Toward a Practical Module System for ACL2

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ACL2

"Applicative Common Lisp" is a first-order, side-effect free subset of Common Lisp.

"A Computational Logic" is classical, first-order logic over a domain of total functions.

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ACL2 is widely used in industry, and won the 2005 ACM Software System Award.

ACL2

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(defun insert (x set) (add-to-set-eql x set))
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ACL2

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(defthm insert/setp
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ACL2

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(defun join (lst set)
  (if (endp lst)
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ACL2

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(defun join (lst set)
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  (implies (and (true-listp lst) (setp set))
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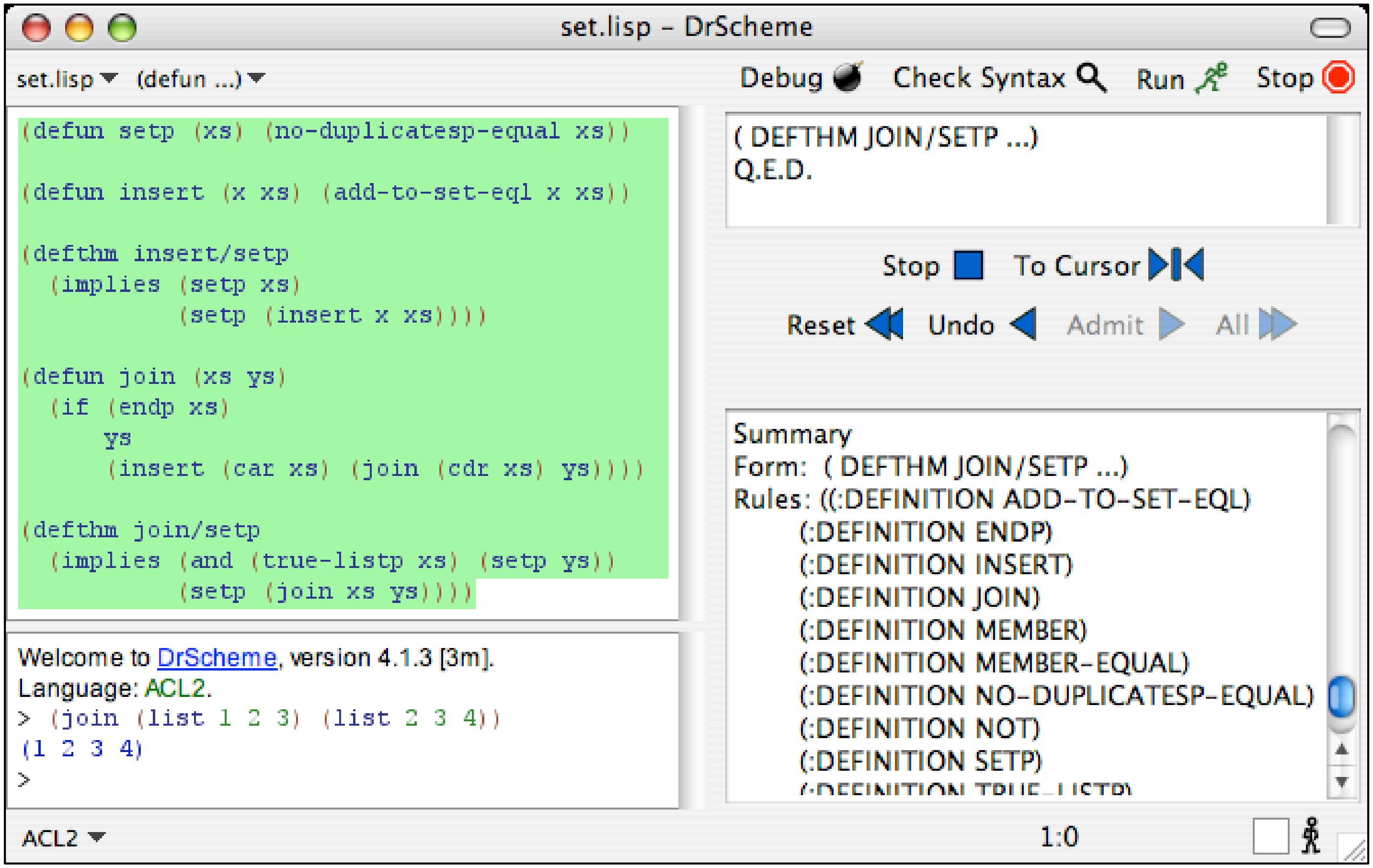
ACL2


set.lisp – DrScheme
set.lisp
(defun ...)
Debug
Check Syntax
Run
Stop
(defun setp (xs) (no-duplicatesp-equal xs))
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Summary
Form: (DEFTHM JOIN/SETP ...)
Rules: ((:DEFINITION ADD-TO-SET-EQL)
(:DEFINITION ENDP)
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(:DEFINITION MEMBER)
(:DEFINITION MEMBER-EQUAL)
(:DEFINITION NO-DUPLICATESP-EQUAL)
(:DEFINITION NOT)
(:DEFINITION SETP)
Welcome to DrScheme, version 4.1.3 [3m].
Language: ACL2.
> (join (list 1 2 3) (list 2 3 4))
(1 2 3 4)
>
ACL2
1:0

