Do Programming Languages need Query Languages?

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Do Programming Languages need Query Languages?

(spoiler alert)

Yes they do!

Programming and data processing

Claims

1. Data processing plays a central role in programming.

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Examples: standard support libraries

1. *Collections* to store data
   binary search trees, hash tables, tuples, dynamic arrays, ...
2. *Algorithms* to operate on data
   sorting, filtering, transforming, set operations, ...

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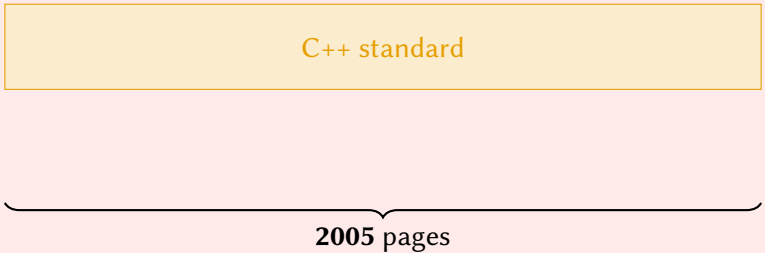
Working Draft of the C++ standard

(Document Number: N4964, Date 2023-10-15.)



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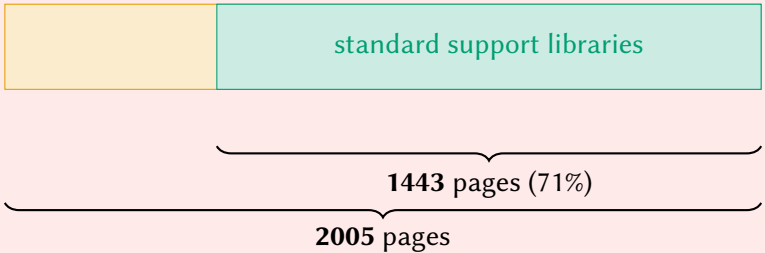

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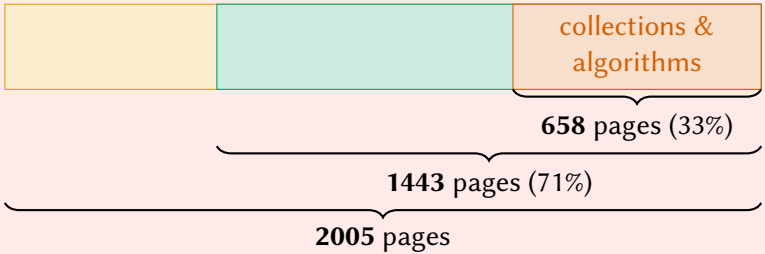

Not counting: numeric, time, formatting, IO, threads, ...

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- **Projection** (π_{columns}): `std::transform`.
- **Selection** ($\sigma_{\text{conditions}}$): `std::copy_if`, `std::views::filter`.
- **Joins** ($\times$, $\bowtie$): loops, `std::views::cartesian_product`.
- **Set operations** ($\cap$, $\cup$, $\setminus$): `std::set_union`, ...

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- **Sorting**: `std::sort`, `std::stable_sort`.
- **Deduplication**: `std::unique_copy`.
- **Aggregation**: `std::accumulate` and `std::reduce`, `std::ranges::fold_left`.

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- **Aggregation**: `std::accumulate` and `std::reduce`, `std::ranges::fold_left`.

- **Parallelization**: execution policies (algorithms), `std::async` (evaluation), ...
- **Pipelined execution**: `std::ranges`, coroutines using `std::generator`.

An example: How to *program* relational algebra in C++

$$\pi_{R.\text{parent}}(\sigma_{R.\text{child}=S.\text{name}}(\rho_R(\text{parentOf}) \times \sigma_{S.\text{place}=\text{“Hamilton”}}(\rho_S(\text{person}))))$$

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$$\pi_{R.\text{parent}}(\sigma_{R.\text{child}=S.\text{name}}(\rho_R(\text{parentOf}) \times \sigma_{S.\text{place}=\text{“Hamilton”}}(\rho_S(\text{person}))))$$

```
using namespace std::views;

auto where_pred = [](auto l) { return l.place == "Hamilton"; };

auto product_pred = [](auto t) {
  auto [po, p] = t; return po.child == p.name; };

auto join = cartesian_product(parents, persons | filter(where_pred));
for (auto [po, p] : join | filter(product_pred)) {
    std::cout << po.parent << std::endl;
}
```

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Efficient data processing

"*Complex*" data processing algorithms even for *simple* data processing tasks.
E.g., join algorithms, join ordering, index usage, selection push down, ...

This complexity is delegated to the programmer.

An example: A *more-efficient* query in C++

```
/* parents is a set, ordered on (parent, child).
 * persons is a set, ordered on (name, place), name is key. */

auto where_pred = [](auto l) { return l.place == "Hamilton"; };
auto filtered = persons | filter(where_pred)
                        | std::ranges::to<std::vector>();

for (auto& [pname, cname] : parents) {
  person_t pcname, "Hamilton";
  bool has_child = std::binary_search(filtered.begin(),
                                      filtered.end(), p);
  if (has_child) {
    std::cout << pname << std::endl;
  }
}
```

An example: A *more-efficient* query in C++

```
/* parents is a set, ordered on (parent, child).
 * persons is a set, ordered on (name, place), name is key. */

for (auto& [pname, cname] : parents) {
  person_t pcname, "Hamilton";
  bool has_child = persons.contains(p);
  if (has_child) {
    std::cout << pname << std::endl;
  }
}
```

An example: A *more-efficient* query in C++

	Runtime complexity	Memory usage
Original	$\Theta(\lvert\text{parents}\rvert \cdot \lvert\text{persons}\rvert)$	$\Theta(1)$
First variant	$\Theta(\lvert\text{parents}\rvert \log \lvert\text{filtered}\rvert + \lvert\text{persons}\rvert)$	$\Theta(\lvert\text{filtered}\rvert)$
Second variant	$\Theta(\lvert\text{parents}\rvert \log \lvert\text{persons}\rvert)$	$\Theta(1)$

Both “improved” versions can be significantly improved to reduce overheads!

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Both “improved” versions can be significantly improved to reduce overheads!

What if we want *unique* parents?

An example: A *more-efficient* query in SQL

```
SELECT pname
FROM parents R, persons S
WHERE R.child = S.name AND S.place = "Hamilton";
```

An example: A *more-efficient* query in SQL

```
SELECT DISTINCT pname
FROM parents R, persons S
WHERE R.child = S.name AND S.place = "Hamilton";
```

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```
SELECT DISTINCT pname
FROM parents R, persons S
WHERE R.child = S.name AND S.place = "Hamilton";
```

Some database systems need a helping hand…

```
SELECT DISTINCT pname
FROM parents
WHERE child IN (SELECT name
                FROM persons
                WHERE place = "Hamilton");
```