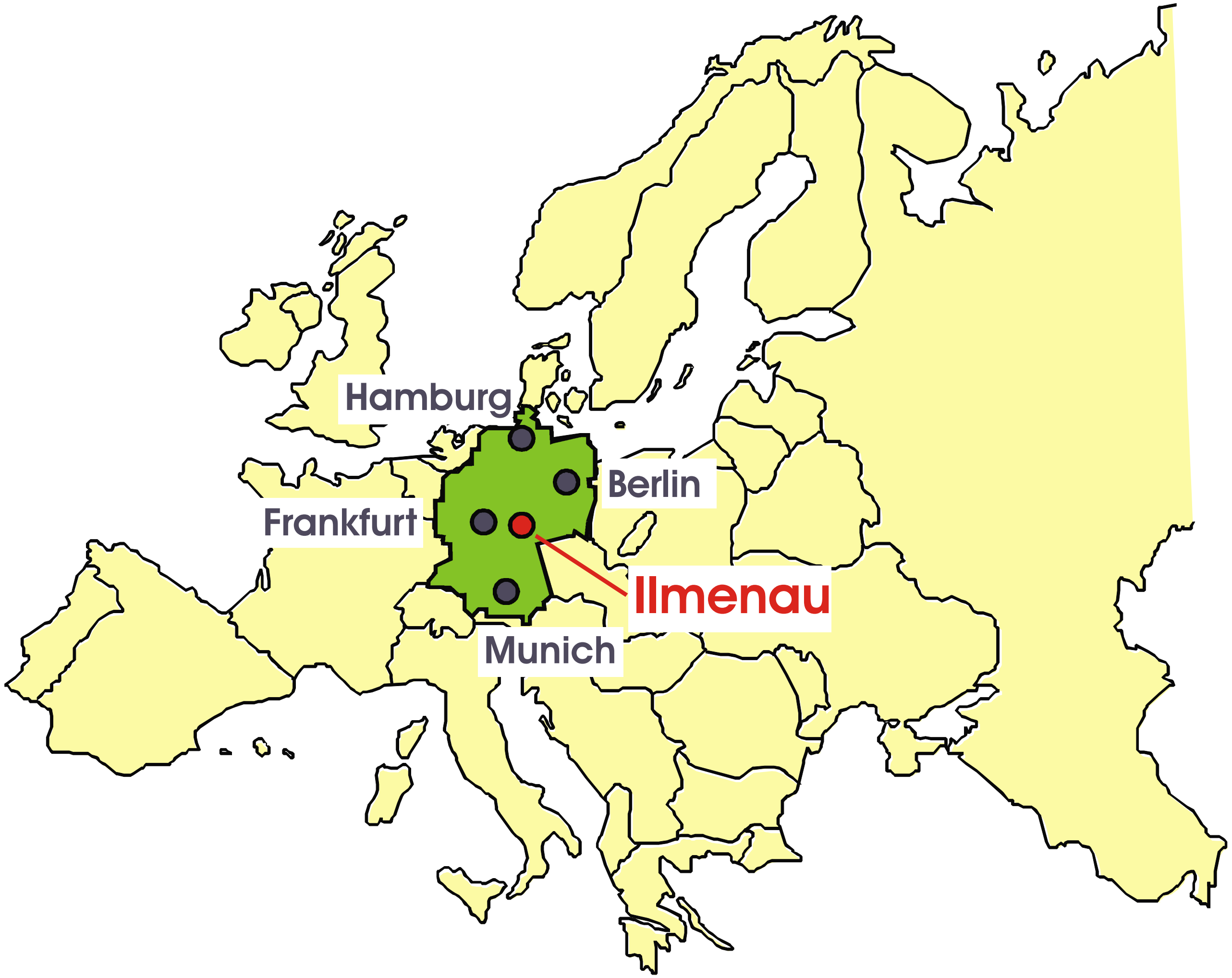
Where is Ilmenau?



