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## Cours MALG & MOVEX

### Vérification d'une annotation

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- ① WP calculus in Frama-c
- ② First annotation
- ③ Second annotation

1 WP calculus in Frama-c

2 First annotation

3 Second annotation

1 WP calculus in Frama-c

2 First annotation

3 Second annotation

Listing 1 – an1.c

```
//@ assert I1: P(x);
  x = e(x);
//@ assert I2: Q(x);
```

### Listing 2 – an1.c

```
//@ assert I1 : P(x);  
x = e(x);  
//@ assert I2 : Q(x);
```

- ▶  $P(x) \Rightarrow WP(x := e(x))(Q(x))$

Listing 3 – an1.c

```
//@ assert I1 : P(x);
  x = e(x);
//@ assert I2 : Q(x);
```

- ▶  $P(x) \Rightarrow WP(x := e(x))(Q(x))$
- ▶  $P(x) \Rightarrow Q[x \mapsto e(x)]$

Listing 4 – an1.c

```
//@ assert I1 : P(x);
  x = e(x);
//@ assert I2 : Q(x);
```

- ▶  $P(x) \Rightarrow WP(x := e(x))(Q(x))$
- ▶  $P(x) \Rightarrow Q[x \mapsto e(x)]$
- ▶  $P(x1) \Rightarrow Q[x \mapsto e(x1)])$  (renaming of free occurrences of x by x1)

### Listing 5 – an1.c

```
//@ assert I1 : P(x);
  x = e(x);
//@ assert I2 : Q(x);
```

- ▶  $P(x) \Rightarrow WP(x := e(x))(Q(x))$
- ▶  $P(x) \Rightarrow Q[x \mapsto e(x)]$
- ▶  $P(x1) \Rightarrow Q[x \mapsto e(x1)]$  (renaming of free occurrences of  $x$  by  $x1$ )
- ▶  $P(x1) \wedge x = e(x1) \Rightarrow Q(x)$

Listing 6 – an1.c

```
//@ assert I1 : P(x);
  x = e(x);
//@ assert I2 : Q(x);
```

- ▶  $P(x) \Rightarrow WP(x := e(x))(Q(x))$
- ▶  $P(x) \Rightarrow Q[x \mapsto e(x)]$
- ▶  $P(x1) \Rightarrow Q[x \mapsto e(x1)]$  (renaming of free occurrences of  $x$  by  $x1$ )
- ▶  $P(x1) \wedge x = e(x1) \Rightarrow Q(x)$
- ▶  $P(x1) \wedge x = e(x1) \Rightarrow Q(x)$

Listing 7 – an1.c

```
//@ assert I1 : P(x);
  x = e(x);
//@ assert I2 : Q(x);
```

- ▶  $P(x) \Rightarrow WP(x := e(x))(Q(x))$
- ▶  $P(x) \Rightarrow Q[x \mapsto e(x)]$
- ▶  $P(x1) \Rightarrow Q[x \mapsto e(x1)]$  (renaming of free occurrences of  $x$  by  $x1$ )
- ▶  $P(x1) \wedge x = e(x1) \Rightarrow Q(x)$
- ▶  $P(x1) \wedge x = e(x1) \Rightarrow Q(x)$
- ▶  $\vdash P(x1) \wedge x = e(x1) \Rightarrow Q(x)$

Listing 8 – an1.c

```
//@ assert I1 : P(x);
  x = e(x);
//@ assert I2 : Q(x);
```

- ▶  $P(x) \Rightarrow WP(x := e(x))(Q(x))$
- ▶  $P(x) \Rightarrow Q[x \mapsto e(x)]$
- ▶  $P(x1) \Rightarrow Q[x \mapsto e(x1)]$  (renaming of free occurrences of  $x$  by  $x1$ )
- ▶  $P(x1) \wedge x = e(x1) \Rightarrow Q(x)$
- ▶  $P(x1) \wedge x = e(x1) \Rightarrow Q(x)$
- ▶  $\vdash P(x1) \wedge x = e(x1) \Rightarrow Q(x)$
- ▶  $P(x1) \wedge x = e(x1) \vdash Q(x)$

## Listing 9 – an1.c

```
//@ assert l1: P(x);  
    x = e(x);  
//@ assert l2: Q(x);
```

- ▶  $P(x) \Rightarrow WP(x := e(x))(Q(x))$
  - ▶  $P(x) \Rightarrow Q[x \mapsto e(x)])$
  - ▶  $P(x1) \Rightarrow Q[x \mapsto e(x1)])$  (renaming of free occurrences of  $x$  by  $x1$ )
  - ▶  $P(x1) \wedge x = e(x1) \Rightarrow Q(x)$
  - ▶  $P(x1) \wedge x = e(x1) \Rightarrow Q(x)$
  - ▶  $\vdash P(x1) \wedge x = e(x1) \Rightarrow Q(x)$
  - ▶  $P(x1) \wedge x = e(x1) \vdash Q(x)$

