Reason-Schemas for Planning
Non-Linear Planner 43

```
(def-backwards-reason PROTOPLAN
    :conclusions "(plan-for plan goal)"
    :condition (interest-variable plan)
    :backwards-premises
       "(protoplan-for plan goal nil nil nil nil nil)"
    :defeasible? t
    :strength .99
    :variables goal plan)

(def-backwards-reason NULL-PLAN
    :conclusions "(protoplan-for plan goal goals nodes nodes-used links bad-link)"
    :condition (and (interest-variable plan) (not (conjunctionp goal))
                         (temporally-projectible goal)
                         (or (null bad-link) (not (eq (causal-link-goal bad-link) *start*))
                              (not (equal goal (causal-link-goal bad-link))))
                         (or nodes nodes-used (not (mem goal goals))))
    :backwards-premises
       "goal"
       "(define plan (null-plan goal))"
    :variables goal plan goals nodes nodes-used links bad-link)

(def-backwards-reason GOAL-REGRESSION
    :conclusions "(protoplan-for plan goal goals nodes nodes-used links bad-link)"
    :condition (and (interest-variable plan) (null nodes-used)
                         (not (conjunctionp goal))
                         (not (mem goal goals))
                         (or (null bad-link)
                              (equal (causal-link-goal bad-link) goal)
                              (not (some #'(lambda (L) (equal (causal-link-goal L) goal)) links))))
    :backwards-premises
       "(define new-goals (cons goal goals))"
       "((precondition & action) => goal)"
       (:condition (and (not (mem precondition goals))
                        (temporally-projectible precondition)
                        (not (some #'(lambda (c) (mem c goals)) (conjuncts precondition)))))
       "(protoplan-for subplan precondition new-goals nodes nodes-used links bad-link)"
       "(define plan (extend-plan action goal subplan bad-link))"
       (:condition (not (null plan)))
    :variables precondition action goal plan subplan goals new-goals nodes
       nodes-used links bad-link)

(def-backwards-reason PROTOPLAN-FOR-GOAL
   :conclusions
      (protoplan-for plan goal goals nil nil nil nil)
   :condition (interest-variable plan)
   :forwards-premises
      "(protoplan-for plan goal goals0 nil nil nil nil)"
       (:condition (every #'(lambda (L) (not (mem (causal-link-goal L) goals))) (causal-links plan)))
    :variables plan goal goals goals0)

(def-backwards-reason SPLIT-CONJUNCTIVE-GOAL
    :conclusions
    "(protoplan-for plan& (goal1 & goal2) goals nodes nodes-used links bad-link)"
    :condition  (and (interest-variable plan&) (temporally-projectible goal1)
                        (temporally-projectible goal2))
    :backwards-premises
      "(protoplan-for plan1 goal1 goals nodes nodes-used links bad-link)"
      "(protoplan-for plan2 goal2 goals nodes nodes-used links bad-link)"
      (:condition
        (not (some #'(lambda (L1)
                             (some #'(lambda (L2)
                                           (and (eq (causal-link-target L1) (causal-link-target L2))
                                                   (equal (causal-link-goal L1) (causal-link-goal L2))
                                                   (not (eq (causal-link-root L1) (causal-link-root L2)))))
                                        (causal-links plan2)))
                          (causal-links plan1))))
      "(define plan& (merge-plans plan1 plan2 goal1 goal2))"
      (:condition (not (null plan&)))
    :variables  goal1 goal2 plan1 plan2 goals plan& nodes nodes-used links bad-link)
```

;;   **UNDERMINING CAUSAL-LINKS**

```
(def-backwards-undercutter UNDERMINE-CAUSAL-LINKS
    :defeatee  protoplan
    :backwards-premises
    "(define links (if (live-links? plan) (live-causal-links plan) (causal-links plan)))"
    "(plan-undermines-causal-links plan links)"
    :variables plan links)

(def-backwards-reason PLAN-UNDERMINES-FIRST-CAUSAL-LINK
    :conclusions  "(plan-undermines-causal-links plan links)"
    :condition  (car links)
    :backwards-premises
       "(define first-link (car links))"
       "(plan-undermines-causal-link plan R node first-link)"
    :variables  plan node links first-link R)
```

(def-backwards-reason **PLAN-UNDERMINES-ANOTHER-CAUSAL-LINK**

```
    :conclusions  "(plan-undermines-causal-links plan links)"
    :condition  (cdr links)
    :backwards-premises
       "(define rest-of-links (cdr links))"
       "(plan-undermines-causal-links plan rest-of-links)"
    :variables  plan links rest-of-links)
```

(def-backwards-reason **PLAN-UNDERMINES-CAUSAL-LINK**

```