Topics

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2. Modelling Environment
3. Requirements for Implementation
4. Scheduling Strategies
5. Signal Buffers
6. Delay Times
7. Partitioning the Model
8. Results and Conclusion

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1. Introduction

Model-Based Design:

- Software design or hardware-software codesign based on formal models
- Checking the model by analysis and simulation
- Avoiding some errors, optimizing the design

- Mixed-domain models desired:
  discrete-event and continuous-time

Implementation Issues

- Limited support for synthesis in many tools
- Conflicting demands of discrete and continuous parts (e.g. scheduling)
- Limited resources in target systems
  (e.g. performance, memory, file system, OS services)

Case study: Finding ways for implementation from a general-purpose modelling tool

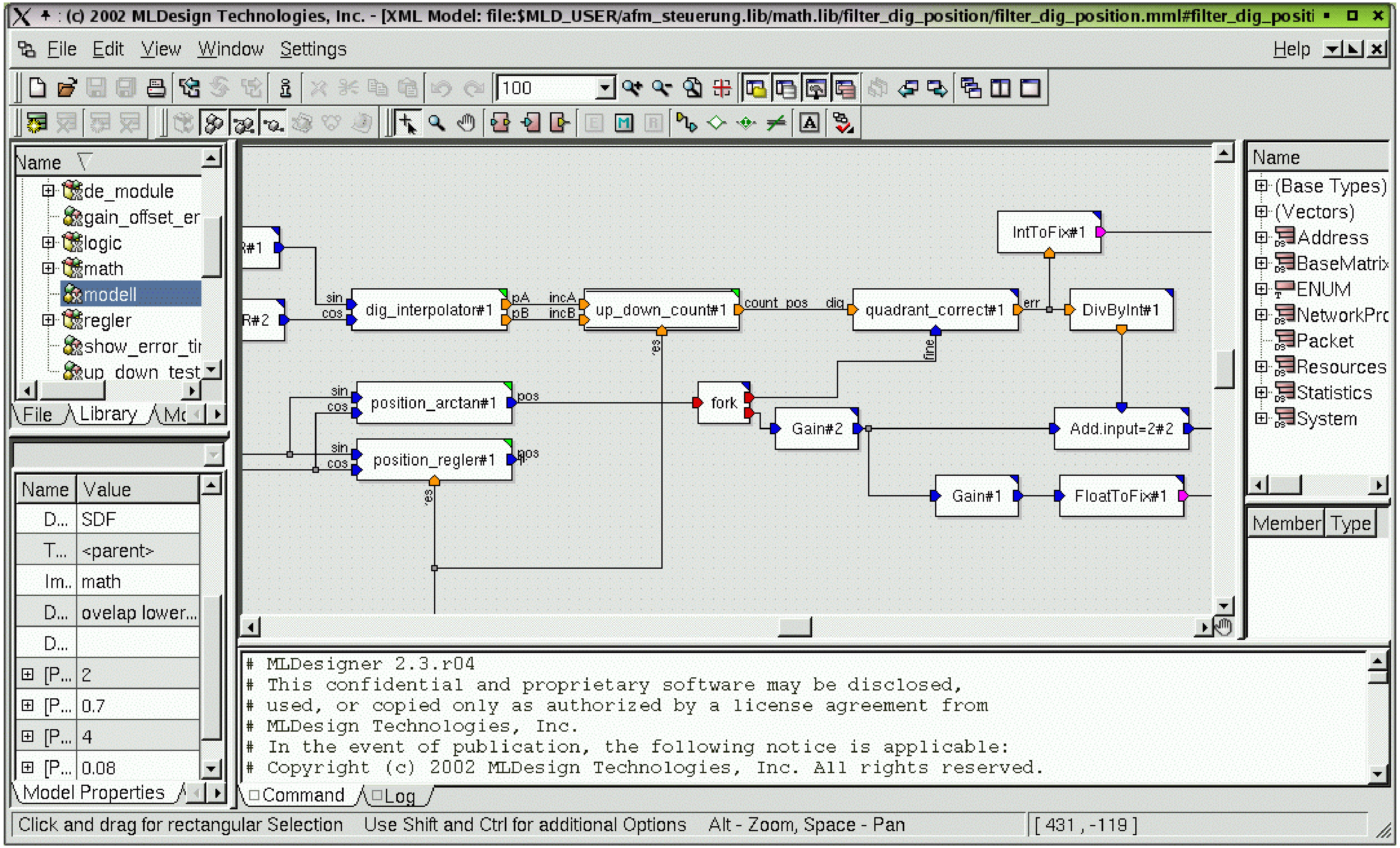
2. Modelling Environment

Modelling tool under consideration:

MLDesigner® from MLDesign Technologies, Inc.

