SimSo: A Simulation Tool to Evaluate Real-Time Multiprocessor Scheduling Algorithms

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July 8, 2014

5th International Workshop on Analysis Tools and Methodologies for Embedded and Real-time Systems (WATERS)
1 Objective

2 SimSo

3 Example

4 Conclusion and Future Work
Objective

SimSo

Example

Conclusion and Future Work
Problem Definition

Independent and periodic tasks
Problem Definition

Independent and periodic tasks

Multiprocessor Architecture
Problem Definition

Independent and periodic tasks

Multiprocessor Architecture

Schedule

Objective
SimSo
Example
Conclusion and Future Work

SimSo: Simulation of Real-Time Scheduling
Many Real-Time Multiprocessor Scheduling Algorithms

Objective
To evaluate their behavior and performance.

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Many Real-Time Multiprocessor Scheduling Algorithms

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To evaluate their behavior and performance.
## Several Approaches

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SimSo: Simulation of Real-Time Scheduling
# Several Approaches

## Theoretical analysis

| Good way to prove schedulability, but hard to take into consideration some aspects |

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## Simulations

| Easy to use and very flexible but less accurate than a real system |
Several Approaches

**Theoretical analysis**
Good way to prove schedulability, but hard to take into consideration some aspects

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Realistic. But require a significant amount of time and skills to handle the tools and the results are specific to a certain platform

**Simulations**
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SimSo: A Simulator to Evaluate Scheduling Algorithms

SimSo\textsuperscript{1}:

- Simulator dedicated to the study of new scheduling algorithms.

\textsuperscript{1}Simulation of Multiprocessor Scheduling with Overheads
**SimSo**: A Simulator to Evaluate Scheduling Algorithms

- Simulator dedicated to the study of new scheduling algorithms.
- Designed to be easy to use, and also easy to extend for new needs.

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1Simulation of Multiprocessor Scheduling with Overheads
SimSo: A Simulator to Evaluate Scheduling Algorithms

- Simulator dedicated to the study of new scheduling algorithms.
- Designed to be easy to use, and also easy to extend for new needs.
- Open Source: http://homepages.laas.fr/mcheramy/simso/

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1Simulation of Multiprocessor Scheduling with Overheads
Two ways of using SimSo

Using the graphical user interface

- Configure a new system
- Save and load configurations (in an XML file)
- Simulate a configuration
- Display the resulting schedule as a Gantt chart
- Access usual metrics
Two ways of using SimSo

Using the graphical user interface

- Configure a new system
- Save and load configurations (in an XML file)
- Simulate a configuration
- Display the resulting schedule as a Gantt chart
- Access usual metrics

😊 Easy to use   😊 Good way to debug an algorithm

😢 Impossible to automate multiple simulations
sad May not give you the metric you are looking for
Two ways of using SimSo

Using it as a Python Module

- Generate a set of systems and launch their simulations from a script
- Collect raw data
- Use predefined methods to retrieve common metrics
- …or develop your methods to compute what you need.
Two ways of using SimSo

Using it as a Python Module

- Generate a set of systems and launch their simulations from a script
- Collect raw data
- Use predefined methods to retrieve common metrics
- ...or develop your methods to compute what you need.

😊 Very flexible

😀 Require to develop and learn the programming interfaces
Software Architecture

Discrete-Event Simulation

SimSo is based on SimPy, a process-based discrete-event simulator.
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**Main classes**

- **Scheduler**
  - `init()`
  - `on_activate(job)`
  - `on_terminated(job)`
  - `schedule(cpu)`
  - `schedule(job,cpu)`
  - Set and launch

- **Processor**
  - `on_activate(job)`
  - `on_terminated(job)`
  - `schedule(cpu)`

- **Task**
  - `launch`

- **Model**
  - `init()`
  - `launch`
  - “migration” event

- **Job**
  - `launch`
  - “activated” event
  - “terminated” event

- **Timer**
  - “timer” event

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- **Task**
  - `launch`
  - `run / interrupt`
  - `migration event`

- **Job**
  - `launch`
  - `run / interrupt`
  - `activated event`
  - `terminated event`

- **Timer**
  - `set and launch`
  - `run / interrupt`
  - `activated event`
  - `terminated event`

- **Process objects**
  - `init()`
  - `on_activate(job)`
  - `on_terminated(job)`
  - `schedule(cpu)`
  - `schedule(event)`
  - `set and launch`
Discrete-Event Simulation

SimSo is based on SimPy, a process-based discrete-event simulator.

