Huge Graph Analysis on Your Own Server with WebGraph in Rust

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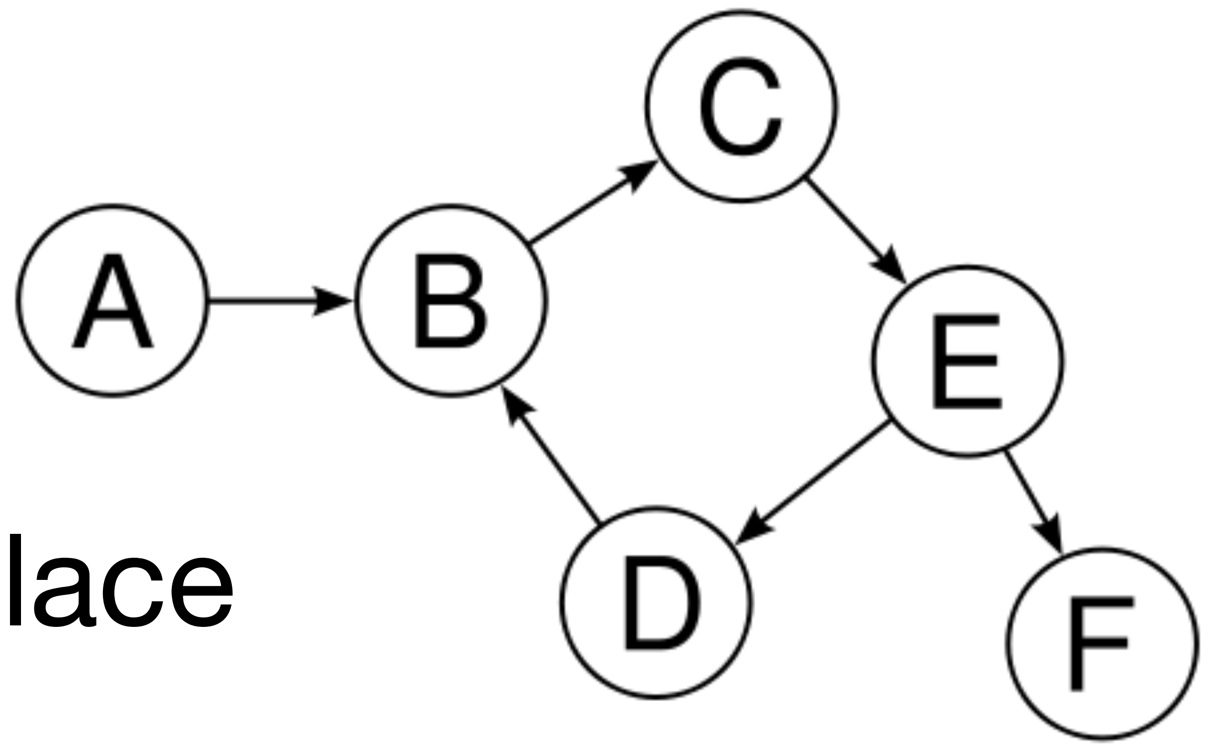