- Hierarchical multi domain modeling framework
- Covers module, system and strategy levels
- Capabilities for simulation, design check, export
- Derived from well-known Ptolemy tool (University of Berkeley)

MLDesigner Sample Workspace



3. Requirements for Implementation

- Handle limited amount of memory
- Deal with real time requirements
  (e.g. response times)
- Adapt to existing runtime environment
  (scheduling, limited OS services)
- Deal with limited language support
  (e.g. C instead of C++)

Initial Restrictions

- Cannot be completely avoided
- Must be chosen carefully

In this study:

- No dynamically sized data
- Two modelling domains only:
  - **DE** (*discrete event*)
  - **SDF** (*synchronous data flow*, kind of continuous time)

4. Scheduling Strategies

- **Single-domain models:**
  Solutions derived from the tool's simulation system and from other sources
- **Mixed-domain models:**
  Solutions discussed for different wormhole hierarchies

Wormhole:

- Concept for nesting a model inside another of different domain
- Boundaries constitute syntactic and semantic interfaces

DE (Discrete Event) Scheduling

- Blocks fire on demand (when events arrive)
- Multitask system with one task per block
- Scheduling in fixed or random order
- Event propagation by message system

Chosen in study: Own round-robin mini scheduler
(for overhead reasons)

SDF (Synchr. Data Flow) Scheduling

- Blocks fire periodically at fixed rates
- Static schedules possible
- Optimize for: code size, data size, time overhead

Chosen in study: Monotonic-rate static scheduling
(available from operating system)

DE Wormholes inside SDF Models

- Periodic events force periodic activation of DE blocks
- DE blocks included in monotonic-rate scheduling
- Time consumption must be certain:
  Exclude uncertainty and infinity by model analysis.

SDF Wormholes inside DE Models

- SDF blocks fire aperiodically (on demand)
- Activation triggers one sequence of the wormhole‘s static schedule
- This sequence appears as just one task
- Periodic activation by explicit clock source only

Deeper Nested Wormholes

- SDF – DE – SDF - ...
  Monotonic-rate behavior is inherited from top level

- DE – SDF – DE - ...
  On-demand behavior is inherited from top level

➔ No extra scheduling policies needed.

5. Signal Buffers

Signal Buffering: At each block‘s inputs

Buffer properties desired:

- Fixed size
- Minimum size
- Static assignment
- Consecutivity

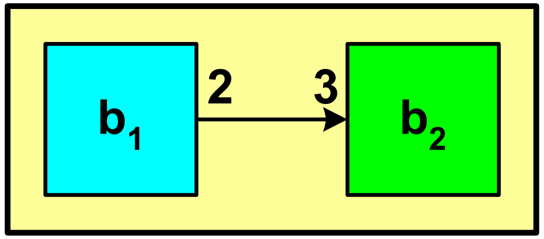
Buffer Sizes

- DE domain:
  Buffer sizes virtually infinite (random schedule)
  - ➔ Limiting size by rule

- SDF domain:
  Buffer sizes fixed (static schedule)
  - ➔ Properties affected by schedule chosen

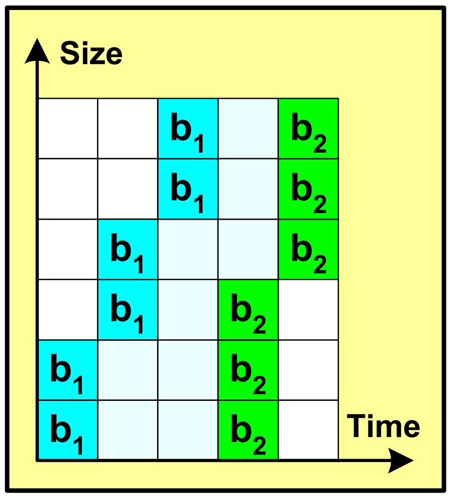
SDF Scheduling Affects Buffers (1)

SDF system:



Schedule **1**: $S_1 = \{b_1, b_1, b_1, b_2, b_2\}$

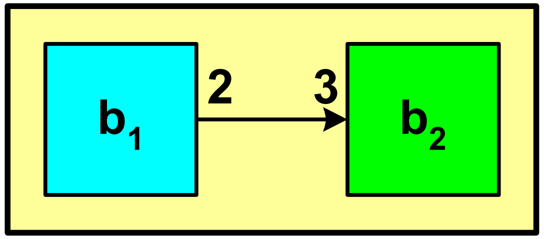
Buffer sequence:



- Size = 6
- Static
- Consecutive

SDF Scheduling Affects Buffers (2)

