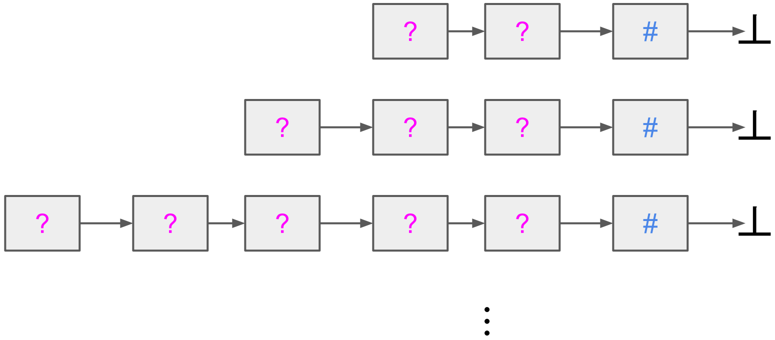
```
list* x = new {.next=NULL, .data=#};
while (nondet())
    y = x; x = new {.next=y, .data=?};

while (x->data != #)
   x = x->next; assert(x != NULL);
```



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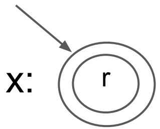
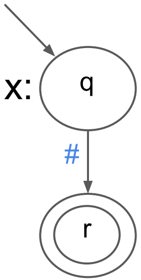
while (nondet())
     y = x; x = new {.next=y, .data=?};

while (x->data != #)
    x = x->next; assert(x != NULL);
```

Predicates

∅





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while (nondet())
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while (x->data != #)
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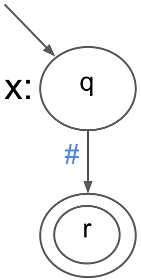
Predicates

∅



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while (x->data != #)
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```
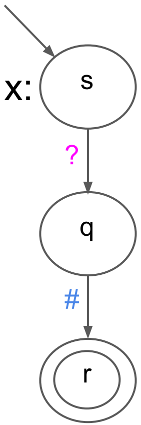

Predicates

∅



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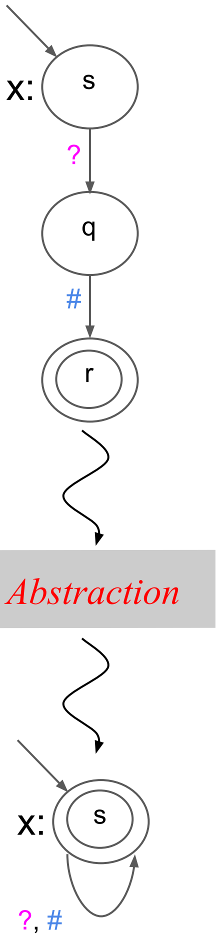
while (nondet())
    y = x; x = new {.next=y, .data=?};

while (x->data != #)
    x = x->next; assert(x != NULL);
```

Predicates

∅



```
list* x = new {.next=NULL, .data=#};
while (nondet())
    y = x; x = new {.next=y, .data=?};

while (x->data != #)
    x = x->next; assert(x != NULL);
```

Predicates

∅

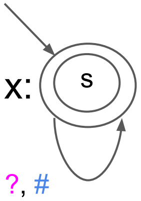
Predicate abstraction collapses states with non-empty intersection with the same set of predicates

