Scheduling Processes with Release Times, Deadlines, Precedence and Exclusion Relations

J. Xu and D. L. Parnas
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Original paper

- Periodic processes in real-time systems
- Pre-run time scheduling
- Arbitrary release times, deadlines, precedence and exclusion relations
- NP-Hard problem
- Branch & bound approach used

Original paper contd.

- Terms:
  - Segments
  - Lateness
  - Feasibility and Optimality
  - Adjusted release time
  - Eligibility
Algorithm

- Initial solution using earliest-deadline first
- Root of the search tree
- Identify segment with maximum lateness
- Z[j]: Set of segments that affect the lateness of the latest segment j
- Calculate lower bound at the root
- Select a segment from Z[j] which when moved to the end will minimize the lateness

Algorithm (contd.)

- G_1: segments which can be preceded by j
- G_2: segments which can be preempted by j
- Successor nodes created for all nodes in G_1
- Appropriate relations are added to the schedule
- Initial solution, lowerbound and lateness calculated at each child node
- Branch and Bound until solution found

Impact

- First paper to consider the most general case of precedence and exclusion relations
- Acceptable performance for reasonably large problem sets
- Used in Air Information Management System for Boeing 777
Related paper 1
Optimal Combined Task and Message Scheduling in Distributed Real-Time Systems

- Pre-run time scheduling algorithm for distributed systems
- Integrated strategy for scheduling both tasks and messages in distributed real-time systems
- Algorithm: At the root
  - Initial schedule using EDF
  - Messages are prioritized according to the sum of the length of the receiving process and the difference between the send and receive times

(Reprint and Title, 6:00 [1995])

Related Paper 1 (contd.)

- Task graph created at root node to calculate adjusted release times and deadlines
- EDF scheduling done again to get complete schedule
- M: latest module, B: Busy period before M (same as II in original paper)
- Branching Functions
  - Set L: Exclusion relations between two modules in B replaced by precedence relations
  - Set M: Increment the priority of a message received by a module in B

(Reprint and Title, 6:00 [1995])

Related Paper 1 (contd.)

- Set N: Deadline of a remote predecessor of a module in B is reduced so that it has the same lateness as M
- Lower bound on lateness is used to bound the search tree
- Search ends when only one node, with a computed schedule, is left in the set of active vertices

(Reprint and Title, 6:00 [1995])
Related Paper 2
Scheduling Fault-Tolerant Distributed Real-Time Tasks Independently of Replication Strategies

Objective
- Scheduling real-time tasks independently of replication strategies (active or passive replication).

Requirements
- Tasks - synchronized using precedence relations.
- Determinism - enforced using ordering constraints.
- 1 and 2 should be satisfied for a scheduling algorithm to be independent of replication.

[Cherif and Badal, ET DSA 2006]

Related Paper 2 (contd.)
Ordering Constraints
- Identical order (IO) relation between two couples of elementary units (segments) that execute in the same site.
- Identical Order (eu, eu) IO (eu, eu)
- E(REP, gr)
  - gr - granularity at which fault-tolerance is applied.
  - Represent the set of all groups of segments that leads to non-deterministic execution.

[Cherif and Badal, ET DSA 2006]

Related Paper 2 (contd.)
- E(\{s, s, R\}); E - Union of E(REP, gr)
  - Set of all segments that use the replica R and are in site s and s.
  - (eu, eu, eu, eu) belongs to E(\{s, s, R\}) and exclusive request, then (eu, eu) IO (eu, eu) is added.

- Extension to Xu and Parnas' algorithm
  - Exclusion relation - segments in different sites.
  - Precedence relation - segments in different sites.
  - Ordering constraints.

[Cherif and Badal, ET DSA 2006]
Related Paper 3
Hybrid Online/Offline Scheduling for Hard Real-Time Systems

- Objective
  - To improve the utilization of the systems that require schedulability guarantees.
- Offline Scheduling
  - Periodic tasks using a modified version of Xu and Parnas' algorithm.
- Online Scheduling
  - Priority based scheduling technique for sporadic tasks.

[young and Shu, 1995]

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Related Paper 3 (contd.)

- Technical Overview
  - Rate monotonic task assignment – A periodic task should finish executing before its period.
  - Optimal allocation of idle times across different periodic tasks – using binary search algorithm
- Algorithm
  - Find a schedule using Xu and Parnas' algorithm.
  - If lateness $> 0$, no valid schedule.
  - Else distribute the idle time across task boundaries using binary search method.

[young and Shu, 1995]

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Related Paper 3 (contd.)

- Advantages of this approach
  - Not all tasks are scheduled offline (compared to pure offline scheduling).
  - Reduces semaphores and context-switch overhead (compared to pure online scheduling).
- Suggested improvements to Xu and Parnas' algorithm
  - Observation – Partial initial schedule vs Complete initial schedule.

[young and Shu, 1995]
Uncited paper

Optimal scheduling of cooperative tasks in a distributed system using an enumerative method

- To minimize the system hazard (maximum normalized task response time)
- Task graphs are used to describe precedence relations and message passing between modules
- Sets of preceded/dependent modules: \( \Omega_0, \Omega_1 \)
- Dominance properties (DPS)
  - \( \Rightarrow^p \)
  - \( \Rightarrow^g \)
  - \( \Rightarrow^n \)
- Used to generate immaterial sets (IM) of modules

[Pharr and Stine, TSE 1987]

Uncited Paper (contd.)

- Branch and bound approach used to schedule the dominant IM at all times
- Search continues until a complete schedule is determined
- Similarities/Extensions to original paper
  - Set of schedules generated at each node
  - Algorithm to compute lower bound similar to the one in the original paper
  - DPS take into account the aftereffects of scheduling a module, not just its deadline/response time

[Pharr and Stine, TSE 1987]

References