Main classes

- **Model**
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  - `on_terminated(job)`
  - `schedule(cpu)`
  - `schedule(event)`
  - `launch()`
  - `migration()`
  - `run / interrupt()`
  - `activated(event)`
  - `terminated(event)`

- **Scheduler**
  - `Set and launch`

- **Processor**
  - `on_terminate(job)`
  - `on_activate()`

- **Task**
  - `launch`

- **Job**
  - `on_activate()`
  - `on_terminated()`

- **Timer**
  - `set and launch`

→ Create the objects and launch the simulation
Software Architecture

Discrete-Event Simulation

SimSo is based on SimPy, a process-based discrete-event simulator.

Main classes

![Diagram showing the main classes of SimSo: Scheduler, Model, Task, Job, and Timer.]

- **Scheduler**
  - init()
  - on_activate(job)
  - on_terminated(job)
  - schedule(cpu)
  - schedule event
  - migration event
  - Set and launch

- **Model**
  - launch

- **Task**
  - launch

- **Job**
  - run / interrupt
  - activated event
  - terminated event

- **Timer**
  - "timer" event

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SimSo: Simulation of Real-Time Scheduling
SimSo is based on SimPy, a process-based discrete-event simulator.

Main classes

- **Scheduler**
  - `on_terminated(job)`
  - `schedule(cpu)`
  - `schedule(cpu)`
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- **Processor**
  - `run/terminate`
  - `activated`
- **Job**
  - `run/terminate`
- **Task**
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  - launch
  - “migration” event
  - run / interrupt
- **Job**
  - launch
  - “activated” event
  - “terminated” event
- **Timer**
  - “timer” event

→ Control the state of the jobs (run/wait)
→ Call the methods of the scheduler
Discrete-Event Simulation

SimSo is based on SimPy, a process-based discrete-event simulator.

Main classes

- **Model**
  - `init()`
  - `on_activate(job)`
  - `on_terminated(job)`

- **Scheduler**
  - `schedule(cpu)`
  - Set and launch

- **Processor**
  - `schedule(event)`
  - `on_activate(job)`
  - `on_terminated(job)`

- **Task**
  - `run / interrupt`

- **Job**
  - `set up timers as in a real system`
  - `terminated` event

- **Timer**
  - `set up timers as in a real system`
  - `schedule` event
  - `timer` event
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**Main classes**

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  - `migration event`
  - `set and launch`

- **Processor**

- **Job**

- **Timer**

- **Model**
  - `launch`

- **Task**
  - `launch`

- **User-provided class that schedules the jobs**
SimSo is based on SimPy, a process-based discrete-event simulator.

- **Scheduler**
  - init()
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- **Task**
  - launch
  - “migration” event

- **Job**
  - launch

- **Timer**
  - “timer” event
SimSo offers multiple ways to simulate the computation time of a job:

- computation time of the jobs = their WCET
- random durations based on an ACET
- with fixed time penalty after a preemption and migration
- using cache models
- considering the speed of the processor (DVFS)
Execution Time Model

- Only one ETM for all the system.
- Each job informs the ETM of every change of state.
- The ETM determines the remaining execution time of the job.
- A job is terminated as soon as `get_ret` returns 0.
Writing a Scheduler

Interface

A scheduler for SimSo is a Python class that inherits from the abstract class `Scheduler`.

This class is loaded dynamically in SimSo and linked to the simulation core.
from simso.core import Scheduler

class G_EDF(Scheduler):
    """Global Earliest Deadline First"""
    def init(self):
        self.ready_list = []

    def on_activate(self, job):
        self.ready_list.append(job)
        # Send a "schedule" event to the processor.
        job.cpu.resched()

    def on_terminated(self, job):
        # Send a "schedule" event to the processor.
        job.cpu.resched()

    def schedule(self, cpu):
        decision = None # No change.
        if self.ready_list:
            # Look for a free processor or the processor
            # running the job with the least priority.
            key = lambda x: (1 if not x.running else 0,
                             x.running.absolute_deadline if x.running else 0)
            cpu_min = max(self.processors, key=key)

            # Obtain the job with the highest priority
            # within the ready list.
            job = min(self.ready_list,
                      key=lambda x: x.absolute_deadline)