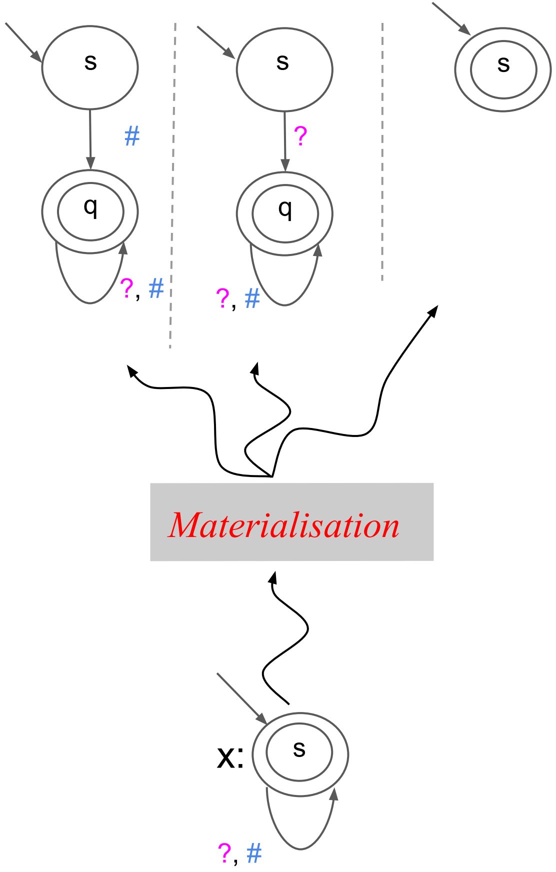
```
list* x = new {.next=NULL, .data=#};
while (nondet())
    y = x; x = new {.next=y, .data=?};

while (x->data != #)
    x = x->next; assert(x != NULL);
```

Predicates

∅





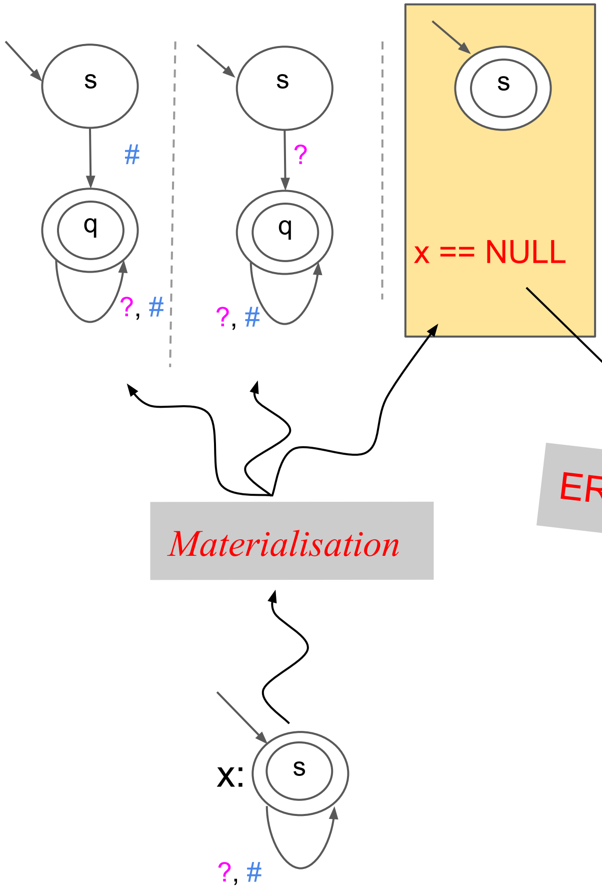
Materialisation

```
list* x = new {.next=NULL, .data=#};
while (nondet())
     y = x; x = new {.next=y, .data=?};

while (x->data != #)
    x = x->next; assert(x != NULL);
```

Predicates

∅



x == NULL

Materialisation

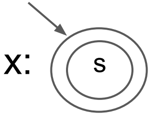
```
list* x = new {.next=NULL, .data=#};
while (nondet())
     y = x; x = new {.next=y, .data=?};

while (x->data != #)
    x = x->next; assert(x != NULL);
```

Predicates

∅

ERROR: Invalid dereference



Validate Counterexample

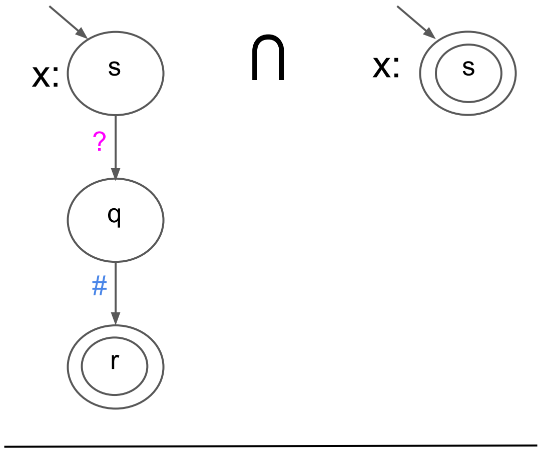
```
list* x = new {.next=NULL, .data=#};
while (nondet())
     y = x; x = new {.next=y, .data=?};

while (x->data != #)
    x = x->next; assert(x != NULL);
```

