Proof General

A Generic Tool for Proof Development

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Introduction

Background
Why Proof General?
What is Proof General?

Background

- Terminology: *machine proof*
  - formal machine representation of mathematical/logical proof
- Machine proofs useful in
  - specification, development, verification of software and hardware
  - teaching mathematical proof and formal logic
  - mathematical research
- Terminology: *proof assistant* (or *prover*)
  - an *interactive* computerized helper for developing machine proofs
- Terminology: *proof script*
  - user-level input to prover which constructs a machine proof
  - may contain procedural proofs (LCF style), or declarative proofs (Mizar style)
  - stored in a file, like a program

Why Proof General?

- Many proof assistants still have only a primitive interface
  - It's easy to program!
  - Experts unafraid of cryptic command language
- But a modern interface has advantages:
  - Saves time for experts, providing short-cuts
  - Helps novices, providing hints
  - Opens the way to higher-level interactions
- A *generic* interface is attractive:
  - Saves time for implementors, can concentrate on logical bits
  - Helps users try different systems, using the same interactions

What is Proof General?

- A generic interface based on Emacs
- It provides many useful features, including:
  - script centred development
  - script management
  - proof by pointing
  - helpful toolbar and menus
  - coloured output and special fonts for maths, . . .
- It presently has support for Isabelle(/Isar), Coq, LEGO, Plastic, HOL98
- More support and development is on the way . . .

An idea: a generic tool to help proof development.
An attitude: be useful both to novices *and* to experts.

Architecture

Generic aspects of proof assistants

Choose Emacs

System architecture

Generic aspects of proof assistants

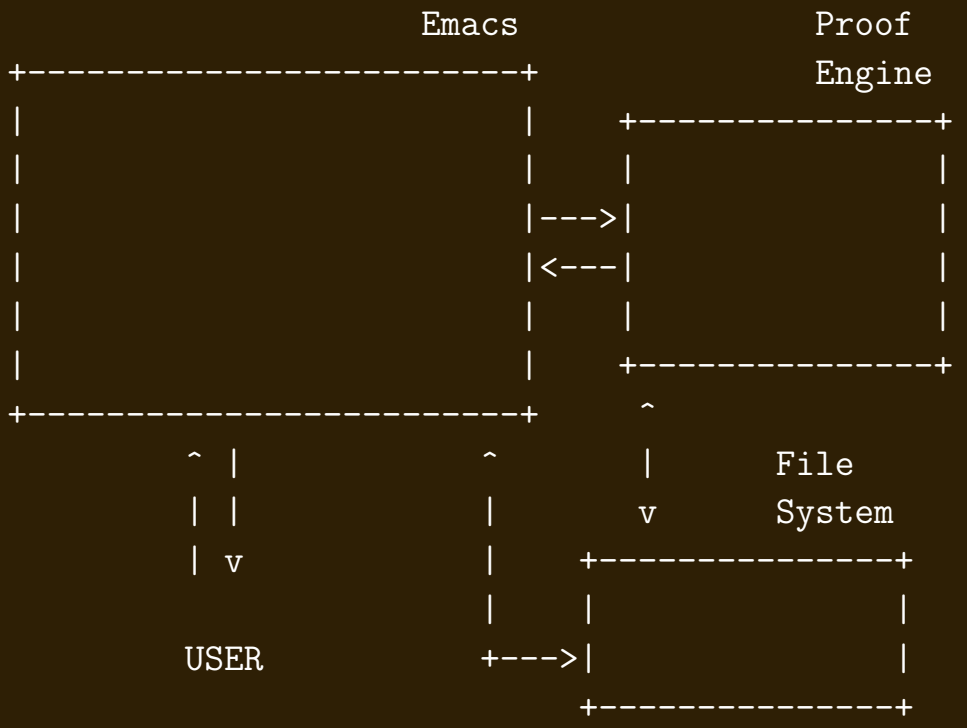
- Interaction has a common structure
  - User makes declarations or definitions
  - User enters *proof dialogue*
    - ⋆ user gives proof step; system responds (e.g. subgoal list)
    - ⋆ repeat
- Proof scripts have a common structure, similarly:
  - declarations and definitions, and
  - *goal* . . . *save* sequences
- Primitive interfaces have common structure:
  - Command-line interface: *proof assistant shell*

How can we build a system to exploit these common structures?

