ECS Back and Forth

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Italian C++ Community

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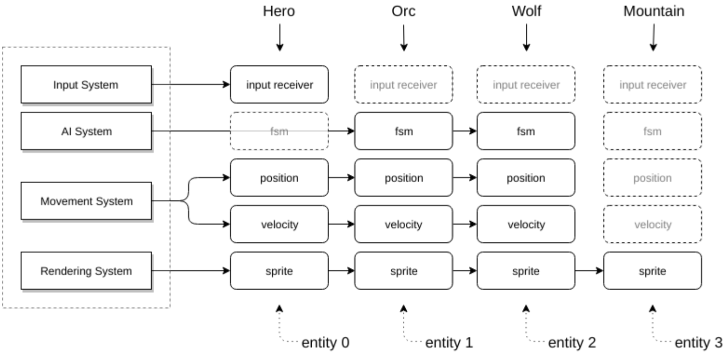
From hierarchies to components

Entity–Component–System (**ECS**) is an architectural pattern.



It favors **composition** over inheritance and sacrifices encapsulation.

Premise

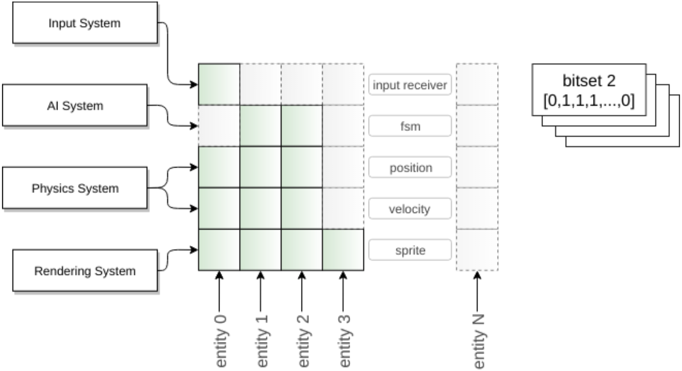
Entity-Component-System (ECS)
offers better code organization and higher performance

but

It is not the Holy Grail
of game development.

A Big Array to rule them all

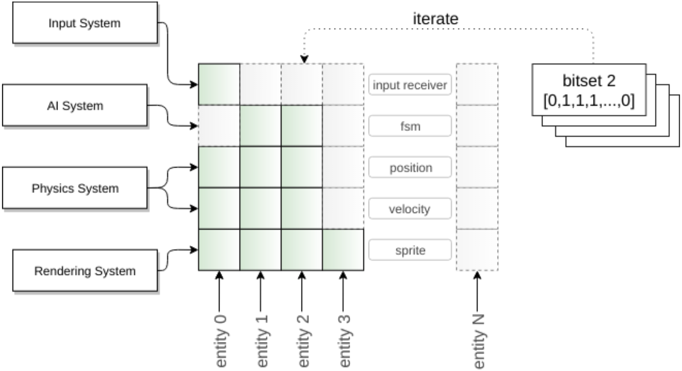
Entity identifiers are **indexes**, bitsets are component masks.



More **holes**, more jumps, more wasted memory, less performance.

Holes, holes everywhere

Iterate **bitmasks**, use entities to get components when needed.



Components are only **apparently** tightly packed, in fact they are not.

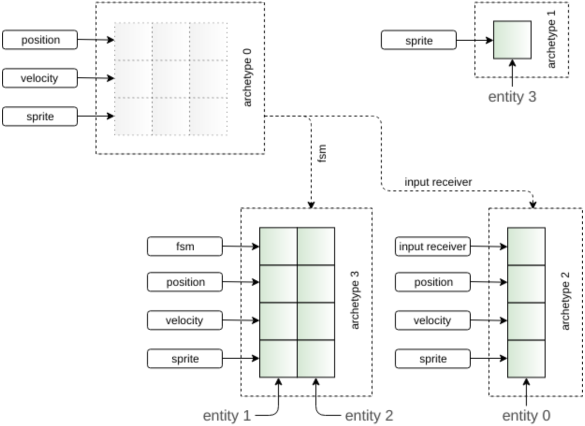
Pros and Cons

The big array is good enough for small games:

- Straightforward to implement and to maintain.
- Best performance on construction/destruction of components.
- Pretty good performance when arrays of components are dense.
- Too much memory is wasted in real world cases.
- Holes defeat the purpose of keeping instances tightly packed.
- We don't know what entities own what components.