Predicates

∅

Forward automaton Backward automaton

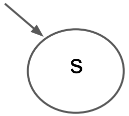


```
list* x = new {.next=NULL, .data=#};
while (nondet())
    y = x; x = new {.next=y, .data=?};

while (x->data != #)
   x = x->next; assert(x != NULL);
```

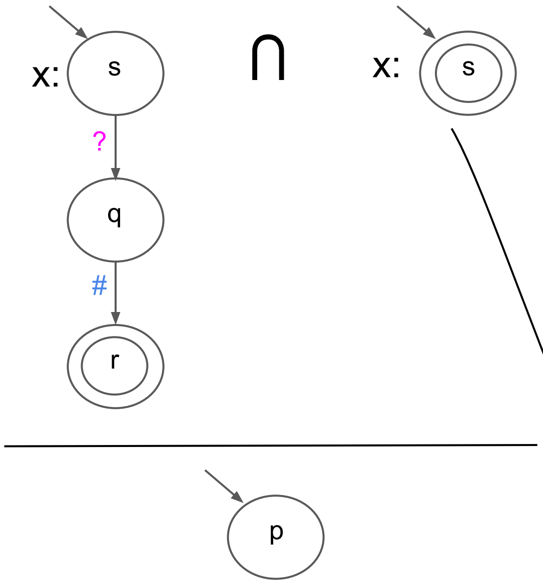
Predicates

∅



Empty Language - Spurious CE

Forward automaton Backward automaton



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while (nondet())
     y = x; x = new {.next=y, .data=?};

while (x->data != #)
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```
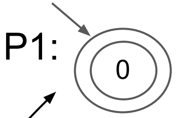
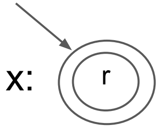

Predicates



Interpolating new predicate
(and renaming states)

Restarting the analysis



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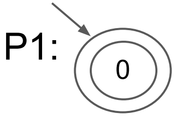
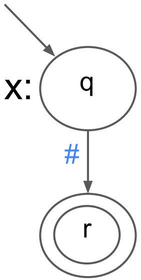
while (nondet())
     y = x; x = new {.next=y, .data=?};

while (x->data != #)
    x = x->next; assert(x != NULL);
```

Predicates





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while (x->data != #)
    x = x->next; assert(x != NULL);
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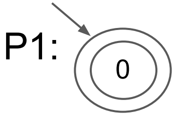
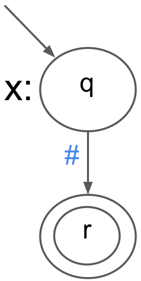
Predicates





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    y = x; x = new {.next=y, .data=?};

while (x->data != #)
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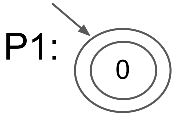
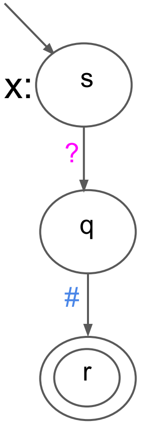
Predicates





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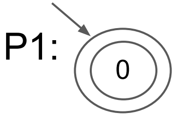
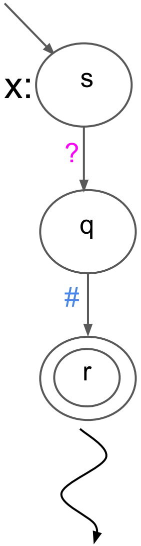
Predicates





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```
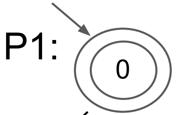

Abstraction

Predicates

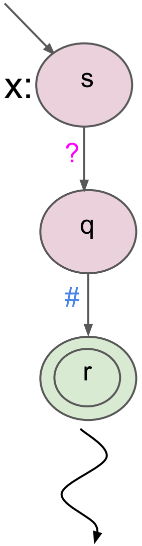


Intersection

$L(P1) \cap L(s) = \varnothing$

$L(P1) \cap L(q) = \varnothing$

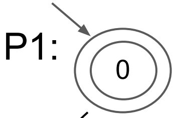
$L(P1) \cap L(r) = \{\varepsilon\}$



Abstraction

