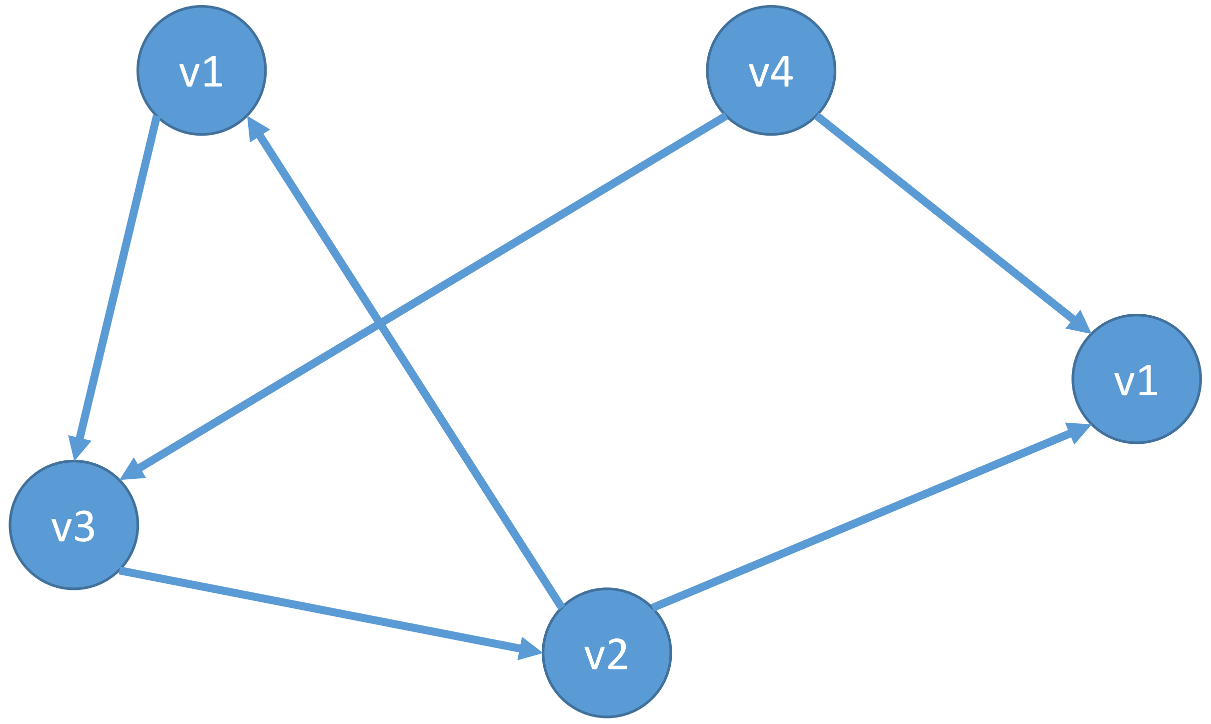
# Graph Database

NPRG051 - Advanced Programming in C++

Assignment #1

2023/24

## Directed Graph



- https://en.wikipedia.org/wiki/Graph_(discrete_mathematics)

## Requirements

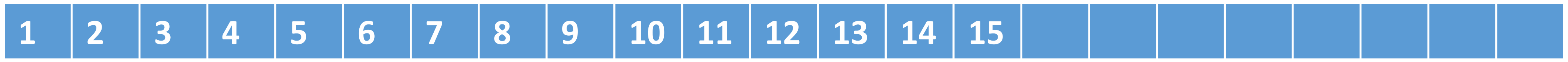
- Graph manipulation
  - Start with empty graph
  - Add a vertex/edge
  - *Vertex/edge removal not supported*
- Graph traversal
  - Pass through all vertexes/edges
  - Pass through all outgoing edges for each vertex
- User-defined types as vertex/edge identifiers
- User-defined lists of vertex/edge attributes
  - Stored column-wise

## Row storage

```
struct point_3d {
  int x;
  int y;
  int z;
};
std::vector<point_3d> points;
```

| std::vector<int [3]> |
|---|
| {1, 2, 3} |
| {4, 5, 6} |
| {7, 8, 9} |
| {10, 11, 12} |
| {13, 14, 15} |

Memory



## Columnar storage

```
struct points_3d {
  std::vector<int> xs;
  std::vector<int> ys;
  std::vector<int> zs;
};
points_3d points;
```

Memory

|  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|
| 1 | 4 | 7 | 10 | 13 |  |  |  |  |
| 2 | 5 | 8 | 11 | 14 |  |  |  |  |
| 3 | 6 | 9 | 12 | 15 |  |  |  |  |

| std::vectors xs[3] |  |  |
|---|---|---|
| xs | ys | zs |
| [1, 4, 7, 10, 13] | [2, 5, 8, 11, 14] | [3, 6, 9, 12, 15] |

# Columnar storage

- A struct of arrays vs. An array of structs
  - https://en.wikipedia.org/wiki/AoS_and_SoA
- Columns optimized for reading of single properties
  - `std::vector<bool>` is specialized
- Easier for SIMD instructions