Choose Emacs

- The world's best text editor also provides a user-interface toolkit!
- Choosing emacs has pros
  - user familiarity: Emacs already used to write scripts
  - portability: runs on MS Windows, Unix, Linux, . . .
  - interpreted scripting language for development: Emacs Lisp
  - extensive libraries, easy user-customization
- . . . and cons
  - hard to learn and over complicated
  - the original bloatware
  - interoperability limited (live in Emacs!)
  - single-threaded

System architecture



User Features

Script centered development
Script management
Proof by Pointing
User friendliness
Other Emacs features

Script centered development

- Hide irrelevant information
  - shell hidden
  - but still available for emergencies
- Buffer display model: two-of-three window panes
  - *script*
  - *goals* or *response*
- Script buffer centred around “latest” proof command
- Goals buffer centred around working subgoal
- Response buffer displays other relevant messages
  - urgent messages
  - result of non-proof step (search results, command feedback)
- Customizable to use three buffers and multiple windows

Script management

- Synchronizes editor with proof assistant
- Provides visual feedback

  blue background — processed text

  pink background — text being processed

- Highlighted text is *locked* to prevent accidental editing
- Connects with prover's history mechanism, for *retraction*
  - undo individual steps within a proof
  - block-structure outside proof
- Connects with prover's file handling
  - extend synchronization to multiple files
  - dependencies communicated or deduced automatically
- Avoids using cut-and-paste or "load file" commands

Proof by Pointing

- Click on subterm of goal
  - generates proof command to simplify/solve goal
  - inserts command into proof
  - executes it
- Support from proof assistant required!
  - annotations to markup term-structure
  - communication of position in AST
  - proof command generation
- Many possibilities
  - context-sensitive menus
  - other gestures (e.g. drag term to rearrange equation)
  - not yet implemented

User friendliness

- Toolbar
  - buttons to start proof, process step, undo step, finish proof, . . .
- Menus
  - change display modes, start/stop proof assistant, . . .
  - **all** commands available here
- Easy preference setting
- Online documentation
  - variety of formats
  - links to proof assistant documentation
- . . . and of course, speedy short-cut key sequences like

```
C-c C-RET   proof-goto-point
```

Other Emacs features

- Syntax highlighting
  - decoration of proof scripts and prover output
- Symbol fonts
  - glyphs for logical symbols, greek letters, etc

$\phi \longrightarrow \psi$ instead of `phi --> psi`

- Tags
  - search for definitions and proofs amongst many files
- Item menu
  - navigate to definitions and proofs in current window
- Remote proof assistant
  - run prover on different machine using `rsh` or `ssh`

Implementation

Implementation notes
Instantiation mechanism
Example instantiation
Development model

Implementation notes

- Main implementation in Emacs Lisp
  - 7000 loc for generic parts
  - 30 – 500 loc per assistant for prover specific parts
- Support in proof assistant (optional)
  - output markup for robustness
  - file loading messages
  - proof by pointing machinery
- Emacs Lisp issues
  - fairly primitive, but has some CL macros (and CLOS emulation)
  - slow, but built-ins and byte-code compilation improve matters
  - easy to learn and use, *docstrings* are wonderful

Instantiation mechanism

- 80 configuration settings total; may only need half. Organized as:
  - Regexps to recognize proof script
  - Regexps to recognize prover messages
  - Commands to control prover
  - Hooks to configure behaviour
- Some important examples:

`proof-goal-command-regexp`	matches goal command in script
`proof-shell-start-goals-regexp`	matches start of goals output
`proof-prog-name`	command to start prover
`proof-shell-insert-hook`	hook to tweak prover input

- One line to add autoloads, name, customizations for new prover
- Use `define-derived-mode` for new script, goals, response, shell
- With new “easy configure” mechanism, no Elisp necessary!