            # If the selected job has a higher priority
            # than the one running on the selected cpu:
            if (cpu_min.running is None or
                cpu_min.running.absolute_deadline >
                job.absolute_deadline):
                cpu_min.running.absolute_deadline =
                job.absolute_deadline
                self.ready_list.remove(job)
                if cpu_min.running:
                    self.ready_list.append(cpu_min.running)
            # Schedule job on cpu_min.
            decision = (job, cpu_min)

        return decision
## Available Schedulers

### Uniprocessor
- RM, DM, FP, EDF, LLF, M-LLF, Static-EDF, CC-EDF

### Partitioned
- Any uniprocessor scheduler combined with various bin packing algorithms (Best Fit, First Fit, Next Fit, Worst Fit...)

### Global
- G-RM, G-EDF, G-FL, EDF-US, PriD, EDZL, LLF, M-LLF, U-EDF
- **PFair**: PD², ER-PD²
- **DP-Fair and BFair**: LLREF, LRE-TL, DP-WRAP, BF, NVNLF

### Semi-Partitioned
- EDHS, EKG, RUN
Generation of Tasksets

Task utilization

The following generators are available:

- RandFixedSum
- UUniFast-Discard
- and other generators

Task periods

The periods can be generated using:

- Uniform distribution
- Log-Uniform distribution
- Discrete uniform distribution
Generation of Tasksets

Use of an external generator

- When SimSo is used from a Python script, it is possible to manually create the tasks with any characteristics.
- It is also possible to generate an XML file compatible with SimSo.
Simulation

**Ready for simulation**
When a system is fully configured (tasks, processors, simulation parameters, etc.), it can be simulated.

**Speed**
SimSo is able to run thousands simulations per hour (depending on the scheduler and system configuration).
Simulation output

Output

The output of the simulation is a trace of the events that occurred.

Example of events: start of a job (together with its processors), interruption, resumption, scheduling decision, etc.

Analysis

It is possible to parse the trace to retrieve any specific metric.

But, in order to ease the retrieval of usual metrics, some functions are provided.
1 Objective

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**Objective**

To show how SimSo can be used to conduct an experiment on scheduling policies.

**Example**

Comparison of the number of preemptions and migrations in function of the number of tasks.

Studied Schedulers: G-EDF, NVNLF, EKG\(^2\), RUN and U-EDF.

\(^2\)with \(K=\)number of processors
Generation of the Configurations

Parameters

- Number of tasks: 20, 30, 40, 50, 60, 70, 80, 90, 100
- Number of processors: 2, 4, 8
- System utilization: 85%, 95%
- Periods: log-uniform distribution in [2, 100ms]
- Simulation on [0, 1000ms]
- Execution Time Model: ACET (average value=75% of WCET)

Simulations

For each configuration (tasks, processors, utilization), 20 tasksets are generated.
## Simulation

<table>
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<td>5400 simulations executed in $\sim$2 hours.</td>
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<th><strong>Collection of the results</strong></th>
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<td>The number of preemptions and migrations are extracted from each simulation and stored in an SQLite3 database.</td>
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Preemptions and migrations depending on the number of tasks. Results for 8 processors and a total utilization of 95%:
A few comments

- EKG generates a lot of migrations
- the results of NVNLF are getting better with more processors
- G-EDF gives the best results but a few jobs missed their deadline
- RUN acts as a partitioned scheduler with more than 30 tasks
- RUN and U-EDF results are good
Possible improvements

- EKG could do less migrations with a better choice of K and with other improvements
- the implementation of RUN could benefit from minor improvements (see paper about RUN presented at ECRTS)
- U-EDF could probably do better with clustering or with some improvements (eg. by using the idle times)
Current and Future Work

Improvement in SimSo

- Inclusion of other task models (e.g., task dependencies, sporadic tasks).
- Validation of the results regarding the use of cache models.

Experiments

- SimSo was used to run approximately 500,000 simulations.
- We are currently analyzing the results. In particular, many existing experiments were reproduced.
Conclusion

SimSo

SimSo is a simulator dedicated to the evaluation of scheduling algorithms.

Thanks to its design, it is easy to extend it to new models.

Schedulers

- Implementing a scheduler is simplified
- More than 25 scheduling algorithms were implemented
- SimSo is capable of handling partitioned, global and hybrid scheduling approaches.
Questions?

Thank you for your attention.