Background: The k²fS Project

Shortcut 'k²fS' stands for 'konfigurierbarer, komponentenbasierter, flexibler Scheduler', in English: 'configurable, component-based, flexible scheduler'.

Efficient scheduling is essential in high-tech production or service-oriented environments like laboratories. Using a workflow description language different jobs are scheduled in advance for automated systems being subjects to manifold timing and conditional constraints. Working plans are executed and monitored. The process is reactive to spontaneous events from the process and users' ad-hoc requests.

Due to configurable components the software may be adapted to different types of industry. The system may also be used in master-detail configurations, where different k²fS cooperate.

Our testing scenario includes semiconductor industry and a laboratory automation environment in chemical/pharmaceutical industry.

Next steps

- create a workflow description language (WDL) with TCMB constructs (under development);
- implement scheduling algorithms using workflows defined by our WDL;
- experiment with different algorithms with respect to TCMBs:
  - bottom-up versus top-down scheduling (direction in an activity tree, in which to propagate computed execution times),
  - propagation of times, delays, constraints etc. between different levels in an activity tree.

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Overview

One Idea

for two scheduling issues:
- Robustness against varying activity durations.
- Flexibility in expressing time dependencies of activities.

Purpose

Scheduling algorithms need a precise description of the scheduling problem:
- a crucial part of this description is the modelling of time dependencies between activities: it should
  - be flexible to be able to express all necessary kinds of time dependencies,
  - allow robust handling of activities with varying durations.

Methods

This is a conceptual work that models time dependencies in the laboratory automation domain.

Results

As a result the ‘time constraints by mutual boundaries’ (TCMB) approach

- expressively models
  - all kinds of delays between activities from a fixed time delay to a very flexible one;
  - arbitrary time dependencies between activities: sequential, parallel, or overlapping execution.
- is applicable to all levels in a master-detail hierarchy, too.

Conclusions

Semi-static Scheduling

There are two important aspects to be taken into account for achieving a good schedule: dynamic and static ones.

Dynamic Aspects

Say there is an activity with variability in its duration immediately followed by another one: the abstract workflow and the schedule (and its executor as well) then have dynamic properties. Without this dynamics it is impossible to model many interesting workflows.

Static Aspects

On the other hand there is the goal to keep reservation times of devices low: this needs as many fixed activity starting times as possible. Otherwise the dynamics from the previous point leads to more and more larger reservation times.

Solution

The TCMB approach allows to model workflows
- having dynamic properties during executing,
- while - at the same time! - having enough static properties for reaching a good scheduling result!

FF Relationships

To model FF (finish-to-finish) relationships of activities with variability in their durations an interval-like concept is necessary: it may not be known which activity finishes first, but in spite of this it could be interesting to say that both should finish within some time interval. The TCMB approach provides this feature: an example is the TCMB between the activities $A_4$ and $A_5$ in Formal Notation of an Abstract Workflow.

Master-Detail Modelling

The TCMB approach is applicable to two kinds of master-detail modelling:
- higher order activities in an activity tree consisting of lower level activities, and
- master and detail plans, whereas detail plans could be seen as activities in their master plan.

Higher Order Activities

Activities may be constructed from subactivities with finer granularity, these, as well, may be constructed from sub-subactivities and so on (see diagram below). At each level in such an activity tree TCMBs are the interconnectors and the limits $d_{min}$, $d_{max}$ are available to express variability in durations.

The diagram below shows a simple example: $A_1$, $A_2$, $A_3$, $A_4$, $A_5$ are master activities constructed from some detail activities shown inside them. In both hierarchy levels there are TCMBs connecting the activities.

Detail Plans as Activities in their Master Plan

If there are multiple schedulers working at different granularity a detail plan can be - if some conditions are met - an activity in its master plan.

For example imagine the following scenario:

Producing a whole television involves producing circuit boards in it. The circuit boards could be made by complex machines working according to detail plans, the assembly of the whole television could be made following a master plan then. Since usually there will be made many televisions in a factory, the circuit board detail schedule could and should be reused. So, using more time to find a good schedule for the detail plan, could increase productivity immensely, in this case.