ACL2

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Summary
Form:  ( DEFTHM JOIN/SETP ...)
Rules: ((:DEFINITION ADD-TO-SET-EQL)
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        (:DEFINITION SETP)
        (:DEFINITION TRUE-LISTP)
```

Proof Engineering

Components

Namespaces

Abstraction

Specification

ACL2

Components `include-book`: namespace clashes

Namespaces

Abstraction

Specification

ACL2

Components	`include-book`: namespace clashes
Namespaces	`in-package`: Common Lisp packages
Abstraction	
Specification	

ACL2

Components	`include-book`: namespace clashes
Namespaces	`in-package`: Common Lisp packages
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Specification	

ACL2

Components	**`include-book`: namespace clashes**
Namespaces	**`in-package`: Common Lisp packages**
Abstraction	**`encapsulate`: hides `local` definitions from reasoning & execution**
Specification	**“Modular” style: uses the above, plus code duplication**

	ACL2	Modular ACL2
Components	`include-book`: namespace clashes	
Namespaces	`in-package`: Common Lisp packages	
Abstraction	`encapsulate`: hides `local` definitions from reasoning & execution	
Specification	"Modular" style: uses the above, plus code duplication	`interface`: external, reusable specification

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Components	`include-book`: namespace clashes	
Namespaces	`in-package`: Common Lisp packages	
Abstraction	`encapsulate`: hides `local` definitions from reasoning & execution	`import`: restricts reasoning, but not execution