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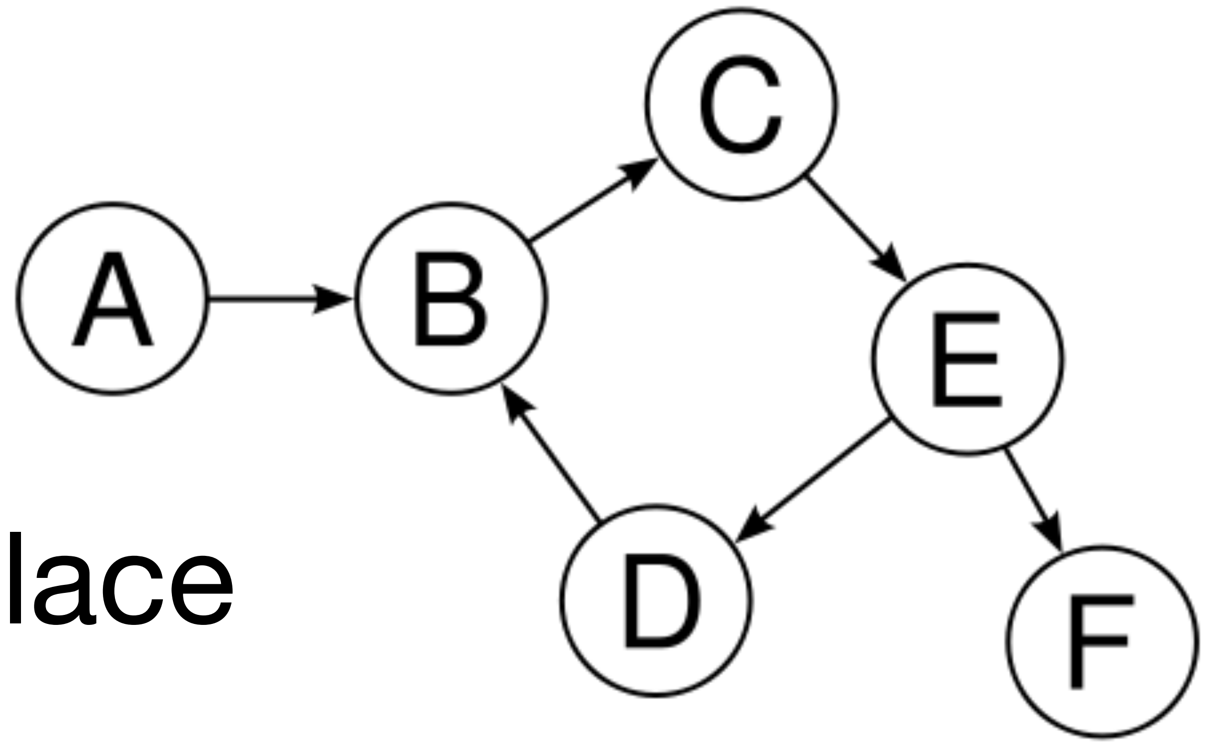

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- What can we do? Compression!

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- Common Crawl distributes data using WebGraph

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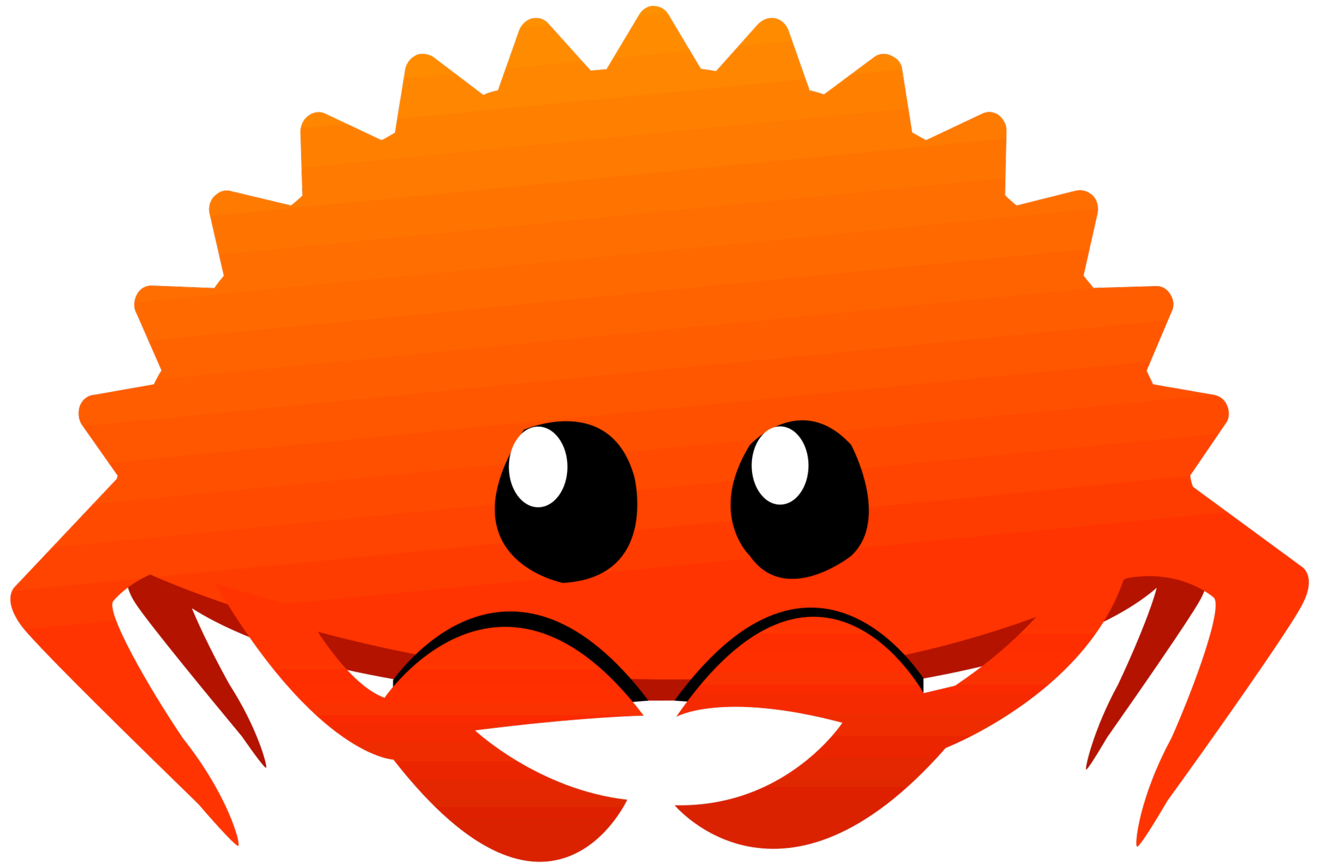
- Still, Java started to get in the way

