Discovering Security Protocol Attacks by Refuting Incorrect Conjectures

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Finding attacks on faulty protocols tricky

Model checking and other state-exploration approaches used

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Result:

Some attacks outside scope, e.g. Paulson attack on simplified Otway Rees.

Some protocols outside scope, e.g. conference key protocols

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Paulson and Bella

Protocols formalised in HOL as traces

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BUT: No support for non-theorem detection

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Many applications

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A more sophisticated method is ‘Proof by Consistency’

Proof by Consistency

Developed by Musser (1980), Huet & Hullot (1982), Kapur & Musser (1987), Jouannaud & Kounalis (1986), Bachmair (1988), Ganzinger & Stuber (1993) and others.

Conjecture C is an inductive consequence of E

if and only if:

C is consistent with equations E in standard model.

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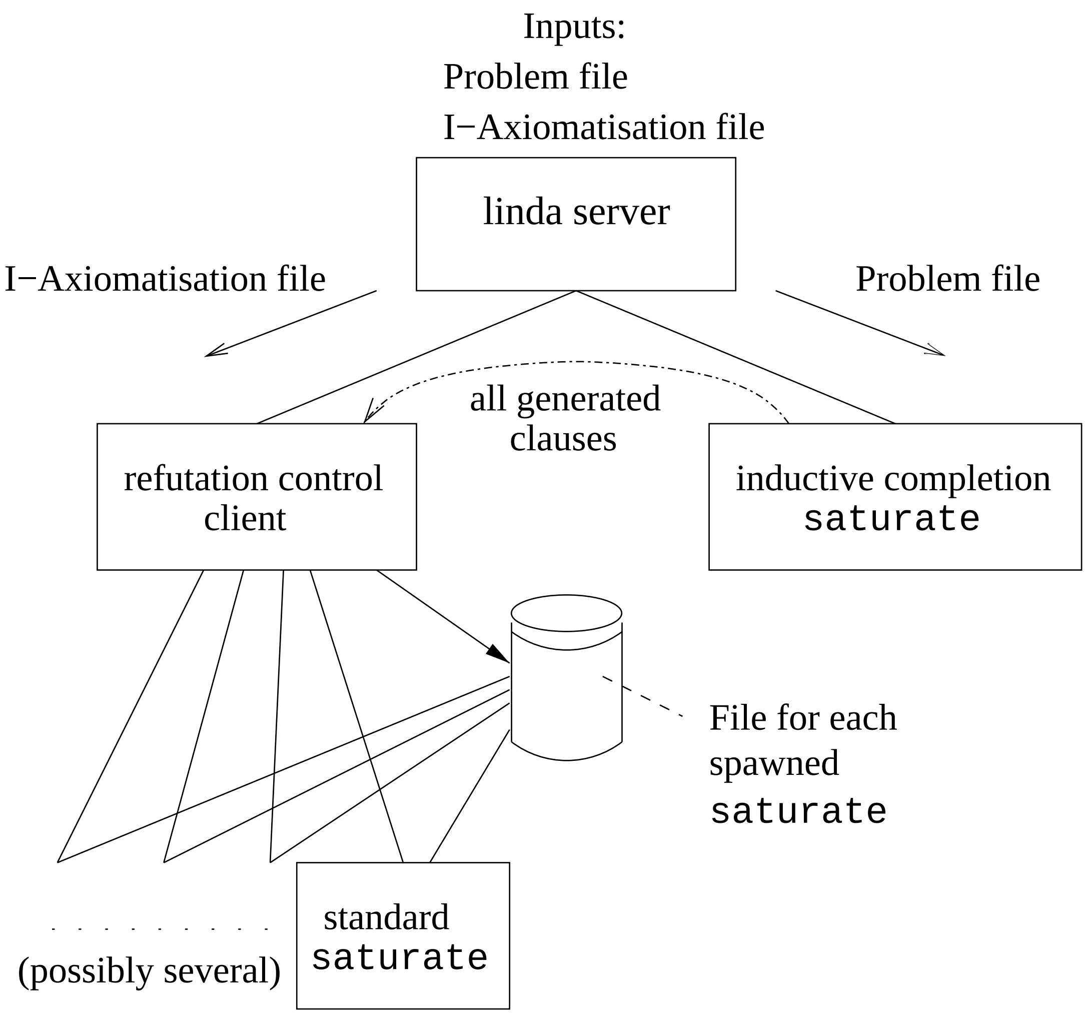
Re-cast by Comon and Nieuwenhuis (1999): can handle non-equational case, non-convergent specs., free or non-free constructors, and is refutation complete.

Two stage approach: I-Axiomatisation + First-order consistency


Inputs:
Problem file
I−Axiomatisation file
linda server
I−Axiomatisation file
Problem file
all generated
clauses
refutation control
client
inductive completion
saturate
File for each
spawned
saturate
. . . .
(possibly several)
standard
saturate

Protocol Model

Aim is first-order version of Paulson’s model

Lists for traces, sets for intruder knowledge, arbitrary numbers of agents, nonces, keys, etc.

Free constructors, so can define equality completely

This allows us to keep it Horn

- by defining both $member(x,l) = true$ and $member(x,l) = false$.

Early Results

Clark and Jacob attack

$$1.\ A \longrightarrow B : \{\!|\, N_A \,|\!\}_{K_{AB}}$$
$$2.\ B \longrightarrow A : \{\!|\, s(N_A) \,|\!\}_{K_{AB}}$$

$$1.\ A \longrightarrow C_B : \{\!|\, N_A \,|\!\}_{K_{AB}}$$
$$1'.\ C_B \longrightarrow A : \{\!|\, N_A \,|\!\}_{K_{AB}}$$
$$2'.\ A \longrightarrow C_B : \{\!|\, s(N_A) \,|\!\}_{K_{AB}}$$
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Very simple, but note A is initiator in $1.$, responder in $2'$.

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Good results on other non-theorems from the literature (see paper)

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Find attacks in cases where sufficient model has too large a branching rate for model checking

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Exploit ability to attack protocols with many participants

- e.g. ELK group protocol, CLIQUE suite, Cocaine auction, etc.

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Develop formalism

- would like to be able to accept exact conjectures used in Isabelle/HOL approach

Conclusions

Comon-Nieuwenhuis method for proof by consistency fully implemented

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More information:

`http://www.dai.ed.ac.uk/~grahams/fcs/`