## API: graph schema

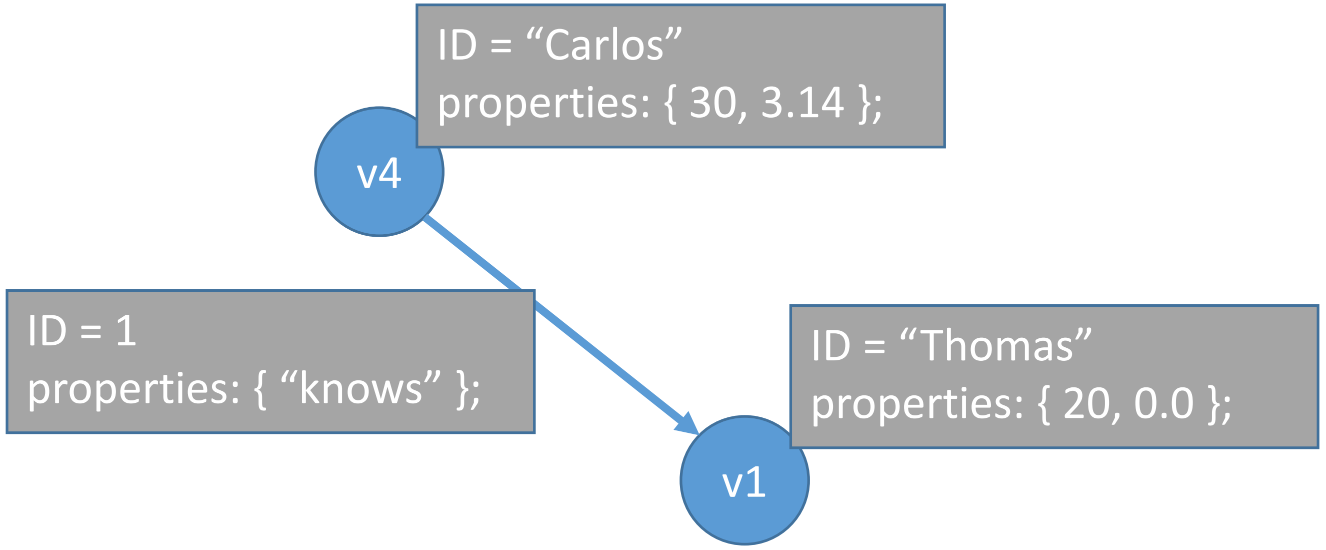
```
struct graph_schema {
  using vertex_user_id_t = // vertex id type
  using vertex_property_t = // vertex property type

  using edge_user_id_t = // edge id type
  using edge_property_t = // edge property type
};
```

# API: graph schema example

```
struct graph_schema {
  using vertex_user_id_t = std::string;
  using vertex_property_t = std::tuple<int, double>

  using edge_user_id_t = int;
  using edge_property_t = std::tuple<std::string>;
};
```



## API: the class `graph_db`

- Header: `graph_db.hpp`
  - Documented

```
template<class GraphSchema>
class graph_db {
  // types
  // functions for vertexes
  // functions for edges
};
```

## API: functions for vertexes

```
// Add a new vertex into the DB with default properties
vertex_t add_vertex(GraphSchema::vertex_user_id_t &&);

// Add a new vertex into the DB with given properties
vertex_t add_vertex(GraphSchema::vertex_user_id_t &&,
                    Props &&...);

// Return [begin(),end()] iterators to all vertexes in DB
std::ranges::subrange<vertex_it_t> get_vertexes();
```

## std::ranges::subrange

- Contains two iterators of given type
- Readable using
  - begin(), end()

```
for ( auto && v : graph.get_vertexes() ) {/*...*/}
```

  - get<0>(), get<1>()

```
auto [b, e] = graph.get_vertexes();
std::for_each(b, e, /*...*/);
```

# API: functions for edges

```
// Add a new edge between 2 vertexes into the DB with default
//  property values
edge_t add_edge(GraphSchema::edge_user_id_t &&,
                const vertex_t &, const vertex_t &);

// Add a new edge between 2 vertexes into the DB with given
//  property values
edge_t add_edge(GraphSchema::edge_user_id_t &&,
                vertex_t, vertex_t, Props &&...);

// Return [begin(),end()] iterators to all edges in DB
std::ranges::subrange<edge_it_t> get_edges();
```

## API: types

```
using vertex_t = // The vertex type
using edge_t = // The edge type

using vertex_it_t = // The vertex iterator type
using edge_it_t = // The edge iterator type

using neighbor_it_t = // The neighbor iterator type
```

# API: the vertex class

```
// Returns id of the vertex
GraphSchema::vertex_user_id_t id();

// Returns all properties of vertex
GraphSchema::vertex_property_t get_properties();

// Returns a single property value on I-th place
auto get_property<I>();

// Set all values of properties
void set_properties(PropsType &&...);

// Set a single property value on I-th place
void set_property<I>(PropType);

// A iterator type that traverses outgoing edges
using neighbor_it_t =

// Return [begin(),end()] iterators to the neighbors
std::ranges::subrange<neighbor_it_t> edges();
```

# API: the edge class

```
// Returns id of the edge
GraphSchema::edge_user_id_t id();

// Returns all properties of edge
GraphSchema::vertex_property_t get_properties();

// Returns a single property value on I-th place
auto get_property<I>();

// Set all values of properties
void set_properties(PropsType &&...);

// Set a single property value on I-th place
void set_property<I>(PropType);

// Returns the source vertex
graph_db::vertex_t src();

// Returns the destination vertex
graph_db::vertex_t dst();
```

## Evaluation

- Upload `graph_db.hpp` with the correct API into Recodex
  - You can include also your own files
- Testing suite is available with the example test
  - If it compiles & runs on your machine, it should compile & run in Recodex too
- Resulting points based on the manual evaluation
- 10 points in total
  - Functionality (major)
  - Code culture (minor)
    - Readability, no warnings, no memory-leaks, const-correctness, no necessary copies (rvalues, references, …), ...

# Hints

- Use proxy pattern for vertex/edge classes
  - https://en.wikipedia.org/wiki/Proxy_pattern
- Output iterators
  - https://en.cppreference.com/w/cpp/named_req/OutputIterator