    :conclusions  "(plan-undermines-causal-link plan+ R node link)"
    :backwards-premises
       "(define -goal (neg (causal-link-goal link)))"
       "(define node1 (if (not (eq *start* (causal-link-root link))) (causal-link-root link)))"
       "(define node2 (causal-link-target link))"
       "(define before (before-nodes plan+))"
       "(define not-between (not-between plan+))"
       "(embellished-plan-for plan plan+ -goal node1 node2 before not-between)"
       "(define node (penultimate-node plan))"
       "(define R
          (let ((u-links
                    (subset #'(lambda (L)
                                    (not (some
                                            #'(lambda (L*)
                                                (and (eq (causal-link-target L*) node)
                                                    (equal (causal-link-goal L) (causal-link-goal L*))))
                                            (causal-links plan+))))
                                (call-set node plan))))
                (when u-links (gen-conjunction (mapcar #'causal-link-goal u-links)))))"
        ;; R is used for CONFRONTATION
    :variables  plan plan+ link -goal node node1 node2 R before not-between)

;;                  SEARCHING FOR EMBELLISHED-PLANS

(def-backwards-reason EMBELLISHED-PROTOPLAN
    :conclusions "(embellished-plan-for plan plan+ -goal node1 node2 before not-between)"
    :condition (interest-variable plan)
    :backwards-premises
        "(embellished-protoplan-for plan plan+ -goal node1 node2 before not-between)"
    :defeasible? t
    :strength .99
    :variables plan plan+ -goal node1 node2 before not-between)

(def-backwards-undercutter UNDERMINE-EMBEDDED-CAUSAL-LINKS
    :defeatee  embellished-protoplan
    :backwards-premises
    "(define links (set-difference (causal-links plan) (causal-links plan+)))"
    "(plan-undermines-causal-links plan links)"
    :variables plan plan+ links)
```

```
(def-backwards-reason **EMBELLISHED-PROTOPLAN-for-GOAL**
    :conclusions  "(embellished-protoplan-for plan plan+ -goal node1 node2 before not-between)"
    :condition  (interest-variable plan)
    :forwards-premises
        "(protoplan-for plan0 -goal goals nil nil nil)"
        (:condition (subplan plan0 plan+))
        "(define p-nodes (penultimate-nodes plan0))"
        (:condition
          (if node1 (subsetp p-nodes
                        (possibly-intermediate-nodes
                              node1 node2 plan+ (plan-steps plan+) before not-between))
                     (subsetp p-nodes
                          (possibly-preceding-nodes node2 plan+ (plan-steps plan+) before))))
        "(define new-order
            (let ((before0 (remove-finish before))
                   (not-between0 (remove-not-between-finish before not-between)))
              (dolist (L (causal-links plan0))
                  (when (eq (causal-link-target L) *finish*)
                        (push (cons (causal-link-root L) *finish*) before0)))
              (dolist (penultimate-node p-nodes)
                  (dolist (n (possibly-succeeding-nodes
                                       penultimate-node plan+ (plan-steps plan+) before0))
                      (multiple-value-bind
                           (before-nodes* not-between*)
                           (add-before *finish* n plan+ before0 not-between0)
                           (setf before0 before-nodes* not-between0 not-between*))))
              (list before0 not-between0)))"
        (:condition (not (null new-order)))
```

```
       "(define plan
           (build-plan
             (plan-steps plan+) -goal (causal-links plan0) (car new-order) (cadr new-order)))"
    :variables  plan plan0 plan+ -goal node node1 node2 p-nodes
                goals before not-between new-order)

(def-backwards-reason EMBEDDED-GOAL-REGRESSION
    :conclusions "(embellished-protoplan-for plan plan+ goal node1 node2 before not-between)"
    :condition (interest-variable plan)
    :forwards-premises
       "((& precondition action) => goal)"
       (:condition (temporally-projectible precondition))
       "(define possible-nodes
                   (if node1
                     (possibly-intermediate-nodes
                          node1 node2 plan+ (plan-steps plan+) before not-between)
                     (possibly-preceding-nodes node2 plan+ (plan-steps plan+) before)))"
       (:condition (not (null possible-nodes)))
       "(plan-node new-node action)"
       (:condition (member new-node possible-nodes))
       "(define new-order
           (multiple-value-bind
                (before* not-between*)