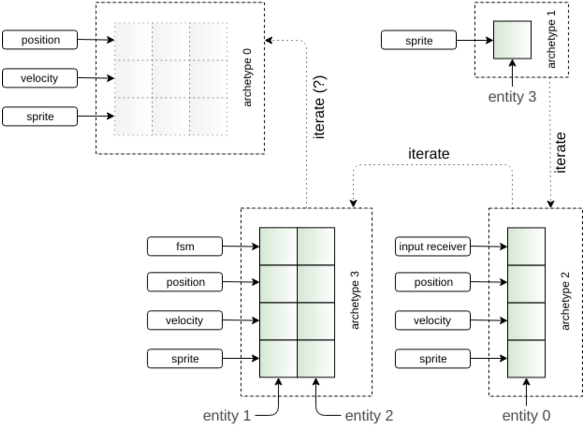
It can be refined to match the requirements of medium (?) sized games.

Archetypes (the easy version)



- Entities are **moved** between archetypes.
- More combinations means higher **fragmentation**.
- **Multithreading** friendly (with block-based archetypes).

Fragmentation: yay or nay?



- Components are only **tightly packed** per archetype.
- **Fragmentation** cannot be any way worse than this.
- Cache or search archetypes matched with **queries**.

Pros and Cons

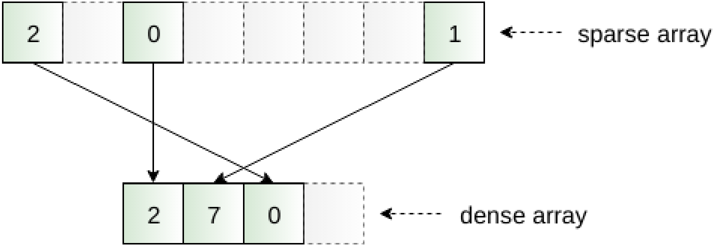
Well suited when performance matters:

- Really good performance both on single and multiple components.
- Multithreading is straightforward to achieve in some cases.
- Best performance on bulk creation of entities and components.
- Assigning and removing components is intrinsically slow.
- Fragmentation can affect performance to an extent.
- Some operations are not supported out-of-the-box (eg sorting).

It can be refined to increase even further benefits and performance.

They call me Packed Array

Lookup, insertion, deletion, . . . **complexity** is $O(1)$.



Iteration is $O(N)$ and the dense array is tightly packed.

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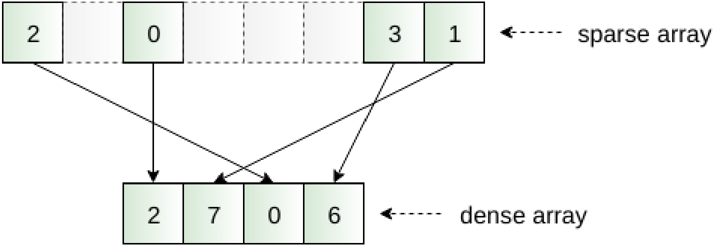

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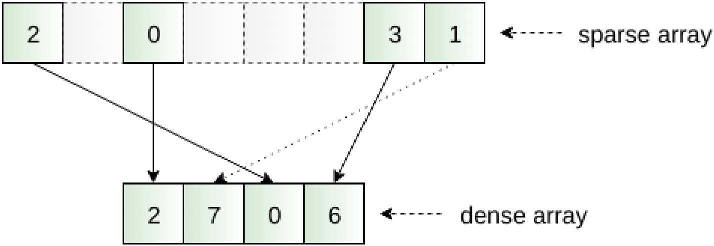

