Improving Eliminate-Irrelevance for ACL2

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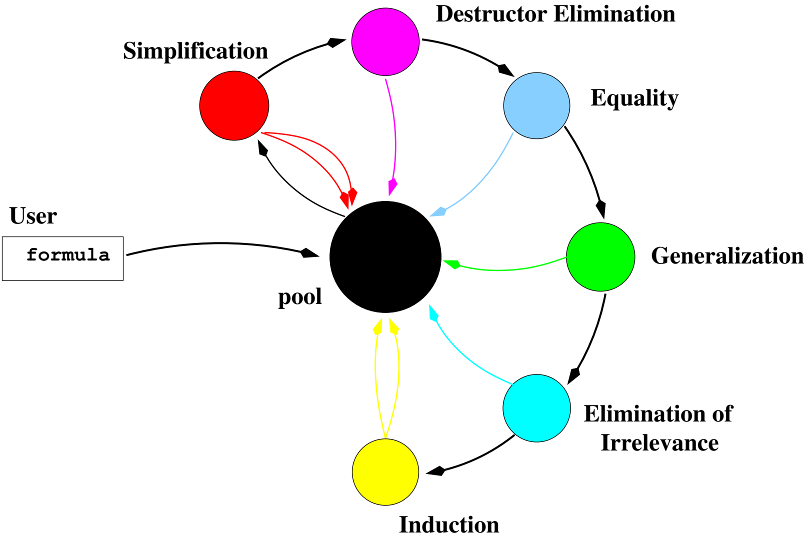
October 14, 2016

OUTLINE

Organization of this talk.

1. Review the ACL2 *waterfall* and its *eliminate-irrelevance* clause-processor.
    - Section **Waterfall**
    - Section **Eliminate-Irrelevance**
2. Present a recent change in its heuristics.
    - Section **Example**
    - Section **Details**
3. Remark on considerations when designing and implementing that change.
    - Section **Further Considerations**

THE ACL2 WATERFALL



CLAUSE PROCESSORS

Every ACL2 goal is represented as a *clause*: a list that is viewed as a disjunction of terms (called *literals*).

Example: A goal and corresponding clause:

```
(implies (and (p1 x) (p2 x y))
         (p3 y))
```

```
((not (p1 x)), (not (p2 x y)), (p3 y))
```

Each waterfall step uses a *clause-processor*: a function that maps a clause to a list of clauses (possibly empty). Key property:

If every result clause is a theorem, then the input clause is a theorem.

NOTE: Converse need not hold!

INTRODUCTION TO ELIMINATE-IRRELEVANCE

Example from the ACL2 regression suite, in:
`books/workshops/2006/cowles-gamboa-euclid/Euclid/fld-u-poly/`.

```
(ld "fuproducto.port")
(in-package "FUPOL")
(rebuild "fuproducto.lisp" '*)
; Succeeds:
(thm ; polinomiop-*
 (polinomiop (* p q)))
; Fails:
(thm ; polinomiop-*
 (polinomiop (* p q))
 :hints
 (("Goal"
   :do-not '(eliminate-irrelevance))))
```

From successful proof, after `(set-gag-mode nil)`:

```
Subgoal *1/2'5'
(IMPLIES (AND (MONOMIOP P1)
              (POLINOMIOP P2)
              (POLINOMIOP V*0))
         (POLINOMIOP (APPEND (*-MONOMIO P1 Q) V*0))).

We suspect that the term (POLINOMIOP P2) is irrelevant to the truth
of this conjecture and throw it out.  We will thus try to prove

Subgoal *1/2'6'
(IMPLIES (AND (MONOMIOP P1) (POLINOMIOP V*0))
         (POLINOMIOP (APPEND (*-MONOMIO P1 Q) V*0))).

Name the formula above *1.1.

...

We will induct according to a scheme suggested by (POLINOMIOP V*0).
```

In the failed proof, keeping the literal `(POLINOMIOP P2)`:

```
We will induct according to a scheme suggested by (POLINOMIOP P2).
```

A HEURISTIC

Consider again this goal:

```
(IMPLIES (AND (MONOMIOP P1)
              (POLINOMIOP P2)
              (POLINOMIOP V*0))
         (POLINOMIOP (APPEND (*-MONOMIO P1 Q) V*0)))
```

ACL2 represents this as a clause (disjunction of literals):

```
{(NOT (MONOMIOP P1)),
 (NOT (POLINOMIOP P2)),
 (NOT (POLINOMIOP V*0)),
 (POLINOMIOP (APPEND (*-MONOMIO P1 Q) V*0))}
```

The relation of *sharing a variable* has two components.

```
{ {(NOT (MONOMIOP P1)),
   (NOT (POLINOMIOP V*0)),
   (POLINOMIOP (APPEND (*-MONOMIO P1 Q) V*0))},
  {(NOT (POLINOMIOP P2))}
}
```

ACL2 drops the component that has a single member.