                (catch 'merge-plans
                   (add-befores (if node1 (list (cons node1 new-node) (cons new-node node2))
                                            (list (cons new-node node2)))
                                      before not-between plan+))
                (list before* not-between*)))"
```

```
      (:condition (car new-order))
      "(define new-before (mem1 new-order))"
      "(define new-between (mem2 new-order))"
   :backwards-premises
      "(embellished-protoplan-for
                      subplan plan+ precondition nil new-node new-before new-between)"
      "(define plan
          (extend-embellished-plan new-node goal subplan plan+))"
      (:condition (not (null plan)))
   :variables plan plan+ subplan goal node1 node2 new-node precondition before not-between
                new-order new-before new-between possible-nodes action)

(def-backwards-reason **EMBEDDED-NULL-PLAN**
   :conclusions
      "(embellished-protoplan-for plan plan+ goal node1 node2 before not-between)"
   :condition (and (interest-variable plan) (null node1) (not (conjunctionp goal))
                      (temporally-projectible goal))
   :backwards-premises
      "goal"
      "(define plan (embedded-null-plan goal plan+ before not-between))"
      (:condition (not (null plan)))
   :variables plan+ goal plan node node1 node2 before not-between)

(def-backwards-reason **SPLIT-EMBEDDED-CONJUNCTIVE-GOAL**
   :conclusions
      "(embellished-protoplan-for plan& plan+ (goal1 & goal2) node1 node2 before not-between)"
   :condition
      (and (interest-variable plan&) (null node1) (temporally-projectible goal1)
                                    (temporally-projectible goal2))
  :backwards-premises
     "(embellished-protoplan-for plan1 plan+ goal1 node1 node2 before not-between)"
     "(define before1 (before-nodes plan1))"
     "(define not-between1 (not-between plan1))"
     "(embellished-protoplan-for plan2 plan+ goal2 node1 node2 before1 not-between1)"
     "(define plan& (merge-embellished-plans plan1 plan2 goal1 goal2))"
     (:condition (not (null plan&)))
  :variables
     plan+ plan& plan1 plan2 nodes goal1 goal2 node1 node2 before
          not-between before1 not-between1)

;;                            ADDING ORDERING-CONSTRAINTS

(def-forwards-reason ADD-ORDERING-CONSTRAINTS
  :conclusions
  "(protoplan-for plan goal goals nil nil nil nil)"
  :forwards-premises
     "(plan-undermines-causal-link plan- R node link)"
     (:clue? t)
     "(protoplan-for plan- goal goals nil nil nil nil)"
     "(define plan (add-not-between node link plan- t))"
     (:condition (not (null plan)))
  :variables  plan plan- node link goal goals R)

(def-forwards-reason ADD-EMBEDDED-ORDERING-CONSTRAINTS
  :conclusions "(embellished-protoplan-for plan plan+ goal node1 node2 before not-between)"
  :condition (interest-variable plan)
```

```
    :forwards-premises
        "(plan-undermines-causal-link plan- R node link)"
        (:clue? t)
        "(embellished-protoplan-for plan- plan+ goal node1 node2 before not-between)"
        "(define plan (add-not-between node link plan- nil))"
        (:condition (not (null plan)))
    :variables  plan- plan+ plan goal node1 node2 before not-between R node link)

;;                                          REUSING-NODES

(def-forwards-reason REUSE-NODES
    :conclusions
    "(protoplan-for plan goal nil nil nil nil nil)"
    :forwards-premises
         "(plan-undermines-causal-link plan+ R node bad-link)"
         (:clue? t)
         "(protoplan-for plan+ goal nil nil nil nil nil)"
         (:node node1)
         "(define goal0 (causal-link-goal bad-link))"
         "(protoplan-for plan0 goal0 goals nodes nil links0 link0)"
         (:node node2)
         (:condition (and (subplan plan0 plan+)
                          (member node2 (node-ancestors node1))
                          (some #'(lambda (L)
                                      (and (eq (causal-link-target L) *finish*)
                                           (eq (causal-link-root L) (causal-link-root bad-link))
                                           (equal (causal-link-goal L) goal0)))
                                (causal-links plan0))
```

```
                              (goals-used (cons goal0 goals) plan+ bad-link)))
        (:clue? t)
        "(define new-nodes
                (cons node (possibly-preceding-nodes
                                  node plan+ (plan-steps plan+) (before-nodes plan+))))"
        "(define links (remove bad-link (causal-links plan+)))"
    :backwards-premises
        "(protoplan-for new-plan0 goal0 goals new-nodes nil links bad-link)"
