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Type inference for variables and functions (slides)

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Type inference for variables and functions

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Policy

- *extend* the standard
 - valid code remains valid
 - new feature integrates syntactically and semantically
- fix as much requirements as possible through constraints
 - specific syntax
 - explicit constraints
- avoid new undefined behavior
 - only, if property is not (or hardly) detectable at translation time
 - or we leave design space to implementations
- don't mess with ABI
 - no changes
 - no extensions



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Example: simple function return

How to catch the return of a `<tgmath.h>` function?

```
#include <tgmath.h>
guessType y = cos(x);           // error prone: silent conversion
```

With the new **typeof** extension this can already be done:

```
typeof(cos(x)) y = cos(x);     // error prone: paste and copy
```

With **auto** this becomes much simpler:

```
auto y = cos(x);               // type safe and copy safe
```

Even works if we don't use `<tgmath.h>`



Example: implementation dependent type

- What is the type of an integer literal? (`int`, `long` or `long long`)

```
[[1]1]div(38484848448, 448484844);
```

- So, which function to use? (`div`, `ldiv`, `lldiv`)
- Use a generic expression

```
#define div(X, Y) \
    _Generic((X)+(Y), \
            int: div, \
            long: ldiv, \
            long long: lldiv) \
    ((X), (Y))
```

- Which return type? (`div_t`, `ldiv_t`, `lldiv_t`)

```
auto res = div(38484848448, 448484844);
auto a = b * res.quot + res.rem;
```

Example: local variables for macros

```

#define dataCondStoreTG(P, E, D) \
  do { \
    auto* _pr_p = (P); \
    auto _pr_expected = (E); \
    auto _pr_desired = (D); \
    bool _pr_c; \
    do { \
      mtx_lock(&_pr_p->mtx); \
      _pr_c = (_pr_p->data == _pr_expected); \
      if (_pr_c) _pr_p->data = _pr_desired; \
      mtx_unlock(&_pr_p->mtx); \
    } while(!_pr_c); \
  } while (false)

```


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Syntax: current

underspecified declarations

- C17's syntax does not impose a type specifier

```
auto y = cos(x); // valid syntax in C17, but constraint violation
```

type completion from initializer

```
double R[] = { 1.0, 2.0 }; // valid syntax in C17, type inferred
```

Syntax: extension

extended use of `auto`

- combination with other storage class specifiers
- allow in file scope
- allow combination with qualifiers including `_Atomic`
- allow combination with pointer

```
static auto const string = "α";
```



Semantic

different qualification and pointer derivation

```

static auto          const string1 = "α"; // valid
static auto*        const string2 = "α"; // valid
static auto          const* string3 = "α"; // invalid

```

as-if **auto** were replaced by a **typeof**

```

static typeof((0, "α"))    const string1 = "α";
static typeof((0, "α")[0])* const string2 = "α";
static typeof(????)        const* string3 = "α";

```

initializer expression is evaluated **exactly once**

```

static char*          const string1 = "α"; // same qual type
static char*          const string2 = "α"; // same qual type
static XXX             const* string3 = "α"; // different type

```

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Example: simple function

- The return type is inferred from the **return**.

```
// header
inline auto max(time_t a, long b) {
    return (a < 0)
        ? ((b < 0) ? ((a < b) ? b : a) : b)
        : ((b >= 0) ? ((a < b) ? b : a) : a);
}
```

- Most of such functions will be **inline** or **static**.

```
// one TU
auto max(time_t a, long b); // emit external symbol
auto max(time_t, long);    // same
auto max();                // same
auto max;                  // same
```

- Declaration that is not a definition => only if a definition is visible.



Example: recursive function

- The return type is inferred from the *lexicographic first return*.

```
inline auto sum(size_t n, strength A[n]){
  switch(n) {
    case 0: return +((strength)0); /* return the promoted type */
    /* ----- sum now visible ----- */
    case 1: return +A[0];          /* same type */
    default: return sum(n/2, A) + sum(n - n/2, &A[n/2]); /* same */
  }
}
```

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Rules

- Inferred return type must exist before the function definition.
 - Don't use this feature to export types from a function.
- The return type is inferred from the lexicographic first **return**.
 - visibility of function name after that
 - visibility of function name after end of body if there is none
 - all other **return** expressions must have *same* type
- Use mainly restricted to **inline** and **static** functions
- Declaration that is not a definition => only if a definition is visible.
 - useful for *instantiation* of **inline** functions (objects?)
 - useful for access to file scope identifiers via **extern**



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Existing extensions

C++ and widely used gcc extensions

inference	C++	gcc <i>et al</i> C extension	current C23
from type	decltype		
from lvalue	decltype		
from type		typeof	typeof
from lvalue		typeof	typeof
from lvalue			remove_quals
from value	auto	__auto_type	