Assume {

$$P(x_1)$$

- $x = e(x1)$

}

Prove:  $Q(x)$

1 WP calculus in Frama-c

2 First annotation

3 Second annotation

Listing 10 – an1.c

```
void ex(void) {
    int x=12,y=24;
    /*@ assert l1: 2*x == y;
    x = x+1;
    /*@ assert l2:  y == 2*(x-1);
}
```

## Annotation simple(I)

---

```
[kernel] Parsing an1.c (with preprocessing)
[wp] Running WP plugin...
[wp] Warning: Missing RTE guards
[wp] 2 goals scheduled
[wp] Proved goals:    4 / 4
Terminating:      1
Unreachable:     1
Qed:              2
```

## Annotation simple (I)

---

```
Goal Assertion 'l1' (file an1.c, line 3):
Assume {
  Type: is_sint32(x) /\ is_sint32(y).
  (* Initializer *)
  Init: x = 12.
  (* Initializer *)
  Init: y = 24.
}
Prove: (2 * x) = y.
Prover Qed returns Valid
```

## Annotation simple (I)

---

```
Goal Assertion 'l2' (file an1.c, line 5):
Assume {
  Type: is_sint32(x) /\ is_sint32(x_1) /\ is_sint32(y).
  (* Initializer *)
  Init: x_1 = 12.
  (* Initializer *)
  Init: y = 24.
  (* Assertion 'l1' *)
  Have: (2 * x_1) = y.
  Have: (1 + x_1) = x.
}
Prove: (2 + y) = (2 * x).
Prover Qed returns Valid
```

## Annotation simple(I)

---

```
[kernel] Parsing an1.c (with preprocessing)
[wp] Running WP plugin...
[wp] Warning: Missing RTE guards
[wp] 2 goals scheduled
[wp] Proved goals:    4 / 4
Terminating:      1
Unreachable:     1
Qed:              2
```

1 WP calculus in Frama-c

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Listing 11 – an2.c

```
void ex(void) {
    int x=12,y=24;
    /*@ assert l1: 2*x == y;
    x = x+1;
    /*@ assert l2:  y == 2*(x-1);
    x = x+2;
    /*@ assert l3:  y+6 == 2*x;
}
```

```
[kernel] Parsing an2.c (with preprocessing)
[wp] Running WP plugin...
[wp] Warning: Missing RTE guards
[wp] 3 goals scheduled
[wp] Proved goals:      5 / 5
Terminating:          1
Unreachable:          1
Qed:                  3
```

## Annotation simple (ii)

---

```
Goal Assertion 'l1' (file an2.c, line 3):
Assume {
  Type: is_sint32(x) /\ is_sint32(y).
  (* Initializer *)
  Init: x = 12.
  (* Initializer *)
  Init: y = 24.
}
Prove: (2 * x) = y.
Prover Qed returns Valid
```

## Annotation simple (ii)

---

```
Goal Assertion 'l2' (file an2.c, line 5):
Assume {
  Type: is_sint32(x) /\ is_sint32(x_1) /\ is_sint32(y).
  (* Initializer *)
  Init: x_1 = 12.
  (* Initializer *)
  Init: y = 24.
  (* Assertion 'l1' *)
  Have: (2 * x_1) = y.
  Have: (1 + x_1) = x.
}
Prove: (2 + y) = (2 * x).
Prover Qed returns Valid
```

## Annotation simple (ii)

---

Goal Assertion 'l3' (file an2.c, line 7):

```
Assume {
  Type: is_sint32(x) /\ is_sint32(x_1) /\ is_sint32(x_2) /\ is_s
  (* Initializer *)
  Init: x_2 = 12.
  (* Initializer *)
  Init: y = 24.
  (* Assertion 'l1' *)
  Have: (2 * x_2) = y.
  Have: (1 + x_2) = x_1.
  (* Assertion 'l2' *)
  Have: (2 + y) = (2 * x_1).
  Have: (2 + x_1) = x.
}
Prove: (6 + y) = (2 * x).
Prover Qed returns Valid
```

### Listing 12 – an2bis.c

```
void ex(void) {
    int x=12,y=24;
    //@ assert l1: 2*x == y;
    x = x+1;
    //@ assert l2: y == 2*(x-1);
    x = x+2;
    //@ assert l3: y+6 == 2*x;
}
```

