A Case Study in Using ACL2 for Feature-Oriented Verification

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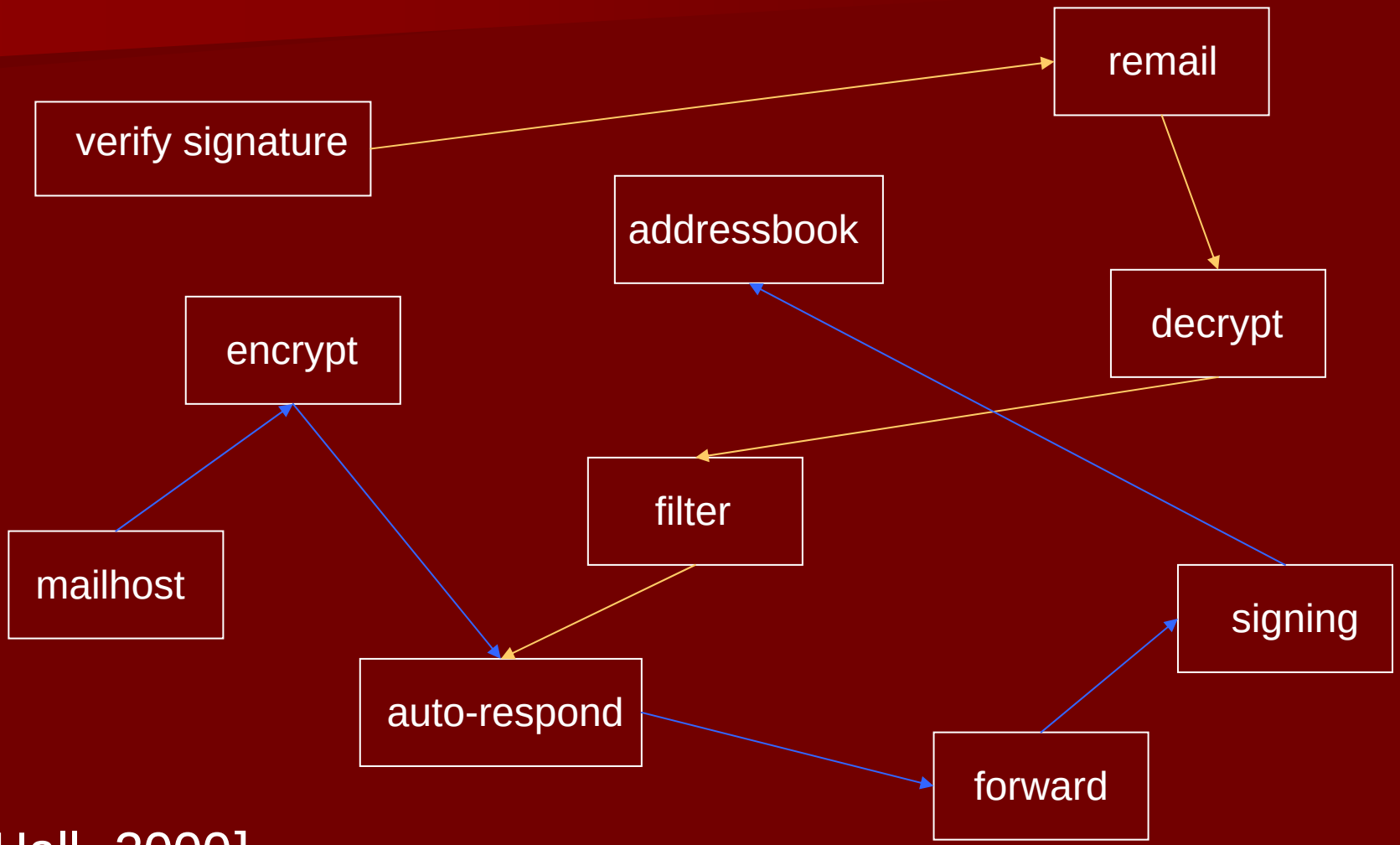
Configurations of Features



[Hall, 2000]

Feature-Oriented Design

Modules encapsulate features, not objects

Features

	Command loop	User Pref Database	Incoming Messages	Outgoing Messages
auto-reply	set-msg, enable	response	check/send reply	
encryption	set-key, enable	key	check encrypted	encrypt message

Components

Feature-Rich Systems

- Telecommunications industry
- NASA's next-generation software base
- Symbian
- Aspects

Still greatly lacking in verification tools

Verification Challenges

- Exponential number of possible products!
  - verify individual features once
  - verify compositions cheaply
- Feature interactions
  - does voice mail always engage after 4 rings?
- Features can share data

The Case Study

- Model an email system with four features
  - Host/postmaster (report unknown users)
  - Auto-response (aka *vacation*)
  - Encryption
  - Decryption
- Determine lemmas to modularly
  - prove properties of individual features
  - confirm properties and detect interactions

