Analysing gCSP Models Using Runtime and Model Analysis Algorithms

Communicating Process Architectures 2009

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Introduction

Runtime Analysis Algorithm

Model Analysis Algorithm

Conclusions
CSP usage at Control Engineering

Modelling tool → gCSP

Par4 = REP_P || REP_C
REP_C = Seq_C; REP_C
Seq_C = Consumer1; Consumer2
Consumer1 = C1_Rd; C1_C
Consumer2 = C2_Rd; C2_C
REP_P = Seq_P; REP_P
Seq_P = Producer1; Producer2
Producer1 = P1_C; P1_Wr
Producer2 = P2_C; P2_Wr
• CSP usage at Control Engineering
  • Modelling tool → gCSP
    • Code generation for (robotic) controllers
      • Using Communicating Threads (CT) library
    • Debugging possibilities while running the code
      • Animating the model (processes and channels)
      • Stepping through model, while showing channel values
- Designer Point of View
  - Detailed modelling
  - Lots of small processes

- Executing Point of View
  - Fast code
  - A few bigger processes

- Both Points of View conflict!
- Translate Designer PoV to Executing PoV

- Requires
  - Analysis of the gCSP model
  - Model transformation

- Solution: two analysis algorithms
  - Runtime analysis for static ordering of processes
  - Model analysis for process scheduling
Contents

- Introduction
- Runtime Analysis Algorithm
  - Introduction
  - Algorithms
  - Results
- Model Analysis Algorithm
- Conclusions
- Why static ordering of processes
  - No complex scheduler required
  - Possibility for grouping of processes

- Goal of Runtime Analysis Algorithm
  - Find a static running order for the processes
- **Process states**
  - **New**  Process is created
  - **Ready**  Process is ready to be started
  - **Running**  Process is started and still running
  - **Blocked**  Process is blocked
  - **Finished**  Process is ended

- Algorithm mainly uses **Finished** state to determine the static running order
- Set of chains
  - Clear view of groups of processes
  - Cross-Reference types
    - To other chain
    - To start of same chain
  - Comparable with a CSP Trace

- Traces
  - Finished processes of running model
  - For demonstration purposes
- **Process Ordering Rules**
  - Chains with no cross-refs (the active chain is not finished yet)
    - Add processes to chain

- **Rules**
  - If the state of a process changes to *Finished* add it to the end of the active chain.
  - If a process is *Finished* and is already present in the active chain, it will become a cross-reference of this chain pointing to a chain starting with this process.

```
A → B → C → B → D → E → F → B
```

```
B → D → E → F → (B*)
[start] → A → B → C → (B)
```
Process Ordering Rules

- **Chains with cross-refts (the active chain got finished already)**
  - Perform validation on chains

**Rules**

- If the active process does not match the *Finished* process the chain must be split.
- Set of chains as expected
  - All processes could be placed in one big process
    - Writer-Reader combinations can be removed
    - Channels become internal variables

P1_C → C1_Rd → C1_C → P1_Wr → P2_C → P2_Wr → C2_Rd → C2_C → (P1_C*)
[start] → (P1_C)
- Scalability of the algorithm
  - Complex traces
    - Hard to verify results
  - Static ordering available

- Working Cartesian plotter model
Working Cartesian plotter model

1. \( \text{Sc}_\text{Rd}8 \rightarrow \text{DoubletoBooleanConversion} \rightarrow \text{Sc}_\text{Wr}17 \rightarrow \text{Sa}_\text{Wr}8 \rightarrow \text{Sa}_\text{Rd}4 \rightarrow \text{MC}_\text{Wr}4 \rightarrow \text{Sa}_\text{Rd}7 \rightarrow \text{MC}_\text{Wr}7 \rightarrow \text{Sa}_\text{Rd}6 \rightarrow \text{MC}_\text{Wr}6 \rightarrow \text{Sa}_\text{Rd}5 \rightarrow \text{MC}_\text{Wr}5 \rightarrow \text{Sa}_\text{Rd} \text{ESX2}_2 \rightarrow \text{Sa}_\text{Rd} \text{ESX2}_1 \rightarrow \text{Sa}_\text{Rd} \text{ESX1}_2 \rightarrow \text{Sa}_\text{Rd} \text{ESX1}_1 \rightarrow \text{MC}_\text{Rd}12 \rightarrow \text{MC}_\text{Rd}13 \rightarrow \text{Safety}_X \rightarrow \text{Sa}_\text{Rd} \text{ESY1} \rightarrow \text{Sa}_\text{Rd} \text{ESY2} \rightarrow \text{Safety}_Y \rightarrow \text{Safety}_Z \rightarrow \text{MC}_\text{Rd}1 \rightarrow \text{MS}_\text{Wr}1 \rightarrow \text{MC}_\text{Rd}2 \rightarrow \text{MS}_\text{Wr}2 \rightarrow \text{Sa}_\text{Wr}9 \rightarrow \text{Sc}_\text{Rd}9 \rightarrow \text{MC}_\text{Rd}3 \rightarrow \text{LongtoDoubleConversion} \rightarrow \text{Controller} \rightarrow \text{MS}_\text{Wr}3 \rightarrow \text{Sc}_\text{Rd}10 \rightarrow \text{Sa}_\text{Wr}10 \rightarrow \text{(Sc}_\text{Rd}11) \)

2. \( \text{Sc}_\text{Rd}11 \rightarrow \text{DoubletoShortConversion} \rightarrow \text{Sc}_\text{Wr}14 \rightarrow \text{Sc}_\text{Wr}15 \rightarrow \text{Sc}_\text{Wr}16 \rightarrow \text{Sa}_\text{Wr}11 \rightarrow \text{(Sc}_\text{Rd}8, \text{HPGLParser}) \)