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	ACL2	Modular ACL2
Components	`include-book`: namespace clashes	`link`: respects lexical scope
Namespaces	`in-package`: Common Lisp packages	`module`: delimits lexical scope
Abstraction	`encapsulate`: hides `local` definitions from reasoning & execution	`import`: restricts reasoning, but not execution
Specification	"Modular" style: uses the above, plus code duplication	`interface`: external, reusable specification

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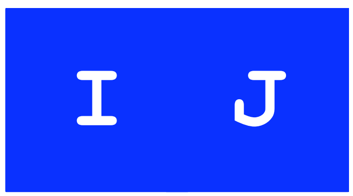

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Modular ACL2 Engineering

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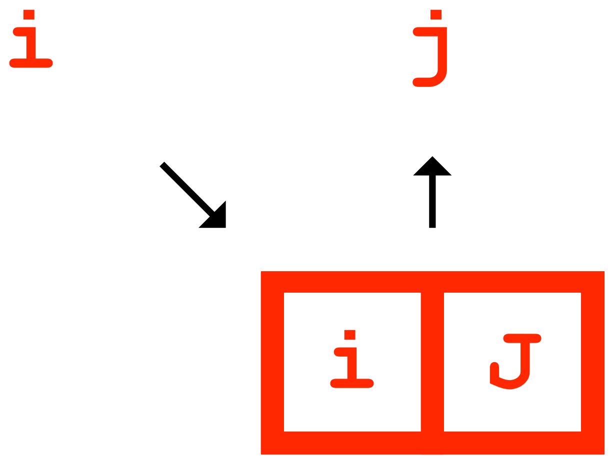