Example instantiation

```
(require 'proof-easy-config)     ; easy configure mechanism
(proof-easy-config
 'demoisa "Isabelle Demo"
 proof-prog-name                 "isabelle"
 proof-terminal-char             ?\;
 proof-comment-start             "(*"
 proof-comment-end               "*)"
 proof-goal-command-regexp       "^Goal"
 proof-save-command-regexp       "^qed"
 proof-goal-with-hole-regexp     "qed_goal \"\\(\\(.*\\)\\)\""
 proof-save-with-hole-regexp     "qed \"\\(\\(.*\\)\\)\""
 proof-non-undoables-regexp      "undo\\|back"
 proof-goal-command              "Goal \"%s\";"
 proof-save-command              "qed \"%s\";"
 proof-kill-goal-command         "Goal \"PROP no_goal_set\";"
 proof-showproof-command         "pr()"
 proof-undo-n-times-cmd          "pg_repeat undo %s;"
 proof-auto-multiple-files       t
 proof-shell-cd-cmd              "cd \"%s\""
 proof-shell-prompt-pattern      "[ML-=#>]+>? "
 proof-shell-interrupt-regexp    "Interrupt"
 proof-shell-start-goals-regexp  "Level [0-9]"
 proof-shell-end-goals-regexp    "val it"
 proof-shell-quit-cmd            "quit();"
 proof-assistant-home-page
 "http://www.cl.cam.ac.uk/Research/HVG/isabelle.html"
 proof-shell-annotated-prompt-regexp  "^\\(val it = () : unit\n\\)?ML>? "
 proof-shell-error-regexp
 "\\*\\*\\*\\|^.*Error:\\|^uncaught exception \\|^Exception- "
 proof-shell-init-cmd
 "fun pg_repeat f 0 = () | pg_repeat f n = (f(); pg_repeat f (n-1));"
 proof-shell-proof-completed-regexp    "\\(\\(.\\|\n\\)*No subgoals!\n\\)"
 proof-shell-eager-annotation-start    "^\\[opening \\|^###\\|^Reading")
(provide 'demoisa)
```

Development model

- Successive generalization
  - generalize as needed
  - sometimes extend and redesign core, as needed
  - LEGO mode $\longrightarrow$ Proof Mode $\longrightarrow$ *Proof General*
- Developer/maintainer in each camp
  - Emacs and prover support for each prover
  - adds specific features, generalizes if useful elsewhere
  - serves as primary user/tester
- CVS server, access to whole repository for all developers
- Frequent pre-release versions, quick response to bugs
- Open source, user contributions welcomed

Appraisal

Usage
Comparison
Benefits of Proof General

Usage

- Target users of currently supported proof assistants:

	User community	Other interfaces?
LEGO	30	no
Coq	80	yes
Isabelle	200	yes
Isabelle/Isar	20	no
Plastic	5	no
HOL98	200	yes

- Other possible systems (HOL variants, Agda, VDM, ACL2, . . .)
- Use in teaching
  - 2000 EEF Foundations school in Deduction and Theorem Proving
  - 1999 Types Summer School: 50 learning LEGO, Coq, and Isabelle
  - MSc/PhD course in formal reasoning at Edinburgh
- Current version is 3.1, about 100 registered users as of May 2000.

Comparison

- There's more sophistication elsewhere:
  - Graphical representations: proof-trees, direct manipulation
  - Structure editing, integrated environments, . . .
- However, Proof General has complementary aspects:
  - intended for day-to-day proof, not an experiment in HCI
  - draws on familiarity (text editor), uniformity (between systems)
  - scales to large proofs
  - portable, easy to adapt and extend

Proof General occupies a middle ground in interface technology

Benefits of Proof General

- A nice front-end for doing real work!
- Is being used by experts, doesn't get in their way (much)
- But is also used for teaching novices
- Replaying proofs is trivial
- By construction, it suggests a protocol for interactive proof
  - New project to design standard extensible protocol . . .
- Very easy to install; self-configuring
- Very easy to adapt to new systems, to get basic features

Proof General achieves a lightweight, *useful* interface at little cost

Future

- Evolutionary
  - More features — completion, favourites, theory browser
  - More proof assistants
- Revolutionary
  - Factor out script management, use for programming languages
  - Standardize markup mechanism (XML, MathML, OpenMath, ATerms)
  - Focus on protocols, move away from purely Emacs
  - Middleware layer connects proof engine to front-ends (CORBA)
- Imaginary
  - Prover-independent syntax mechanisms
  - Logic and theory mappings, standard taxonomies

Working title of next project: ***Proof General Kit***

The End

New Users, Developers Welcome!

- Enjoy using Proof General
- Add support for another prover
- Undertake a project
- Contribute to future design

Credits:

- Thomas Kleymann,
- Yyves Bertot and CtCoq
- Dilip Sequeira, • Healfdene Goguen,
- Markus Wenzel, David von Oheimb, . . .
- Funding: LFCS, EPSRC LEGO, EC BRA Types

For more, visit http://www.lfcs.informatics.ed.ac.uk/proofgen

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