```
list* x = new {.next=NULL, .data=#};
while (nondet())
     y = x; x = new {.next=y, .data=?};

while (x->data != #)
    x = x->next; assert(x != NULL);
```

Predicates

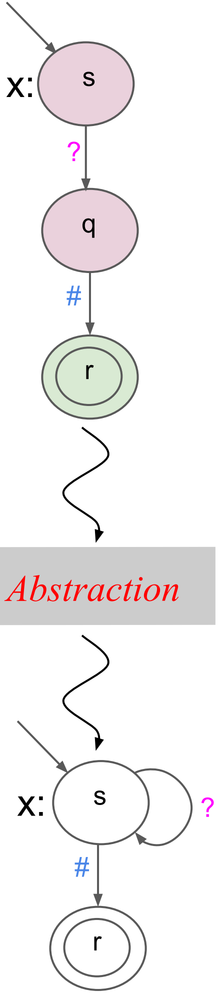


Intersection

L(P1) ∩ L(s) = ∅

L(P1) ∩ L(q) = ∅

L(P1) ∩ L(r) = {ε}



```
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while (x->data != #)
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```
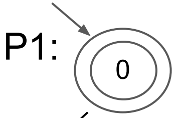

Predicates



Intersection

L(P1) ∩ L(s) = ∅

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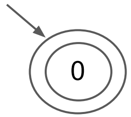
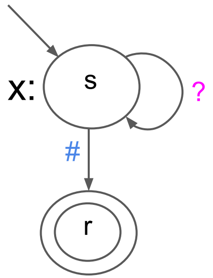
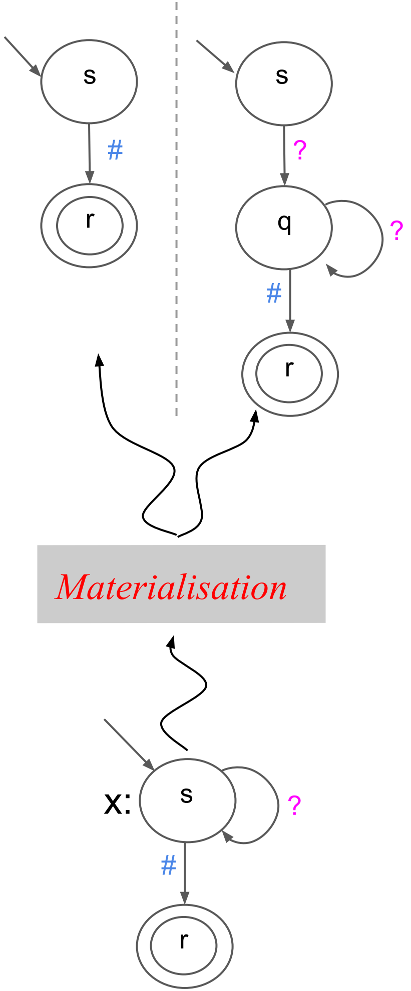
Predicates