A Basic Email System

simulate-network (hostenv, userenv, actions)

do-actions (...) ⟶ do-mail

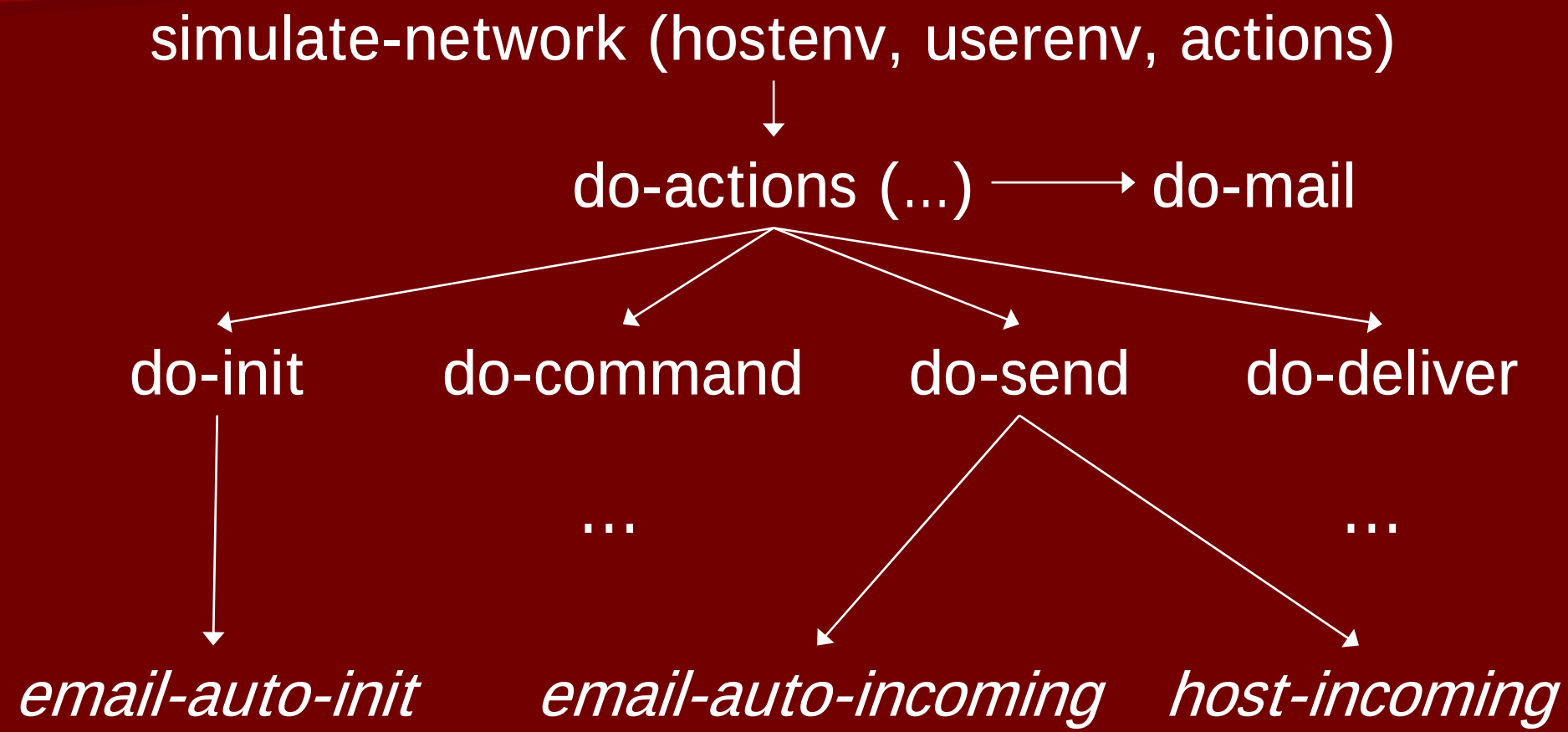
Modeling Features

	Command loop	User Pref Database	Incoming Messages	Outgoing Messages
auto-reply	set-msg, enable	response	check/send reply	
encryption	set-key, enable	key	check encrypted	encrypt message

One function for each extension to the system

- add new actions
- add user info
- add processing on incoming messages
- add processing on outgoing messages

A Basic Email System



Customizing Products

```
(defconst *features-present* '(auto encrypt))

(defund do-init (user)
  (let-seq user
           (fif encrypt (email-encrypt-init user) user)
           (fif decrypt (email-decrypt-init user) user)
           (fif auto    (email-auto-init user) user)
           user))
```

Verifying Features

If user has auto-response enabled and sender not in prev-recip list, send message

- Needs –init and -incoming functions
- Verify against product containing base system and auto-response feature
  - theorem refers to *simulate-network*
  - not really modular

Lightweight Product Verification

Add host to product with auto-response: prove auto-response property still holds

- build (new) product including host feature
- prove *simulate-network* theorem again

Lightweight means proof shouldn't require unanticipated lemmas

Ideally warn of likely feature interactions

Detecting Feature Interactions

- Sample interaction:

  Auto-reply message sent to postmaster
- Often violates no properties of features
- Incompleteness makes more difficult
- Capture interaction as theorem, determine lemmas needed to confirm
  - Hope: failure to prove under lemmas indicates likely interaction

Supporting Modular Verification

- Lemmas about individual features crucial
  - make product verification lightweight
  - help detect feature interactions
- Four kinds of lemmas helpful
  - type/format of inputs and outputs
  - environment info that might/won't change
  - conditions characterizing changes
  - lifting lemmas through call-graph hierarchy
- Ideally automate lemma creation

Why Modularity?

Reviewer: modularity irrelevant for ACL2

We disagree

- modularity key part of design process
- features provide new form of modularity
- Research goal goes beyond ACL2

Reflections on ACL2

- Procedural-style natural match for features
  - features capture functional/behavioral information
- First-order limitation inhibits plug-and-play
  - Implementations use higher-order functions/classes
- Macros crucial
  - generate products and standard lemmas
- Books too restrictive for some feature lemmas
- *Hands-off* and *disable* hints simulate modular environment

Questions for Experts

- Better way to achieve plug-and-play?
- Way to use books for all feature lemmas?
- Results on lemma generation that we should know about?