Lifetimes and References

EECS 211

Winter 2017

Scope

A scope is a region of program text:

- global scope (outside any language construct)
- namespace scope (outside everything but a namespace)
- class scope (inside a class or struct)
- local scope (between { and } braces; includes function scope)
- statement scope (loop variable in a for)

They nest!

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- local scope (between { and } braces; includes function scope)
- statement scope (loop variable in a for)

They nest! Useful because:

- Declarations from outer scopes are visible in inner scopes
- Declarations from inner scopes are not visible in outer scopes
- (Exception: class stuff)

Scope example

```
int number_of_bees = 0;    // global scope — visible everywhere
void increase_bees();      // also global scope

void buzz(int n)           // buzz is global, n is local to buzz
{
    if (number_of_bees > n) {
        cout << 'b';

        for (int i = 0;    // i has statement scope
            i < number_of_bees;
            ++i)
             cout << 'z';
    }

    increase_bees();
}
```

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Local scope is local

Variable names declared in different scopes refer to different objects:

```
bool is_even(int n) { return n % 2 == 0; }
bool is_odd(int n)  { return n % 2 == 1; }
```

There are two *unrelated* objects named n above

Local scope is local

Variable names declared in different scopes refer to different objects:

```
bool is_even(int n) { return n % 2 == 0; }

bool is_odd(int m) { return m % 2 == 1; }
```

There were two *unrelated* objects named `n` above

Lifetimes example

```
double mean(vector<double> w)
{
    double result = 0;
    for (double wi : w) result += wi;
    return result / w.size();
}

double variance(vector<double> v)
{
    double m = mean(v), total = 0;
    for (double vi : v) total += (vi − m) ∗ (vi − m);
    return total / v.size();
}

double std_dev(vector<double> u)
{ return my_sqrt(variance(u)); }
```

Object lifetimes are nested!

v outlives w, m, and total,

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Object lifetimes are nested!

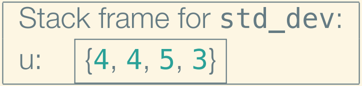
v outlives w, m, and total,

which outlive vi,

which outlives w and result,

which in turn outlive wi.

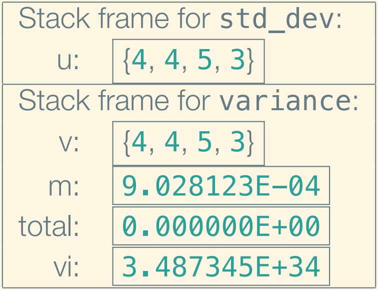
Stack layout for nested scopes



Stack frame for `std_dev`:

u: {4, 4, 5, 3}

Stack layout for nested scopes



Stack frame for `std_dev`:

u: {4, 4, 5, 3}

Stack frame for `variance`:

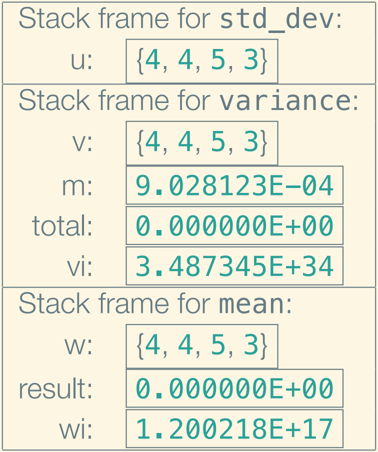
v: {4, 4, 5, 3}

m: 9.028123E−04

total: 0.000000E+00

vi: 3.487345E+34

Stack layout for nested scopes



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Stack frame for `mean`:

w: {4, 4, 5, 3}

result: 0.000000E+00

wi: 1.200218E+17

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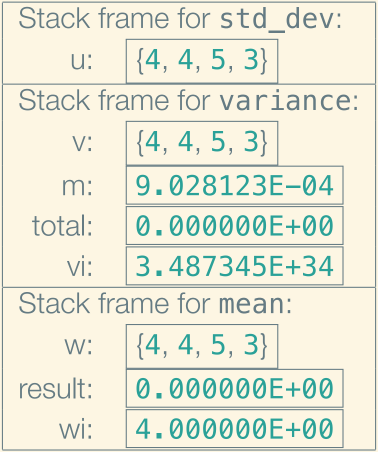

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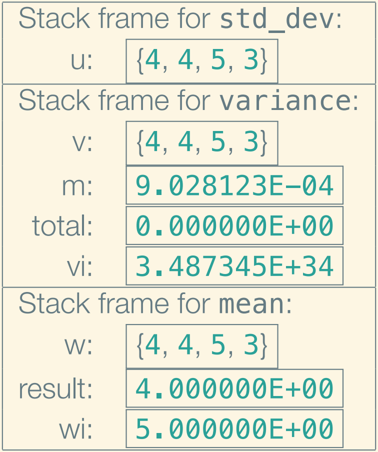