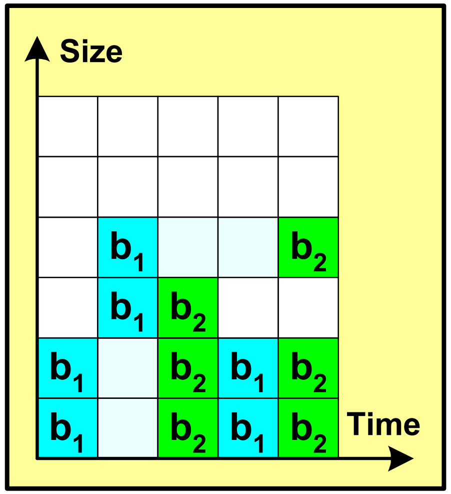
SDF system:



Schedule **2**:

$$S_2 = \{b_1, b_1, b_2, b_1, b_2\}$$

Buffer sequence:



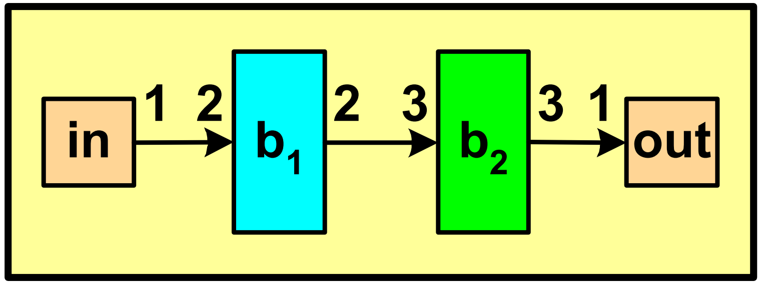
- Size = 4
- Static
- Not consecutive
- *Consecutivity by circular adressing*

6. Delay Times

- Rate monotonic input / output sampling:
  required for digital filters, control loops etc.
- Delay time: response from input to output
  (in SDF systems)
- Very important for closed loop control
  (stability!)
- Affected by schedule chosen

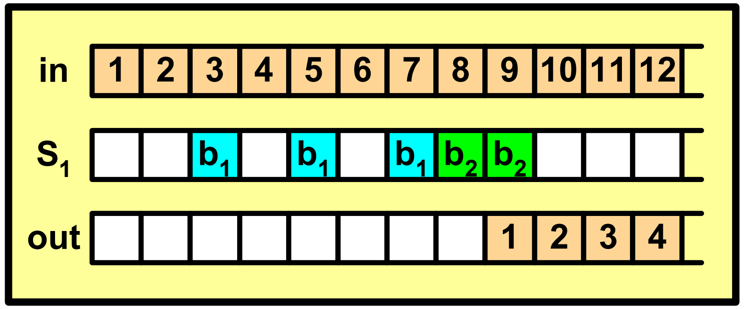
SDF Scheduling Affects Delay (1)

SDF system:



Schedule **1**: $S_1 = \{b_1, b_1, b_1, b_2, b_2\}$

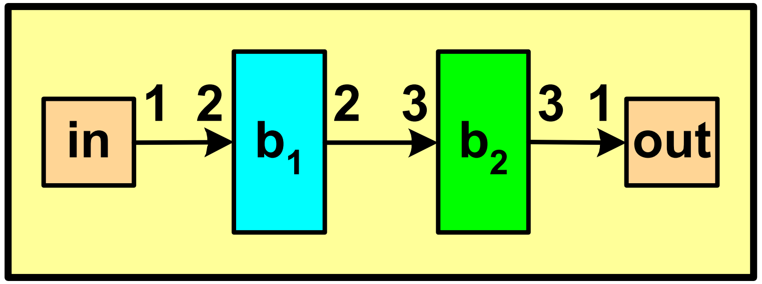
Timing diagram:



Delay = 8

SDF Scheduling Affects Delay (2)

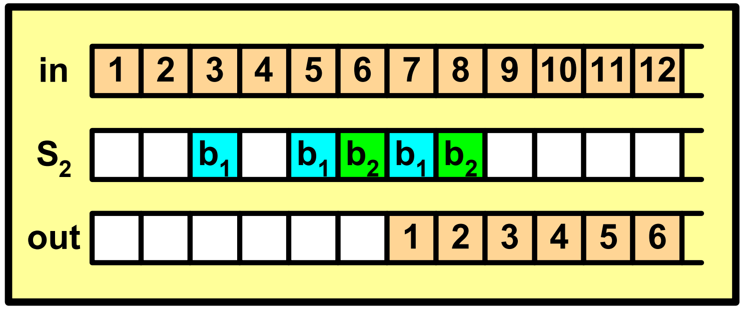
SDF system:



Schedule **2**:

$$S_2 = \{b_1, b_1, b_2, b_1, b_2\}$$

Timing diagram:



Delay = 6

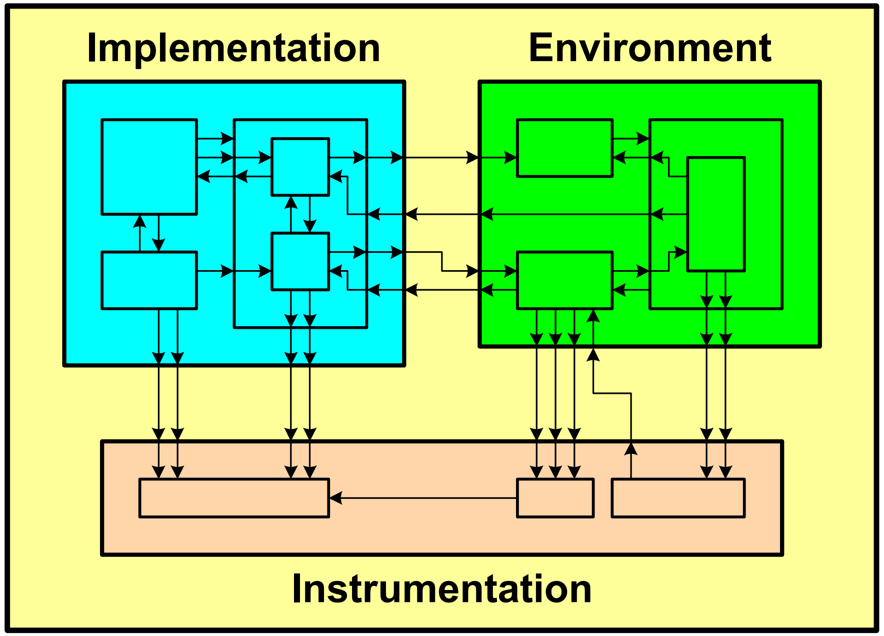
7. Partitioning the Model

Partitions:

- Implementation (Embedded system designed)
- Environment (Embedding process)
- Instrumentation
  (Observation and interaction during simulation)

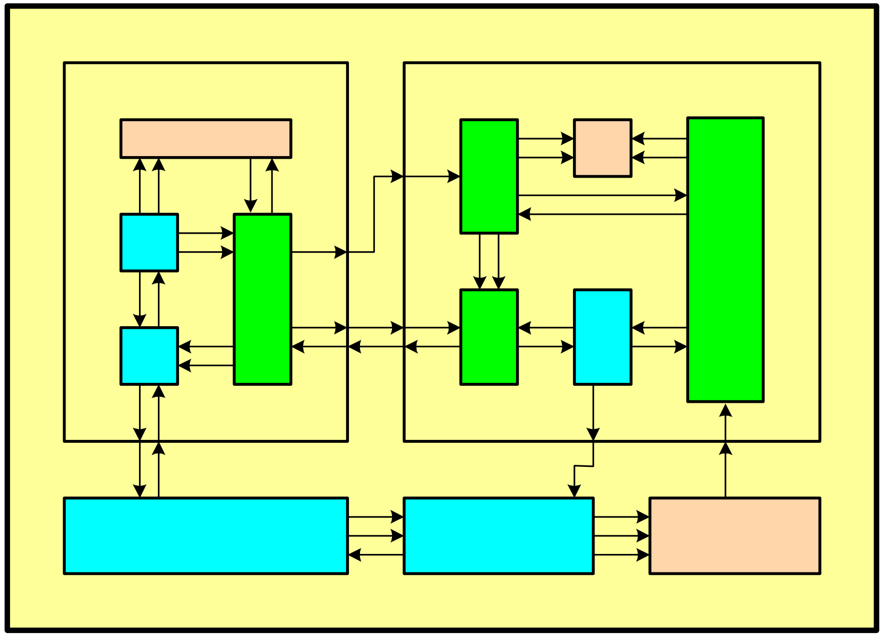
Several partitioning strategies are possible.

One Block per Partition



- Simple notation
- Simple derivation of the implementation‘s interface
- Poor structuring

Individually Flagged Blocks



- Notation requires tool modification
- Better changeable
- Good structuring

8. Results and Conclusion

- Case study: Several tests carried out
- Scheduling and buffer handling demonstrated
- Experimental implementation tool realized

Further work:

- Testing „individually flagged blocks“ approach
- Improvements and generalization of the implementation tool

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