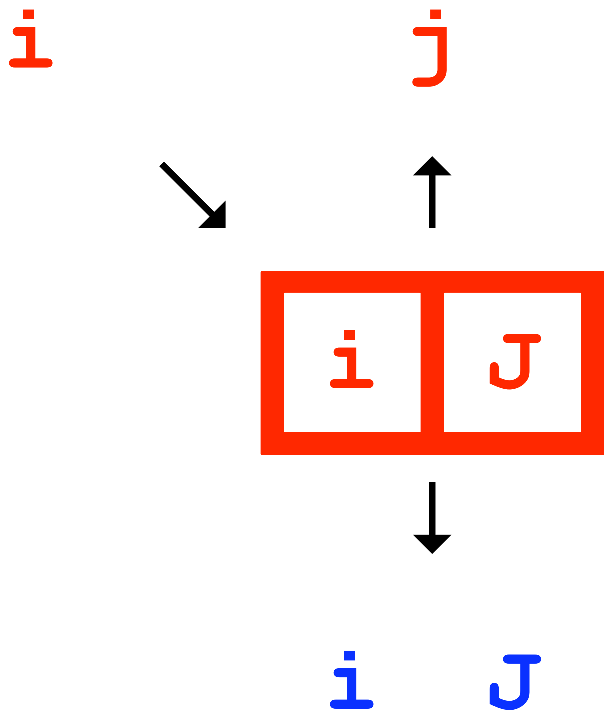
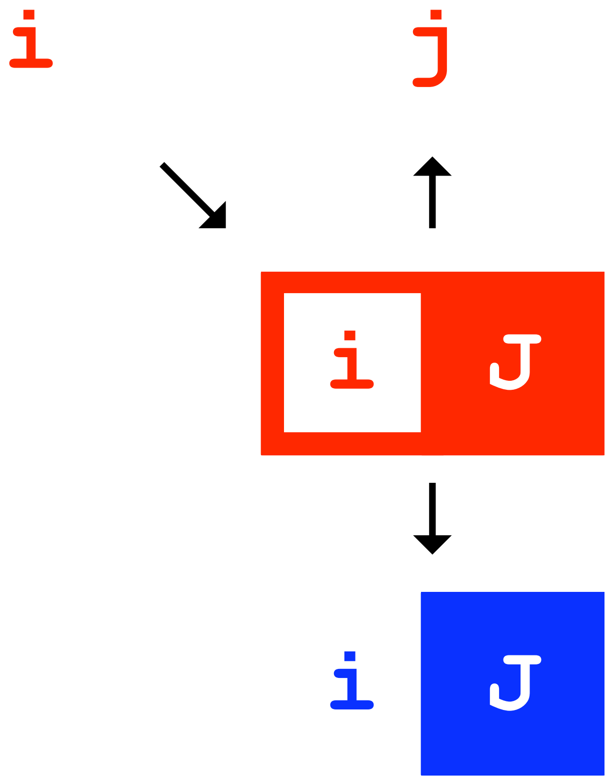
Modular ACL2 Engineering



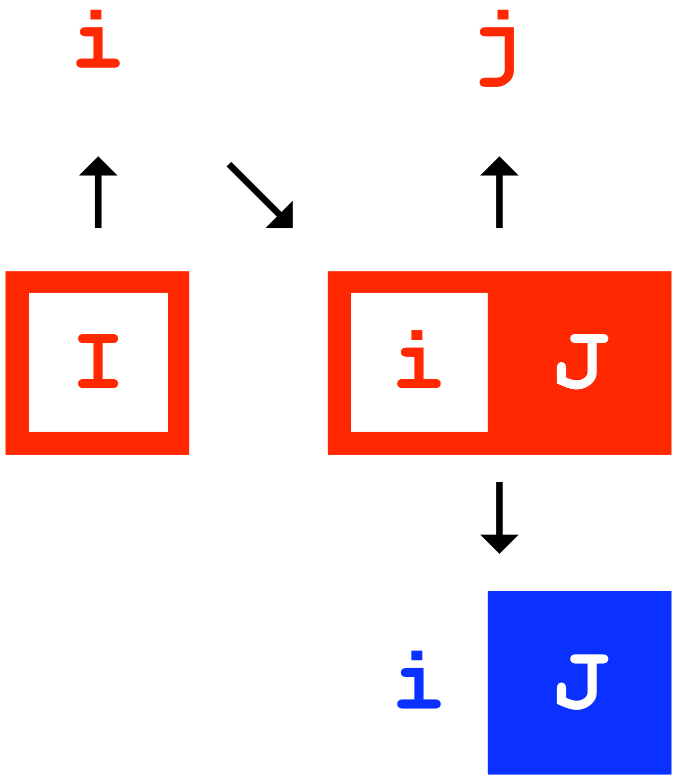
Modular ACL2 Engineering



Modular ACL2 Engineering



Modular ACL2 Engineering



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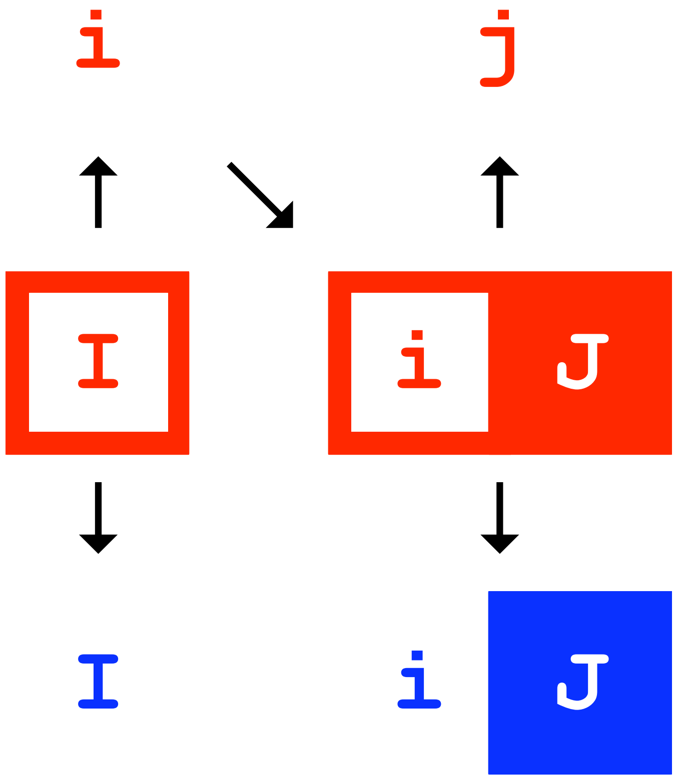

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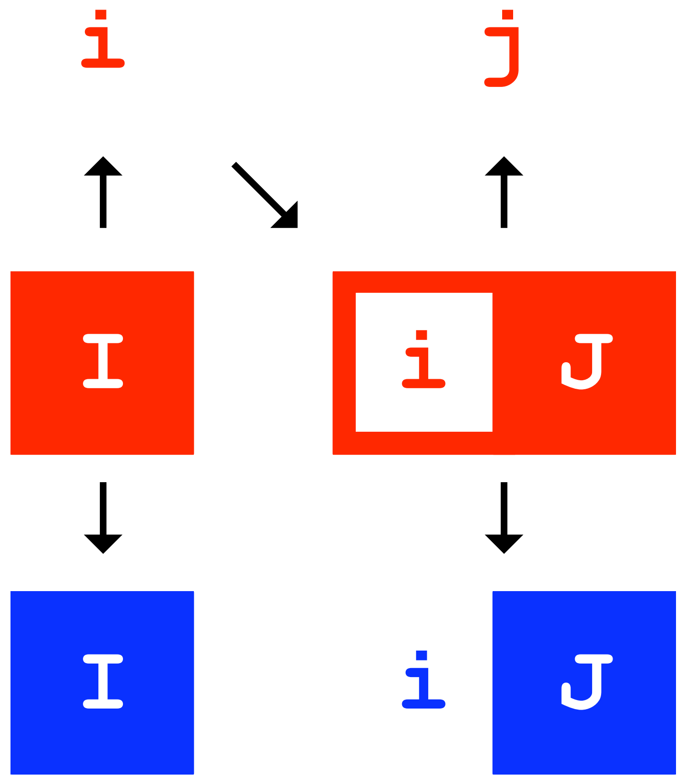

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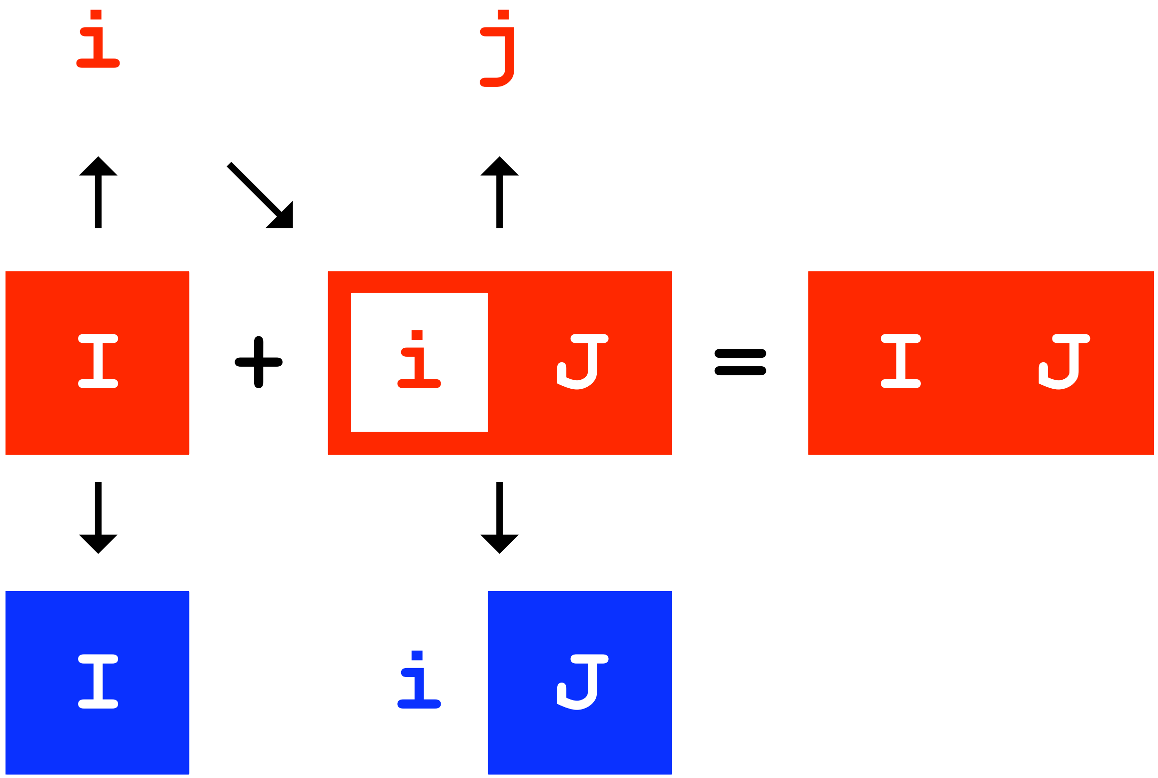

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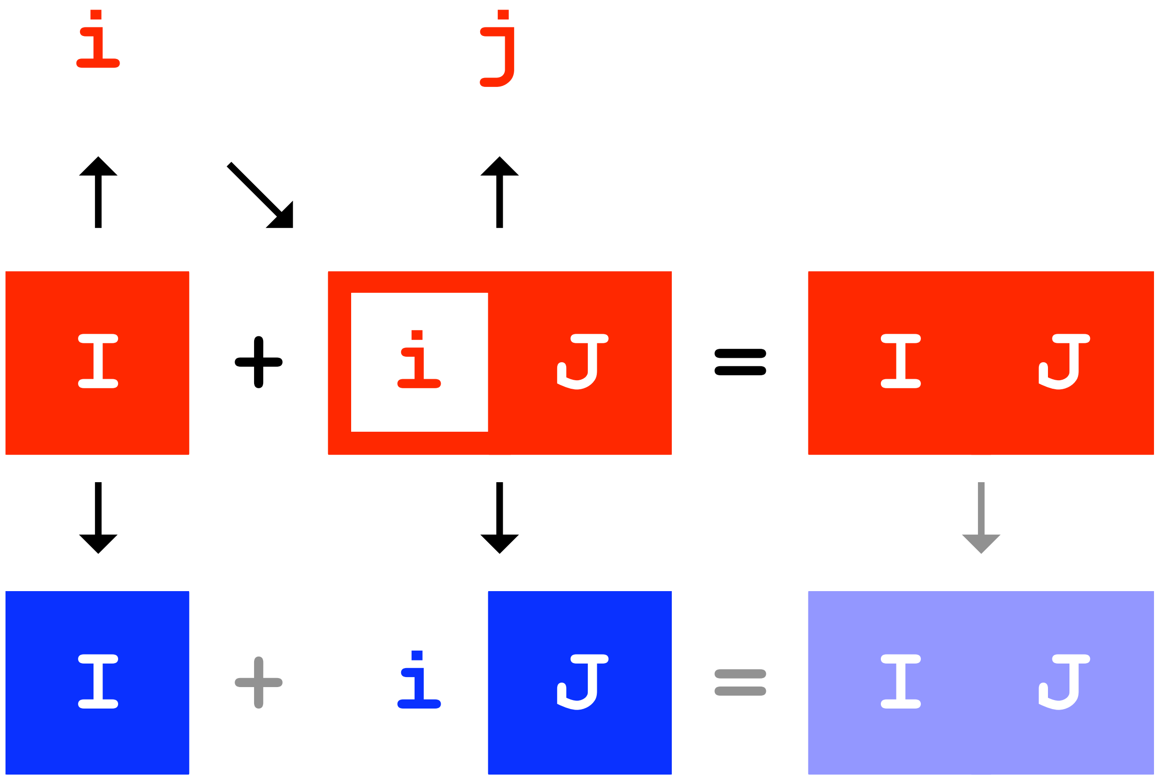
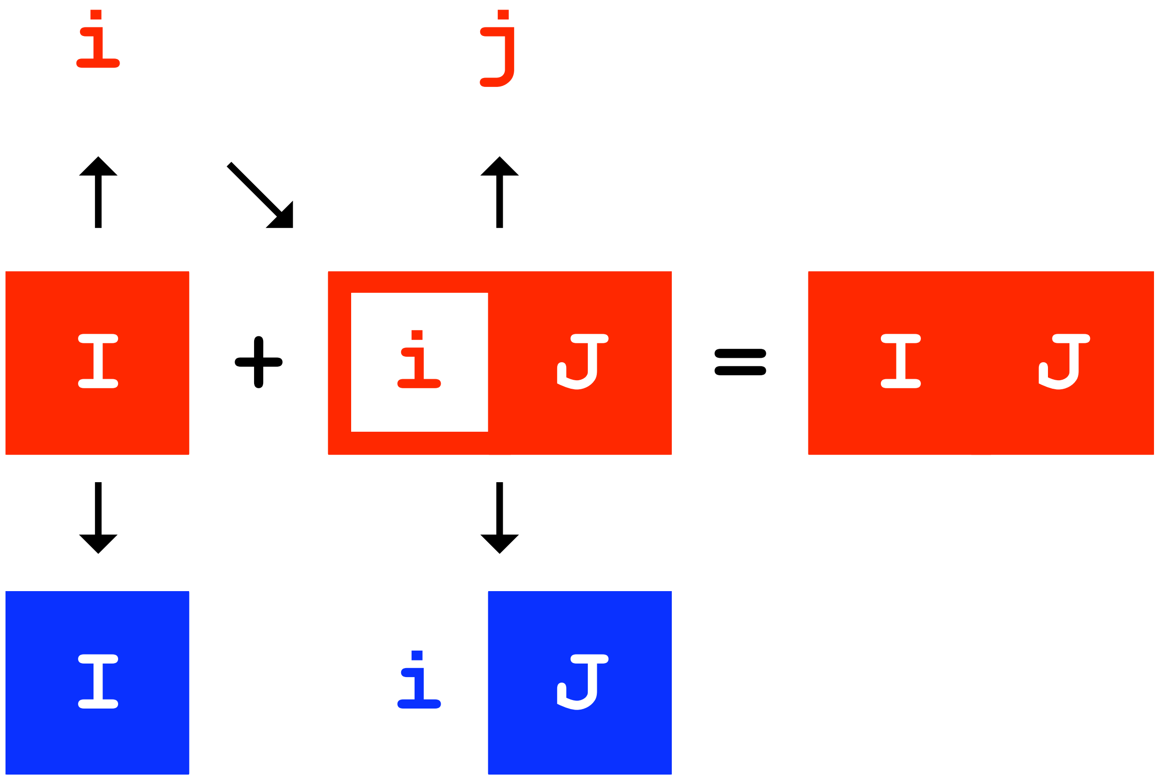
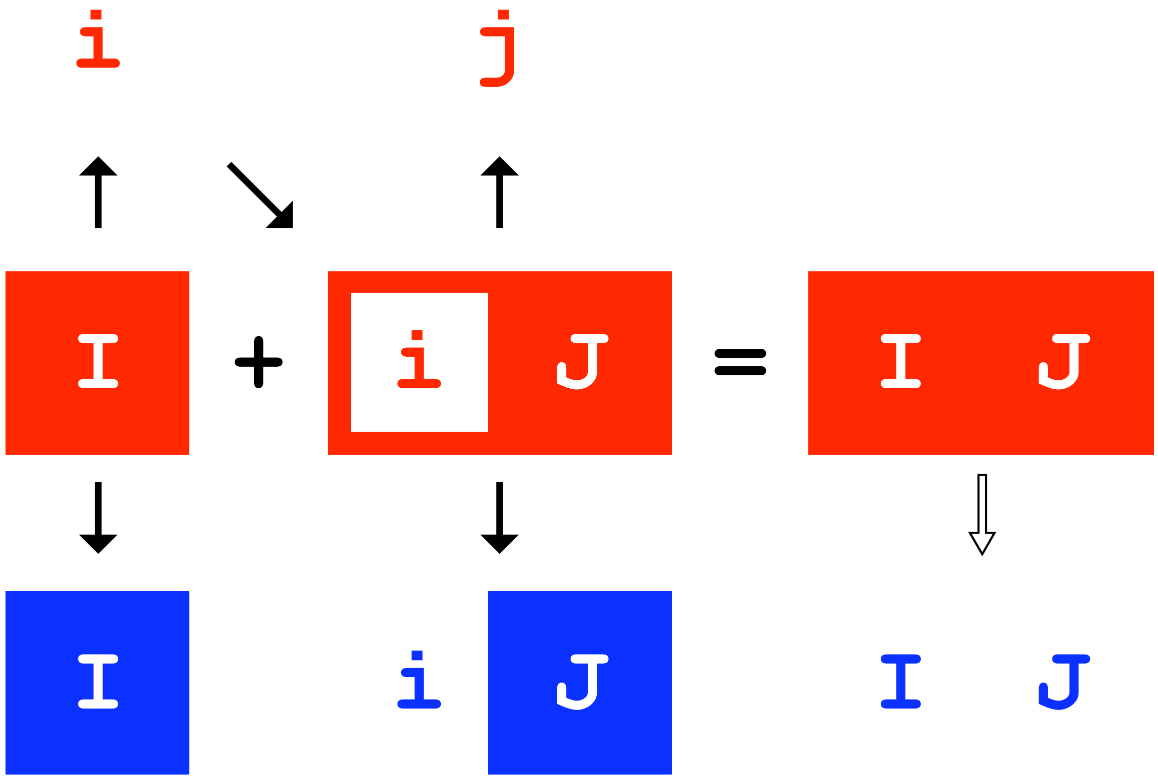


Modular ACL2 Engineering



Modular ACL2 Engineering



Modular ACL2

i