3. \( \text{MC}_\text{Rd}12 \rightarrow \text{MC}_\text{Rd}13 \rightarrow \text{Sa}_\text{Rd} \text{ESX2}_2 \rightarrow \text{Sa}_\text{Rd} \text{ESX2}_1 \rightarrow \text{Sa}_\text{Rd} \text{ESX1}_2 \rightarrow \text{Sa}_\text{Rd} \text{ESX1}_1 \rightarrow \text{MC}_\text{Rd}1 \rightarrow \text{MS}_\text{Wr}1 \rightarrow \text{Safety}_X \rightarrow \text{Sa}_\text{Rd} \text{ESY1} \rightarrow \text{Sa}_\text{Rd} \text{ESY2} \rightarrow \text{Safety}_Y \rightarrow \text{Safety}_Z \rightarrow \text{MC}_\text{Rd}2 \rightarrow \text{MS}_\text{Wr}2 \rightarrow \text{MC}_\text{Rd}3 \rightarrow \text{LongtoDoubleConversion} \rightarrow \text{Controller} \rightarrow \text{MS}_\text{Wr}3 \rightarrow \text{Sa}_\text{Wr}9 \rightarrow \text{Sc}_\text{Rd}9 \rightarrow \text{Sc}_\text{Rd}10 \rightarrow \text{Sa}_\text{Wr}10 \rightarrow \text{(HPGLParser)} \)

4. \( \text{HPGLParser} \rightarrow \text{(MC}_\text{Rd}12, \text{Sc}_\text{Rd}11) \)

\[ \text{[start]} \rightarrow \text{MC}_\text{Rd}12 \rightarrow \text{MC}_\text{Rd}13 \rightarrow \text{HPGLParser} \rightarrow \text{MS}_\text{Wr}1 \rightarrow \text{MC}_\text{Rd}1 \rightarrow \text{MC}_\text{Rd}2 \rightarrow \text{MS}_\text{Wr}2 \rightarrow \text{MC}_\text{Rd}3 \rightarrow \text{LongtoDoubleConversion} \rightarrow \text{Controller} \rightarrow \text{MS}_\text{Wr}3 \rightarrow \text{MC}_\text{Wr}5 \rightarrow \text{Sa}_\text{Rd}5 \rightarrow \text{MC}_\text{Wr}6 \rightarrow \text{Sa}_\text{Rd}6 \rightarrow \text{MC}_\text{Wr}7 \rightarrow \text{Sa}_\text{Rd}7 \rightarrow \text{MC}_\text{Wr}4 \rightarrow \text{Sa}_\text{Rd}4 \rightarrow \text{(HPGLParser)} \]
- Introduction

- Runtime Analysis Algorithm

- Model Analysis Algorithm
  - Introduction
  - Algorithm
  - Results

- Conclusions
More towards model analysis/ model transformation
- What processes are related?
- How to schedule large models onto a target system?

Goal
- Schedule processes on cores/ networked nodes
- Algorithm Architecture
  - Build modular

- gCSP model & User Interface feed the algorithm with data
  - Process weights (or execution times)
  - Available cores or networked nodes
  - Communication (setup) time
- **Model Tree Creator**
  - Recreates the model tree
  - Only for displaying purposes for the user interface

- **Dependency Graph Creator**
  - Finds dependencies between processes
    - Sequential relations
    - Channels

- **Critical Path Creator**
  - Finds the critical path using the dependencies
- **Heaps**
  - Groups of ‘related’ processes
  - Influenced by
    - Process weight
    - Communication (setup) time
  - Reduce complexity of core scheduler

- **Index blocks**
  - Subdivision of heaps
  - When multiple outgoing dependencies are available
- **Cores**
  - Groups of processes to be scheduled on the same core/networked node
  - Find optimum for end time
    - Amount of cores
    - Relative speed of cores
The processes are optimally scheduled
- For the given process weights
- For the given communication times
- For the given target systems (mostly)

Scalable for models of real-life setups
- Cartesian plotter model
- Production cell model
  - 597 Processes
  - 210 Heaps
  - ~50 Cores for optimal ending time
Model Analysis Algorithm Results
• Introduction

• Runtime Analysis Algorithm

• Model Analysis Algorithm

• Conclusions
Both analysis algorithms work as expected
- Functional
- Scale well

Both analysis algorithms complement each other
- Runtime analysis algorithm
  - Groups processes into bigger processes
  - Reduces the amount of context switches
- Model analysis algorithm
  - Schedules processes onto multiple cores
  - Reduces the amount of network communication
- Both reduce execution time
  - Without losing concurrency aspects
Recommendations

- Refinements are necessary
  - Better representation of the results
  - Include more CSP constructs
  - Support for allocating specific processes on a core
  - Better support for networked nodes

- Next steps
  - Include model transformations after the analysis phase
  - Implement the algorithms in the gCSP2 tool
The active chain should be split at process B when process p is unexpected, but a chain starting with process B is present.

- Compare the processes after B with the chain starting with process B \( \rightarrow \) equal!
- Remove the remaining process (E) in the active chain starting at process B.
- Add the cross-references (G) to the chain starting with B if they are not present at this chain.
- Create a new chain starting with I and make it the active chain.

\[
\begin{align*}
G & \rightarrow H \rightarrow B \rightarrow D \rightarrow (G^*) \\
E & \rightarrow F \rightarrow (B) \\
B & \rightarrow D \rightarrow (E,G) \\
A & \rightarrow B \rightarrow C \rightarrow (B)
\end{align*}
\]
- 56 processes
- 10 heaps
- ~4 cores

- 1 core is almost optimal
- **gCSP2**
  - Eclipse based
  - Much more stable compared to gCSP