CHANGING THE HEURISTIC: AN EXAMPLE

J Moore encountered a problem with this heuristic.
The following simple example exhibits the problem.

```
(encapsulate (((p) => *)  ((my-app * *) => *))
  (local (defun p () t))
  (local (defun my-app (x y) (append x y)))
  (defthm my-app-def
    (implies (p)
             (equal (my-app x y)
                    (append x y)))))

(defun rev (x)
  (if (consp x)
      (my-app (rev (cdr x))
              (cons (car x) nil))
    nil))

(thm (implies (and (p)
                   (true-listp x))
              (equal (rev (rev x)) x)))
```

ACL2 Version 7.2 discards `(P)`: proof then fails!

```
Subgoal ⋆1/2’5’
(IMPLIES (AND (P) (TRUE-LISTP X2))
         (EQUAL (REV (APPEND RV (LIST X1)))
                (CONS X1 (REV RV)))).

We suspect that the terms (TRUE-LISTP X2) and (P) are irrelevant to
the truth of this conjecture and throw them out.  We will thus try
to prove

Subgoal ⋆1/2’6’
(EQUAL (REV (APPEND RV (LIST X1)))
       (CONS X1 (REV RV))).

Name the formula above ⋆1.1.
```

But now, ACL2 keeps `(P)`, and the proof succeeds.

```
We suspect that the term (TRUE-LISTP X2) is irrelevant to the truth
of this conjecture and throw it out.  We will thus try to prove

Subgoal ⋆1/2’6’
(IMPLIES (P)
         (EQUAL (REV (APPEND RV (LIST X1)))
                (CONS X1 (REV RV)))).
```

THE CHANGE IN A NUTSHELL

Why does ACL2 now keep the hypothesis `(P)`?
Technically: Why does ACL2 keep the literal `(NOT (P))`?
Recall the theorem exported from our `encapsulate` event.

```
(defthm my-app-def
  (implies (p)
           (equal (my-app x y)
                  (append x y))))
```

- Variables of hypothesis `(p)`: `{}`.
- Variables of left-hand side `(my-app x y)`: `{x,y}`.

These are disjoint sets! So the function symbol `p` is marked as *relevant*, since `(p)` can be useful for rewriting calls that don't involve its (empty set of) variables.

THE NEW HEURISTIC IN MORE DETAIL

Suppose p is a Boolean and we have two terms, as follows.

- Let t_1 be `(FN V1 ... VK)`, an application of a function symbol to distinct variables.
- Let t_2 be a term whose free variables are disjoint from those of t_1.

Then `FN` is *relevant with parity p* whenever t_1 or its negation is a hypothesis (perhaps among others), in which case:

- p = `t` if t_1 is a hypothesis;
- p = `nil` if (not t_1) is a hypothesis.

EXAMPLE OF “RELEVANT WITH PARITY”

Recall our earlier example rewrite rule and the problem goal:

```
(encapsulate (((p) => ⋆)  ((my-app ⋆ ⋆) => ⋆))
  (local (defun p () t))
  (local (defun my-app (x y) (append x y)))
  (defthm my-app-def
    (implies (p)
             (equal (my-app x y)
                    (append x y))))))
```

```
(IMPLIES (AND (P) (TRUE-LISTP X2))
         (EQUAL (REV (APPEND RV (LIST X1)))
                (CONS X1 (REV RV))))
```

The “hypothesis” `(P)` is, internally, the literal `(NOT (P))`. Parity `t` corresponds to “negated literal should be kept”, so:

```
ACL2 !>(assoc-eq ’p
                 (global-val ’never-irrelevant-fns-alist
                             (w state)))
(P . T)
ACL2 !>
```

RELEVANCE WITH PARITY FOR VARIOUS RULES

Assume that terms t_1 = `(FN V1 ... VK)` (distinct `Vi`) and t_2 have disjoint free variables, where for a rule of the given class:

- Rule-classes `:REWRITE` and `:DEFINITION`: t_2 is the rule's left-hand side.
- Rule-class `:LINEAR`: t_2 is a *max-term*.
- Rule-class `:TYPE-PRESCRIPTION`: t_2 is a *typed-term*.
- Rule-class `:FORWARD-CHAINING`: t_2 is the conclusion.