```
(interface i

  (sig setp (x))
  (sig insert (x set))

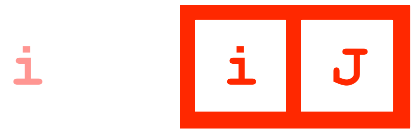
  (con insert/setp
    (implies (setp set)
             (setp (insert x set)))))
```

i j

```
(interface j
  (include i)

  (sig join (lst set))

  (con join/setp
    (implies (and (true-listp lst) (setp set))
             (setp (join lst set)))))
```




```
(module mJ
  (import i)

  (defun join (lst set)
    (if (endp lst)
        set
        (insert (car lst) (join (cdr lst) set))))

  (export j))
```


```
(import i)




(defun join (lst set)
  (if (endp lst)
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(sig setp (x))
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```


```
(defstub setp (x) t)
(defstub insert (x set) t)
(con insert/setp
  (implies (setp set)
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(defun join (lst set)
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(sig join (lst set))
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(defstub setp (x) t)
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(defaxiom insert/setp
  (implies (setp set)
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```

~~(sig join (lst set))~~

```
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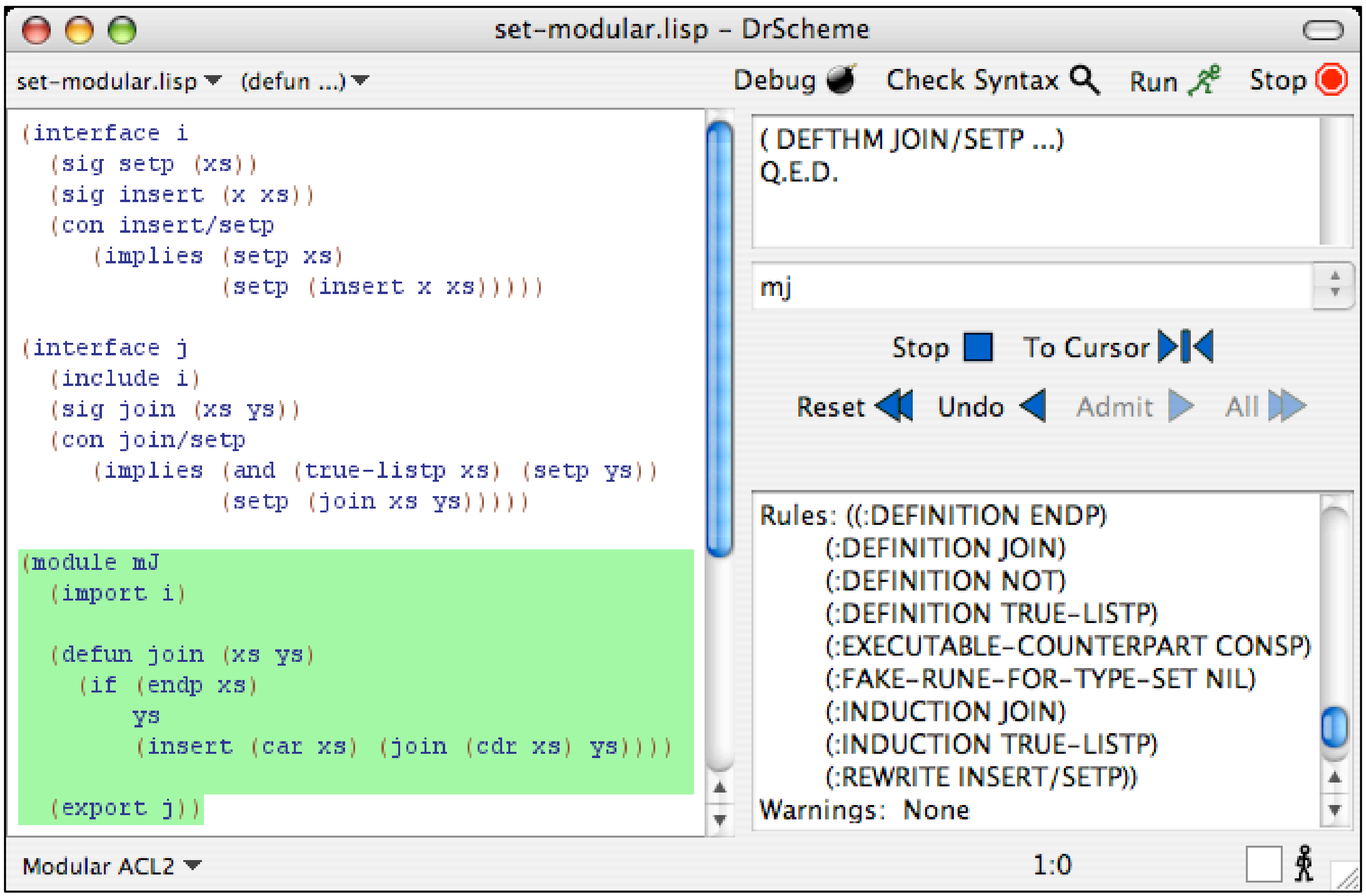
```


i
i
J
i
J


set-modular.lisp – DrScheme
set-modular.lisp (defun ...)
Debug
Check Syntax
Run
Stop
(interface i
(sig setp (xs))
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Q.E.D.
mj
Stop
To Cursor
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Rules: ((:DEFINITION ENDP)
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(:DEFINITION NOT)
(:DEFINITION TRUE-LISTP)
(:EXECUTABLE-COUNTERPART CONSP)
(:FAKE-RUNE-FOR-TYPE-SET NIL)
(:INDUCTION JOIN)
(:INDUCTION TRUE-LISTP)
(:REWRITE INSERT/SETP))
Warnings: None
Modular ACL2
1:0


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Form:  ( DEFTHM JOIN/SETP ...)
Rules: ((:DEFINITION ENDP)
        (:DEFINITION JOIN)
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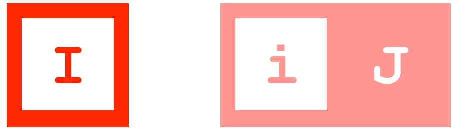
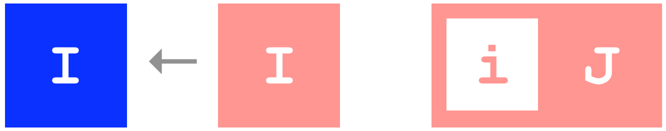