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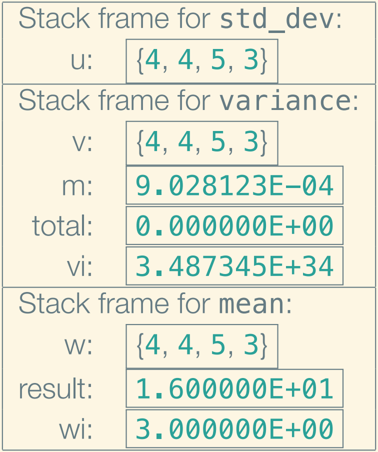

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Stack frame for `variance`:

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m: 9.028123E−04

total: 0.000000E+00

vi: 3.487345E+34

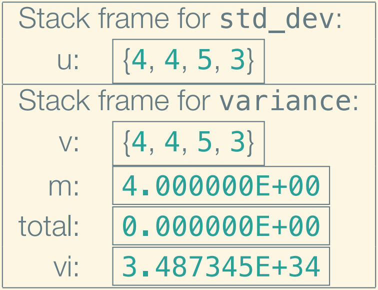
Stack frame for `mean`:

w: {4, 4, 5, 3}

result: 1.600000E+01

wi: 3.000000E+00

Stack layout for nested scopes



Stack frame for `std_dev`:

u: {4, 4, 5, 3}

Stack frame for `variance`:

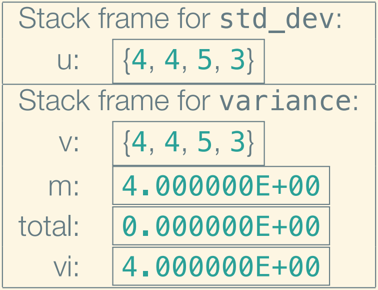
v: {4, 4, 5, 3}

m: `4.000000E+00`

total: `0.000000E+00`

vi: `3.487345E+34`

Stack layout for nested scopes



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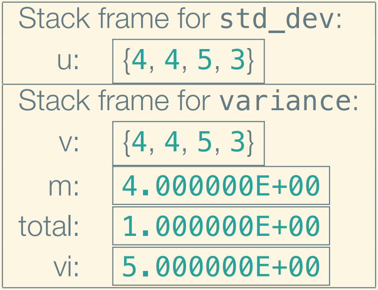

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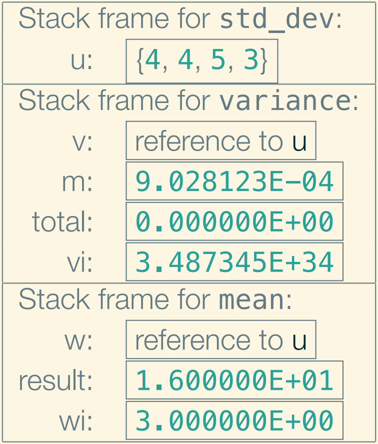
Const reference example

```
double mean(const vector<double>& w)
{
    double result = 0;
    for (double wi : w) result += wi;
    return result / w.size();
}

double variance(const vector<double>& v)
{
    double m = mean(v), total = 0;
    for (double vi : v) total += (vi - m) * (vi - m);
    return total / v.size();
}

double std_dev(vector<double> u)
{ return my_sqrt(variance(u)); }
```

Stack layout for nested scopes



Stack frame for `std_dev`:

u: {4, 4, 5, 3}

Stack frame for `variance`:

v: reference to u

m: 9.028123E-04

total: 0.000000E+00

vi: 3.487345E+34

Stack frame for `mean`:

w: reference to u

result: 1.600000E+01

wi: 3.000000E+00

Copying example: banking

Function deposit gets a copy of the vector, and returns a copy of the copy:

```
struct Account {
    double balance;
    std::string owner;
};

std::vector<Account> deposit(std::vector<Account> accts,
                             long acct_number,
                             unsigned long amount)
{
    check_deposit(acct_number);
    accts[acct_number].balance += amount;
    return accts;
}
```

Reference example: banking

Function deposit *borrows* a reference to the vector and operates on that:

```
struct Account {
    double balance;
    std::string owner;
};

void deposit(std::vector<Account>& accts,
             long acct_number,
             unsigned long amount)
{
    check_deposit(acct_number);
    accts[acct_number].balance += amount;
}
```

Harmful reference example

You can only borrow something for as long as it exists:

```
std::vector<double>& get_input()
{
    std::vector<double> result;
    ⋮
    return result;
}
```

The vector result exists only as long as function get_input is active. So by the time the caller gets it, the reference refers to an object that no longer exists.

Guidelines for borrowing

To avoid harmful (undefined) behavior:

- Most references should be parameters.
  - The caller should guarantee that the object exists through the call.
  - The callee should not save a reference to the object.

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To avoid harmful (undefined) behavior:

- Most references should be parameters.
  - The caller should guarantee that the object exists through the call.
  - The callee should not save a reference to the object.
- Returned references are borrowed parts of objects that were passed in.
  - For example, a vector index operation returns a reference to an element.
  - So the caller knows that the part object lives as long as the whole.

– To CLion! –