Then `FN` is *relevant with parity p* for such rules when:

- p=`t  : (implies (and ...` t_1 `...) ...)`
- p=`nil: (implies (and ... (not` t_1`) ...) ...)`

For a call u of `FN` on distinct variables:

- literal u is never irrelevant (dropped) if p = nil; and
- literal (not u) is never irrelevant (dropped) if p = t.

ADDITIONAL PARITIES

- A function symbol `FN` can be irrelevant with parity `t` in one rule and with parity `nil` in another rule. We then store `FN` with parity `:both`.
- We also store `FN` as irrelevant for suitable occurrences of t_1 in *conclusions*. That might be overkill.
- There is a second criterion for irrelevant components (besides single-literal components based on calls of irrelevant literals): all function symbols the component are among a fixed set of primitives.
  - Unchanged, except that `NOT` has been added to that set (since the other criterion is stricter).

TIMING (1)

Does the use of *irrelevance with parity* slow down ACL2?

- Does *using* of that information slow down the *eliminate-irrelevance* procedure?
  - Not concerning — procedure is invoked only just before a sub-induction; rather rare in practice.
- Is *maintaining* such information expensive?
  - Info is stored in an alist.
  - Each suitable rule causes linear lookup in the alist and possibly its extension — potentially quadratic behavior. (Should we consider an applicative hash-table (*fast alist*)?)

Regression suite didn't show significant time difference, but let's look at other evidence against slowdown.

TIMING (2)

Stress test:

```
(time$ (include-book "doc/top" :dir :system)).
```

Showed essentially no change!

```
;;; old
; 782.20 seconds realtime, 777.17 seconds runtime
; (23,612,574,784 bytes allocated).

;;; new
; 775.99 seconds realtime, 772.39 seconds runtime
; (23,952,558,640 bytes allocated).

ACL2 !>(length (global-val ’never-irrelevant-fns-alist
                           (w state)))
11869
ACL2 !>
```

TIMING (3)

Seems like the new global is a non-issue, since a symbol-alist of length 11,869 is trivial to traverse. On my Mac:

```
ACL2 !>:q

Exiting the ACL2 read-eval-print loop.  To re-enter, execute (
? (defun foo (sym n)
    (let ((x (make-list n :initial-element '(a . b))))
      (time$ (assoc-eq sym x))))
FOO
? (foo 'c 1000000)
; (ASSOC-EQ SYM ...) took
; 0.00 seconds realtime, 0.00 seconds runtime
; (0 bytes allocated).
NIL
? (foo 'c 10000000)
; (ASSOC-EQ SYM ...) took
; 0.03 seconds realtime, 0.03 seconds runtime
; (0 bytes allocated).
NIL
?
```

Miscellaneous Considerations

Question 1: Make the heuristic attachable?
Answer: Seems like overkill. After all, *eliminate-irrelevance* only occurs before a sub-induction, and nobody should rely on sub-inductions.
Question 2: Extend irrelevance with a sort of transitive closure? Suppose for example we have these three rewrite rules.

```
(implies (f1 x) (f2 x))
(implies (f2 x) (f3 x))
(implies (f3 x) (h y z))
```

Then just as we don't want to drop a hypothesis (negated literal for) `(f3 x)`, we don't want to drop `(f1 x)` or `(f2 x)`.
Answer: Nah, seems like overkill for such a last-ditch heuristic.

CONCLUDING REMARKS

- Bottom line: `Eliminate-irrelevance` is fairly minor. But this tweak, which arose from J's work on `apply$`, was helpful for that work and could help others.
- **Thanks for your attention.**
- (If there's extra time, I could give a sense of the source code (e.g., `eliminate-irrelevance-clause` (through `irrelevant-lits` and `irrelevant-clausep`) and `add-rewrite-rule` (through `add-rewrite-rule2` and `extend-never-irrelevant-fns-alist`).)