```
(module mI

  (defun setp (x) (no-duplicatesp-equal x))
  (defun insert (x set) (add-to-set-eql x set))

  (export i))
```

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I ← I i J

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```
(defthm insert/setp
  (implies (setp set)
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```


```
(link mIJ mI mJ)
```


```
(module mIJ

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I + i J = I J

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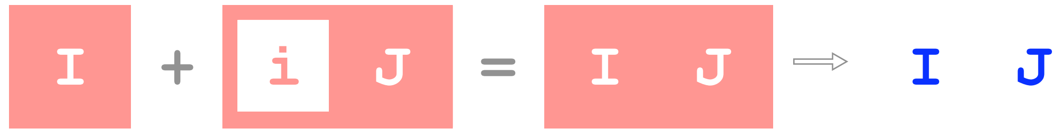
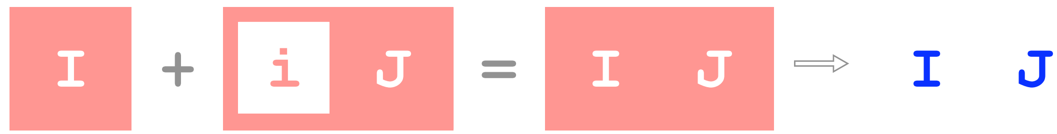



```
(invoke mIJ)
```

```
(join (list 1 2 3) (list 2 3 4))
```

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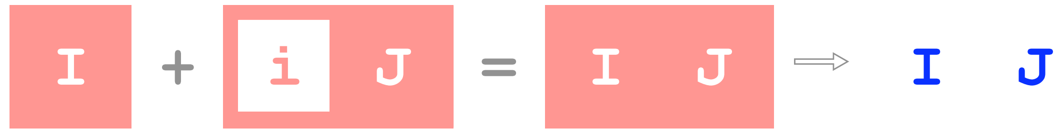


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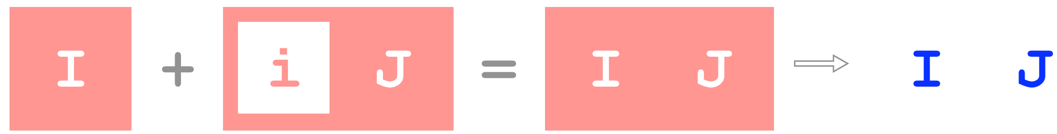


