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Presentation based on
Unreliable Channels are Easier To Verify Than Perfect Channels
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Communicating Finite-State Machines

- Are finite-state automata,
- Communicating through channels that are
  - unbounded,
  - fifo,
  - perfect (no losses, no duplications, no insertions).

Product Automaton

After combination, study on only one machine.

CFSMs, Formally

A machine is noted

\[
(S, C \cup \sum_a, x, \delta)
\]

with

\[
\delta \subseteq S \times \bigcup_a \{c ? a, c ! a \mid a \in \sum_a \} \times S
\]

Configurations are in \(G(M)\) set of:

\[
\{s, x_1, \ldots, x_n\} \text{ with } x_i \in \sum_a^*
\]

Problems of Interest

- With \(R(M)\) the set of reachable configurations of \(M\),
- Reachability: does \(\langle s, x_1, \ldots, x_n \rangle\) belong to \(R(M)\)?
- Deadlock: has \(\langle s, x_1, \ldots, x_n \rangle\) any successor?
- Boundedness: is \(R(M)\) finite?
- Others: finite termination, computation of \(R(M)\), model-checking against CTL*,
- Think about distributed software verification!

But... [BZ83]

- CFSMs are Turing-Powerful
- Mark the first and last cell by a symbol.
- Add a symbol "&" to mark the head.
- Advance one cell is:
  - receive \(s\),
  - if \(s\) is not "&" then emit \(s\) and \(s' = s\)
  - else emit & and emit \(s'\).
- read the list until end symbol, emit symbol.
- Write and go-back are similar.
- Every problem of interest is undecidable!
Unreliable Channels

- Unreliable channels can:
  - lose messages, or
  - duplicate messages, or
  - insert new messages, or
  - a combination of all the above.

Lossy Channels [AJ94]

- Can lose any message.
- Subwords: \( x \leq y \) if \( x = a_1 \ldots a_n \) and \( y = y_1 \ldots y_m \) with \( y \subseteq x \)
- Closure: \( closure(x) = \{ z \in \Sigma^* \mid x \leq z \} \)
- Higman's theorem (1952):
  - There is no infinite set of words \( W \) such that all members of \( W \) are pairWise incomparable.
  - In particular, there is no infinite chain \( W_1, W_2, \ldots \)
  - of upward-closed sets of words.
  - For \( \Gamma \subseteq G(M) \) then the set of predecessors of \( \Gamma \)
  - forms an upward-closed chain. Hence it is finite.
  - A new proof is given.

Duplication Machines

- It is shown that they are Turing expressive.
- Modify the machine so that:
  - each symbol is followed by \( \# \),
  - \( \# \) is not in the alphabet of the machine.
- One can build an homomorphism from modified to plain machines.
- It is shown that one can build a "squeeze repeats" homomorphism from duplication machines to modified machines.

Insertion Machines

- It is shown that:
  - Since one can insert symbols everywhere on the tape, channel languages are upward-closed.
  - Hence:
    - The reachability problem is solvable.

Combination of Errors

- Insertion and Lossiness are "stronger" than duplication.

Questions?

Thank You!
References