Projection of Message Sequence Chart (MSC)

To ABSTRACTION and BEYOND!

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MSCs: **graphical** specifications of communication protocols
(norm of Int. Telecomm. Union)

Ex: RMTP2 (send data on a tree)

1 PARENT sends new DATA to CHILDREN.

2 Each CHILD sends HACK (acknowledgement).

3 If PARENT does not receive quickly all HACK
   Then PARENT RESEND DATA and Goto 2

```
→ early verification
```

I  Definition MSC & Projections
II  Representation of MSC-graph projection
III Algorithms for MSC-graph projection
Definition of MSC [ITU Z120]

Partial order on events a, b, c…

f incomparable with d

Each process: total order

a < c < g < h

FIFO channels (no overtaking)
Definition of MSC-graph [Z120]

\[ L(G) = \text{set of MSC labeling accepting paths of } G \]
Projection of MSC-graphs

MSC-graph specification:
- Collection of scenarios (wanted / unwanted)

Projection = Hide some parts (usually whole processes)
- To run algorithms faster
- For a good understanding of interactions (abstraction of unnecessary parts)
Abstraction for Automata

Transitions are crucial
Abstraction of MSC with MSC Projection

Messages/Ordering is crucial

\[
\begin{align*}
a & \parallel b \\
d & \parallel b \\
a & < c & (a < y < c)
\end{align*}
\]
Abstraction of MSC-graph

\[ \Pi(G) \]

\[ L(\Pi(G)) = \text{set of projected MSC labeling accepting paths of } G \]
Problem of projecting MSC

MSC projections are not MSC

Multitype event
Problem of projecting MSC-graph

Infinite non-decomposable MSC in L(G)
projection of MSC-graph ≠ MSC-graph
Problem of projecting MSC-graph

Not possible with MSC-graph
Representing MSC-graph projection

Goals:

- To understand what happens
- To try to compact representation

Actual representation:

- Implicit
- The whole HMSC & the projected events

Solution: Representation with MSC-based specification

→ compositional MSC-graph
Definition of compositional MSC [GMP01]

MSC ⊊ compositional MSC
Composition of compositional MSC [GMP01]

Because of FIFO

Compositional MSC-graph more powerful than HMSCs (undecidability results)
Definition of comp.MSC-graph [GMP01]

$L(G) = \text{set of (complete) MSCs labeling accepting paths of } G$
Why compositional MSC-graph?

We can do this with compositional MSC-graph
Comp. MSC-graph $\not= \ MSC$-graph projection

More processes needed
Comp. MSC-graph $\not\subseteq$ MSC-graph projection

More processes needed
Claim: few delayed messages in MSC-graph projection
MSC-graph projection \( \subset \) compo. MSC-graph

**Theorem [GHM03]:** We can effectively transform

MSC-graph projection \( G \rightarrow \) compo MSC-graph \( H \).

**Properties:**

- \(|H|\) exponential in nb\_unmatched\_send

- In any factor of \( H \),
  
  \( \text{nb\_unmatched\_send} < \text{nb\_processes}^2 \)
MSC-graph projection \( \subseteq \) compo. MSC-graph

**Proof:**

- We know exactly events, not type
  - Guess the type on the fly
  - Check whether guess is correct

![Diagram showing proof steps](image)
\[
\text{nb\_unmatched\_sends} < \text{nb\_processes}^2
\]

Proof:

\[
\text{Proc\_in\_Future}(a) = \{1,2,3,4\}
\]
\[
\text{Proc\_in\_Future}(b) = \{1,2,3,4\}
\]
\[
\text{Proc\_in\_Future}(c) = \{1,3,4\}
\]
\[
\text{Proc\_in\_Future}(d) = \{1,3\}
\]

\[a < b < c < d\]

\[\text{a can match no more event}\]
Realizable compositional MSC-graph

Theorem [GHM03]: MSC-graph projection coincide with compositional MSC-graph where nb_unmatched_send are bounded