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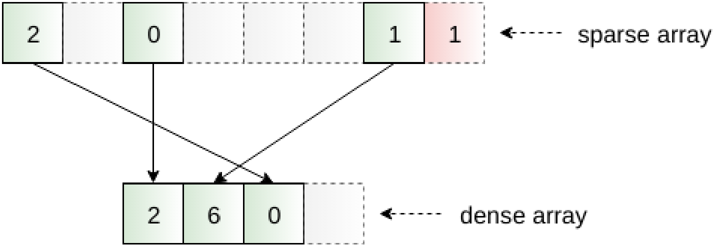
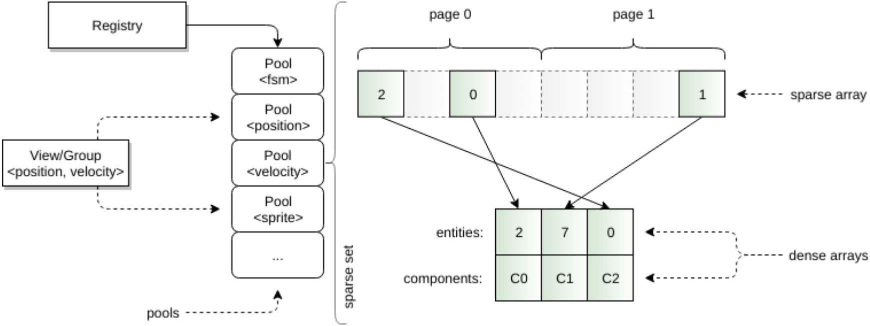


Iteration is $O(N)$ and the dense array is tightly packed.

A real world example: EnTT

A customized **sparse set** is used for the pools of components.



Multiple access patterns supported, from **perfect SoA** to fully random.

Pros and Cons

Well suited when performance matters:

- Grouping functionalities can reach outstanding performance.
- Best performance when it comes to iterating single components.
- Multithreading friendly, not necessarily built-in.
- Users **must** know what are their data to get the best.
- Users **must** know what are their critical paths and what are not.
- Indirection can affect performance to an extent in some cases.

It can be refined to reduce or even eliminate indirection in most cases.

Are they in the same ballpark?

- Know you game/software.
  - The big array plays in a different (lower) league.
  - Archetypes vs Sparse sets: 1M of elements, differences of $0.N$ ms.
- Almost static vs dynamic entities.
  - Archetypes for low level systems (eg rendering).
  - Sparse sets for high level systems (eg gameplay).
  - Both are just fine for going full-ECS.
- Performance on construction/destruction matters.
  - Archetypes: many batch creations, few assignments/deletions.
  - Sparse sets: components to the rescue (eg messaging system).
- Interested in how things are laid out?
  - Archetypes offer many small groups for known patterns.
  - Sparse sets offer always a $(T*, size)$ couple.

The C++ of EnTT

`EnTT` is a C++ framework mainly known for its **ECS** model.

Some things you can spot here and there if you pay attention:

- Type erasure: pools for components, signals, and so on.
- SFINAE (Substitution Failure Is Not An Error): any file of your choice.
- CRTP (Curiously Recurring Template Pattern): `emitter` class.
- Tag dispatching: `process` and `scheduler` classes.
- Type traits: *named types* to make `EnTT` work across boundaries.
- Small object optimization: `meta_any` class.

And much, **much** more...

Questions?

Italian C++ Conference 2019

++it Italian C++ Community

June 15, Milan

Links

- ECS back and forth series
  - Introduction
  - Where are my entities?
  - Sparse sets and grouping functionalities
  - Why you don't need to store deleted entities
  - To be continued. . .
- EnTT - Gaming meets modern C++
- EntityX - A fast, type-safe C++ Entity-Component system
- decs - Prototype data-oriented ECS
- Unity DOTS - Data-Oriented Technology Stack