        (:condition
          (and (not (some
                          #'(lambda (L) (and (eq (causal-link-target L) *finish*)
                                                      (eq (causal-link-root L) (causal-link-root bad-link))))
                          (causal-links new-plan0)))
                   (some #'(lambda (n) (member n new-nodes)) (plan-steps new-plan0))))
        "(define plan (replace-subplan new-plan0 plan+ bad-link))"
        (:condition (not (null plan)))
    :variables
         plan goal goal0 goals nodes plan+ R node new-nodes
         links bad-link plan0 new-plan0 links0 link0 node1 node2)
```

(def-backwards-reason **REUSE-PLANS**

```
   :conclusions
       (protoplan-for plan goal goals nodes nodes-used links bad-link)
   :condition (and (interest-variable plan) (not (null nodes)))
   :forwards-premises
       "(protoplan-for plan goal goals0 nodes0 nodes-used0 links0 bad-link0)"
        (:condition (and (subsetp (plan-steps plan) nodes)
                                   (not (member bad-link (causal-links plan)))
```

```
                              (or (not (equal goal (causal-link-goal bad-link)))
                                  (mem goal goals)
                                  (not (some
                                         #'(lambda (L)
                                              (and (equal goal (causal-link-goal bad-link))
                                                   (eq (causal-link-root L) (causal-link-root bad-link))
                                                   (eq (causal-link-target L) *finish*)))
                                         (causal-links plan))))
                              (or (plan-steps plan)
                                  (null bad-link)
                                  (not (eq (causal-link-target bad-link) *start*))
                                  (not (equal goal (causal-link-goal bad-link))))))
  :variables plan goal goals nodes nodes-used links bad-link
             goals0 nodes0 nodes-used0 links0 bad-link0)

(def-backwards-reason REUSE-NODE
  :conclusions "(protoplan-for plan goal goals nodes nodes-used links bad-link)"
  :condition (and (interest-variable plan) (not (null nodes)) (not (conjunctionp goal)))
  :forwards-premises
    "(=> (& R action) goal)"
    "(plan-node node action)"
    (:condition
      (and (member node nodes)
           (or (null bad-link)
               (not (equal goal (causal-link-goal bad-link)))
               (mem goal goals)
               (not (equal (plan-node-action (causal-link-root bad-link)) action)))))
    "(define new-nodes (remove node nodes))"
```

```
        "(define new-nodes-used (cons node nodes-used))"
    :backwards-premises
        "(protoplan-for subplan R goals new-nodes new-nodes-used links bad-link)"
        "(define plan (extend-plan-with-node node goal subplan bad-link))"
        (:condition (not (null plan)))
    :variables R action plan goal goals nodes node new-nodes
                 subplan nodes-used new-nodes-used links bad-link)

;;                                  CONFRONTATION

(def-forwards-reason CONFRONTATION
    :conclusions
    "(protoplan-for plan goal goals nodes nodes-used links bad-link)"
    :forwards-premises
        "(plan-undermines-causal-link plan- R node link)"
        (:condition (not (null R)))
        (:clue? t)
        "(protoplan-for plan- goal goals nodes nodes-used links bad-link)"
        (:clue? t)
    :backwards-premises
        "(define -R (neg R))"
        "(protoplan-for repair-plan -R nil nodes nodes-used links bad-link)"
        "(define plan (make-confrontation-plan repair-plan plan- -R node links))"
        (:condition (not (null plan)))
    :variables  plan plan- R -R repair-plan node link goal goals nodes nodes-used links bad-link)

(def-forwards-reason EMBEDDED-CONFRONTATION
    :conclusions "(embellished-protoplan-for plan plan+ goal node1 node2 before not-between)"
```

```
:forwards-premises
    "(plan-undermines-causal-link plan+ R node link)"
    (:condition (not (null R)))
    (:clue? t)
    "(embellished-protoplan-for subplan plan+ goal node1 node2 before not-between)"
    (:clue? t)
:backwards-premises
    "(define -R (neg R))"
    "(embellished-plan-for repair-plan plan+ -R node1* node2* new-before new-not-between)"
    "(define plan (make-confrontation-plan repair-plan subplan -R node (list link)))"
    (:condition (not (null plan)))
:variables  plan plan+ goal node1 node2 before not-between R node link subplan
   precondition new-node new-before new-not-between -R node1* node2* repair-plan)
```