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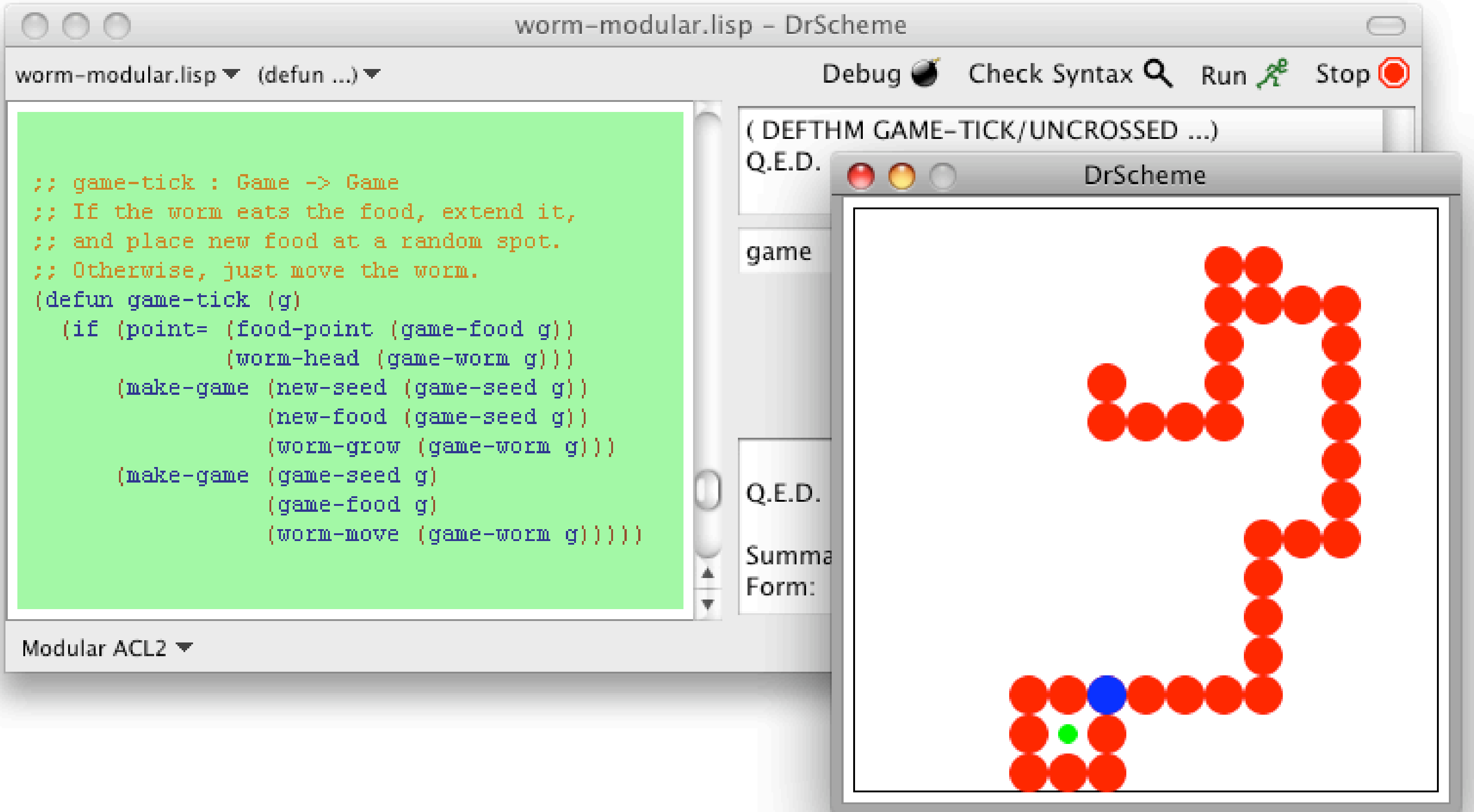
```

Experiments

Experiment: Worm Game



Experiment: Worm Game

```
(interface IGame
  (include IPoint)

  (con uncrossedp/worm-tail
    (implies (uncrossedp g)
             (points-uniquep (worm-tail g))))

  (con game-tick/uncrossedp
    (implies (and (uncrossedp g) (live-gamep g))
             (uncrossedp (game-tick g)))))
```

Experiment: Worm Game

Theorem	Modular	Monolithic
worm-turn/uncrossed-wormp	0.10s	0.48s
random-nat/range	0.10s	0.10s
modulo/range	0.08s	0.08s
connected-wormp/wormp	0.06s	3.00s
worm-turn/in-bounds-wormp	0.06s	0.23s
game-tick/uncrossedp	0.06s	845.95s
game-tick/gamep	0.03s	387.12s
game-tick/in-bounds	0.03s	362.97s
connected-gamep/gamep	0.03s	173.55s
game-key/uncrossedp	0.05s	148.65s

Experiment: Graph Search

Based on J Moore's canonical ACL2 case study. Includes a second graph representation and a second search algorithm.

```
(interface IFindPath
  (include IGraph)
  (con find-path/pathp
       (implies
        (and (graphp g)
             (nodep g x)
             (nodep g y)
             (find-path g x y))
        (pathp g x y (find-path g x y)))))
```

Experiment: Graph Search

1. ```
   (link EdgeDFS
     EdgeListGraph
     DepthFirstSearch)
   ```
2. ```
   (link EdgeBFS
     EdgeListGraph
     BreadthFirstSearch)
   ```
3. ```
   (link NeighborDFS
     NeighborListGraph
     DepthFirstSearch)
   ```
4. ```
   (link NeighborBFS
     NeighborListGraph
     BreadthFirstSearch)
   ```

Experiment: Interpreters

Specified arithmetic language with big-step and small-step interpreters. Attempted to prove equivalence.

```
(interface IEquivalence
  (include IBigStep ISmallStep)
  (con reduce-all=eval
    (implies (exprp e)
             (equal (reduce-all e) (eval e)))))
```

Experiment: Interpreters

```
(interface IBigStep
  (sig eval (e)))

(interface ISmallStep
  (sig reduce (e))
  (sig reduce-all (e)))

(interface IEquivalence
  (include IBigStep ISmallStep)
  (con reduce-all=eval
    (implies (exprp e)
             (equal (reduce-all e) (eval e)))))
```

Summary

Related Work

Modular ACL2 is most closely related to:

- Units and mixin modules
- ML-like module systems (e.g. Twelf, Coq)
- Isabelle locales, Coq sections, etc.

Conclusion

Good News: Modular ACL2 promotes code reuse and abstract reasoning.

Bad News: It needs transparent specifications and convenient linking operations.

Thank You.

DrScheme:
`http://download.plt-scheme.org/`

Dracula:
`http://www.ccs.neu.edu/~cce/acl2/`