Moving to Rust



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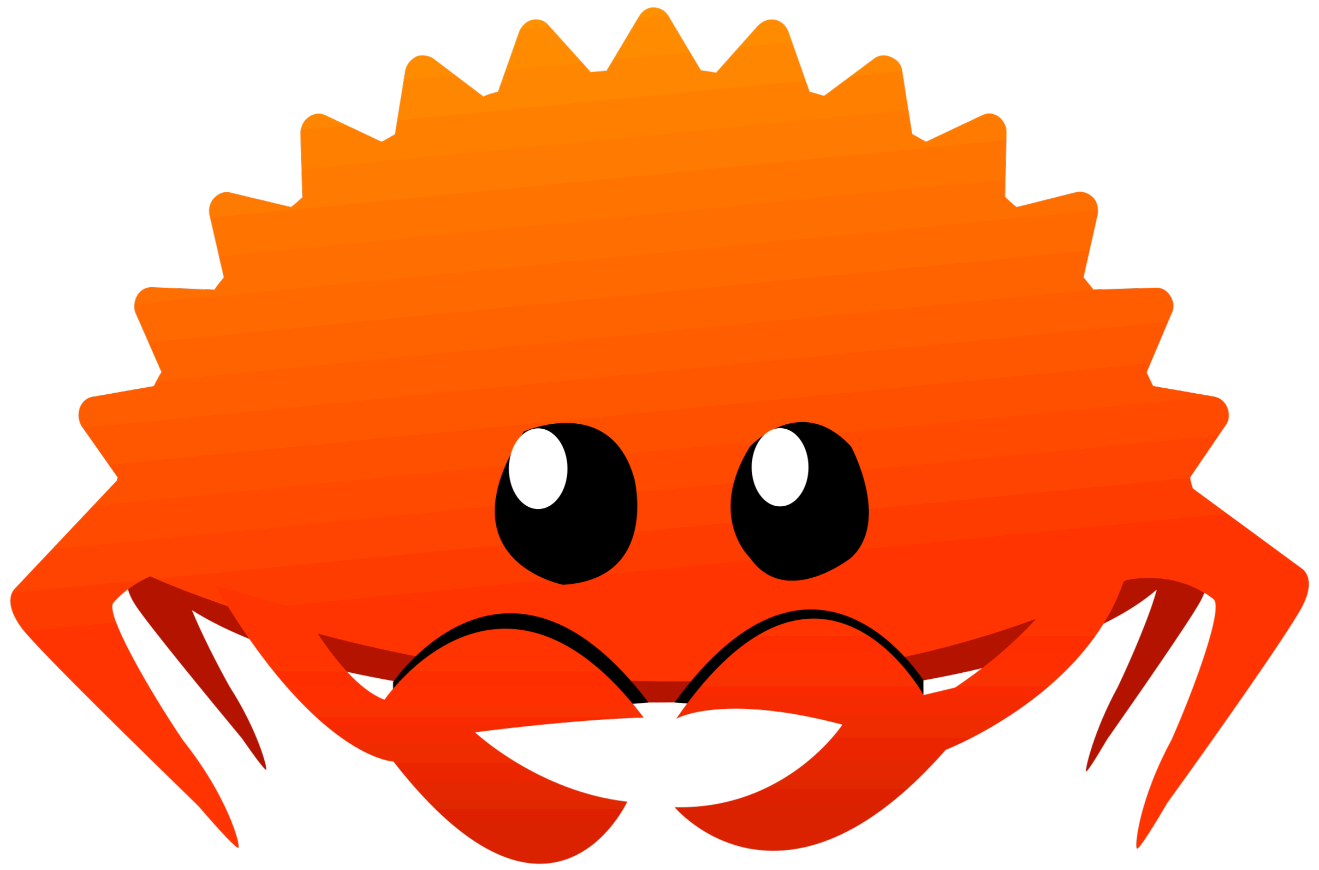