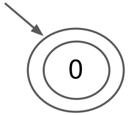
Materialisation

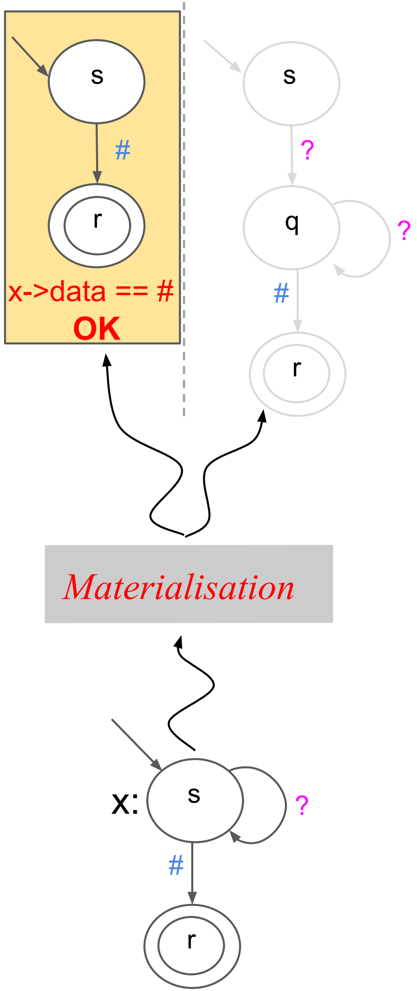
```
list* x = new {.next=NULL, .data=#};
while (nondet())
     y = x; x = new {.next=y, .data=?};

while (x->data != #)
    x = x->next; assert(x != NULL);
```

Valid dereference - exluded CE

Predicates





x->data == #

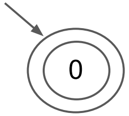
OK

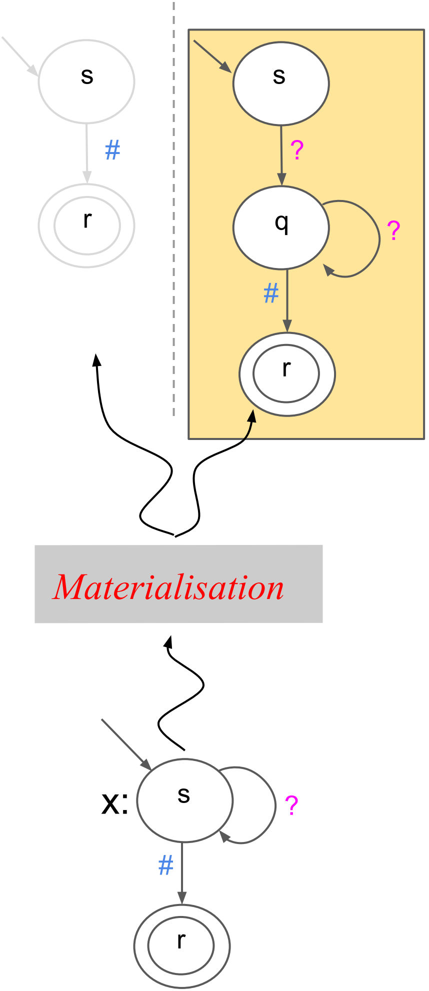
Materialisation

```
list* x = new {.next=NULL, .data=#};
while (nondet())
     y = x; x = new {.next=y, .data=?};

while (x->data != #)
    x = x->next; assert(x != NULL);
```

Predicates





Materialisation

```
list* x = new {.next=NULL, .data=#};
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```
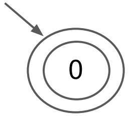
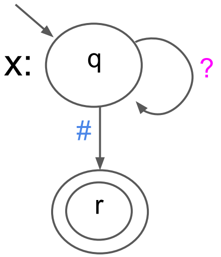
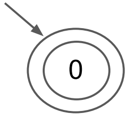

Predicates

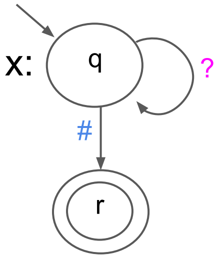




```
list* x = new {.next=NULL, .data=#};
while (nondet())
    y = x; x = new {.next=y, .data=?};

while (x->data != #)
    x = x->next; assert(x != NULL);
```

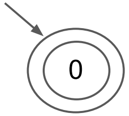
Predicates





```
list* x = new {.next=NULL, .data=#};
while (nondet())
     y = x; x = new {.next=y, .data=?};

while (x->data != #)
    x = x->next; assert(x != NULL);
```

Predicates



Program is safe

END