(Realizable in [GMP01])
Realizable compositional MSC-graph

Realisable

realisable

not realisable

not realisable
Algorithms for projection of MSC-graph

No known algorithms for realizable compositional MSC-graph

Ideas:

- If possible, transform Realizable compo $\rightarrow$ MSC-graph
  Then apply algorithms for MSC-graph

- Devellop new algortihms for Realizable compo.
  when transformation not possible
  or MSC-graph too big
Definition of Atoms [HL00]

Non atomic = decomposable MSC

Atoms = prime MSC
Atoms = strongly connected component of CG
A is atomic if any last event reaches all first in CG
### Properties of Atoms: Powerful

<table>
<thead>
<tr>
<th></th>
<th>Events</th>
<th>Nodes</th>
<th>Atoms</th>
<th>Prime Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>comutation</td>
<td>semi &amp; partial (Traces)</td>
<td>partial (Traces)</td>
<td>partial (Traces)</td>
<td>total</td>
</tr>
<tr>
<td>Decomp of an MSC</td>
<td>unique</td>
<td>not unique</td>
<td>unique</td>
<td>unique</td>
</tr>
<tr>
<td>Member</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>decompose</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>Sub exponent</td>
</tr>
</tbody>
</table>
From projection of MSC-graph to MSC-graph

Th[GHM03] A Realizable compo MSC-graph equivalent to HMSC iff atoms are finite

Th[GHM03] Atoms of a projection MSC-graph form a regular language

Size: exponential in size of pHMSC or rcHMSC
Test: PSPACE & co-NP-hard
Atoms is a regular Language

Proof

- Guess where the suppose atom starts and end.
- On the fly, Check whether Any last event reaches all first events in CG

We just need unmatched sends what they see
Th[GHM03] If atoms of are in finite number, we can transform projection MSC-graph → MSC-graph

\begin{align*}
nb\_atoms \leq 2^{\text{size\_biggest\_atom}}
\end{align*}

**Size:** Exponential in size\_biggest\_atom.
Proof:

Atoms: sr

Because of processes
From projection of MSC-graph to MSC-graph

Technical Lemma[GHM03]:
\[ \text{Nb\_subpaths} \leq \text{size\_biggest\_atom} \times \text{nb\_unmatched\_send} \]

Proof
Algorithms for projection of MSC-graph

- If possible, transform Realizable compo $\rightarrow$ MSC-graph
  Then apply algorithms for MSC-graph
  Checked

- Develop new algorithms for Realizable compo.
  when transformation not possible
  or MSC-graph too big
Model Checking versus MSC-graph

Negative property

Model

\( \neg \emptyset ? \)
Model Checking MSC-graphs

[AY99] // [MP99]: Undecidable for MSC-graphs
Model Checking MSC-graphs: Decidability

Bounded MSC-graphs:
Communication graph of each loop is strongly connected

Th[AY/MP'99]: PSPACE-complete for bounded MSC-graph

Proof: Trace theory applied on sequence of events
Automaton representing $L(G)$ of exponential size
Model Checking MSC-graphs: Decidability

Globally-Connected MSC-graphs:
Communication graph of each loop is weakly connected

Th[GMSZ02]: PSPACE-complete for Globally-Cooperative HMSCs

Proof: Trace theory applied on atoms. Automaton representing representative for L(G) of exponential size
Then $H \cap G = \emptyset$ is PSPACE-complete

Proof: Build $G'$ recognizing sequences of atoms of $H$ that label paths of $G$
Apply known results on globally-cooperative.
Algorithms for projection of MSC-graph

Th[GHM03]: H bounded MSC-graph, H’ a projection of H
G projected MSC-graph

Then H’ ∩ G = ∅ is PSPACE-complete

Proof: The projection of automaton representing L(H)
= automaton representing H’.
Linearise G into an automaton.
Apply known results on automaton.
Conclusion

We have shown

- projection = realizable compositional MSC-graph

- How to build *compositional* from projection of MSC-graph.

- Representation for atoms of any projection MSC-graph

- How to build MSC-graph from pHMSC when possible

- How to Model-check projections of MSC-graph (abstraction) in many cases