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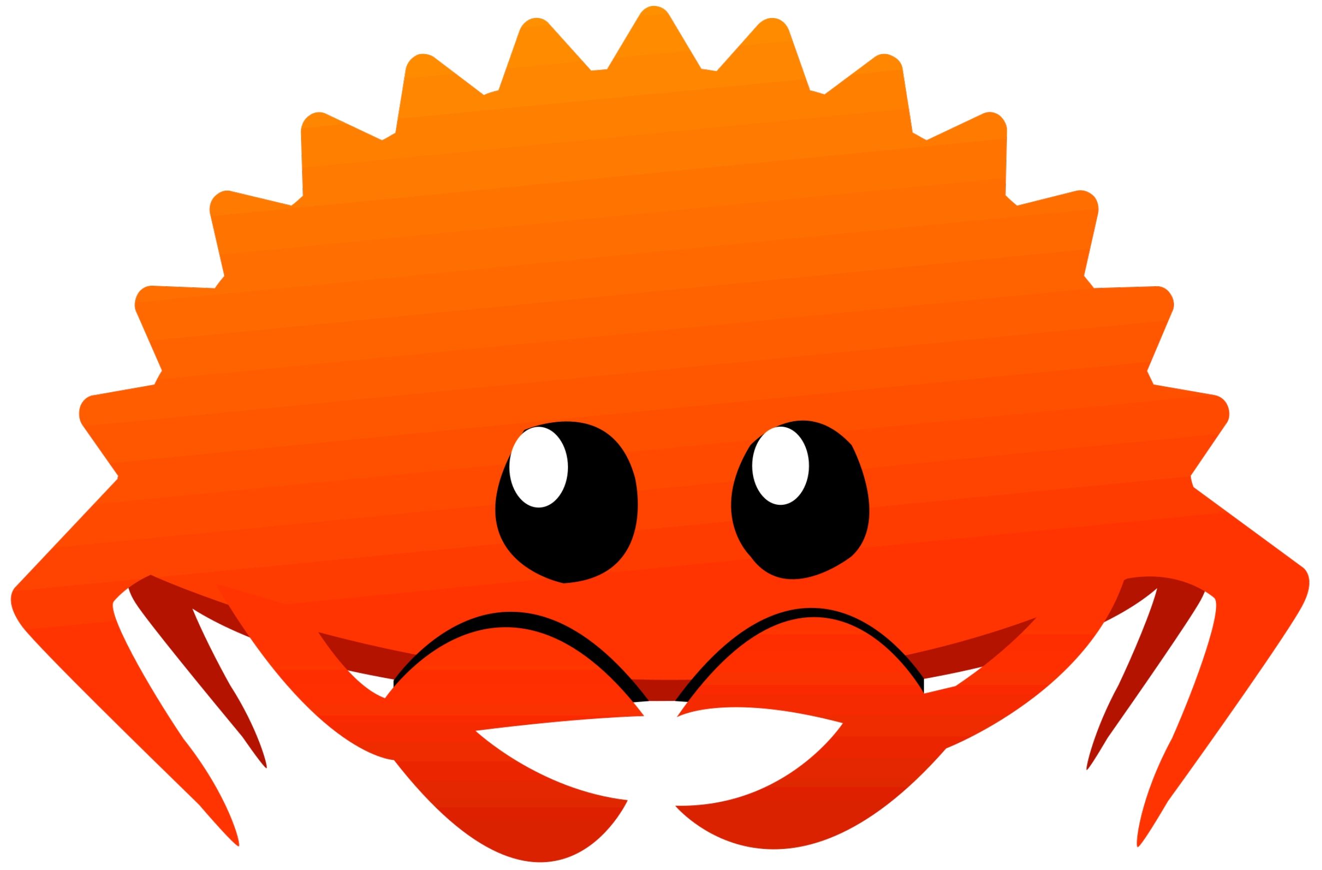

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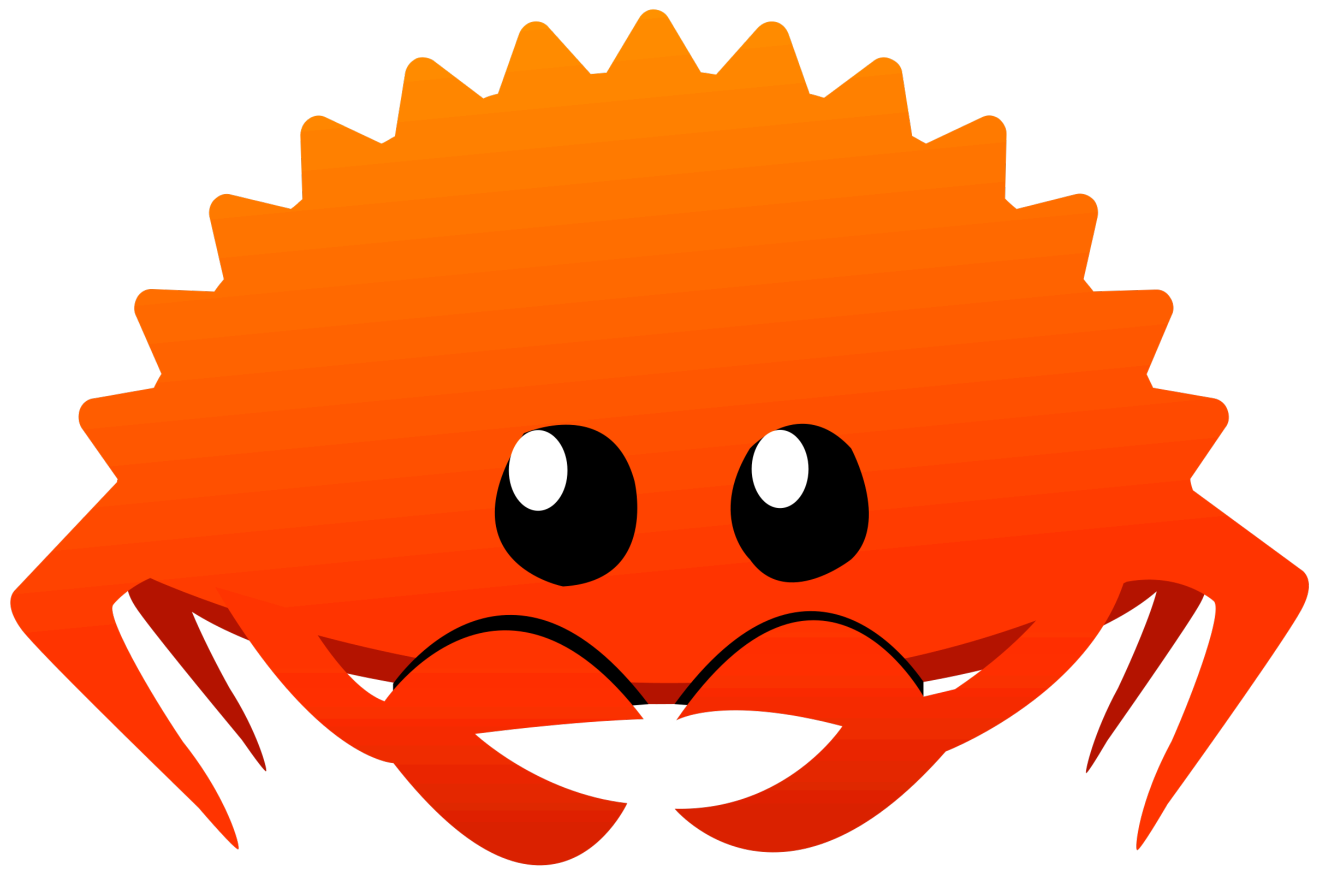

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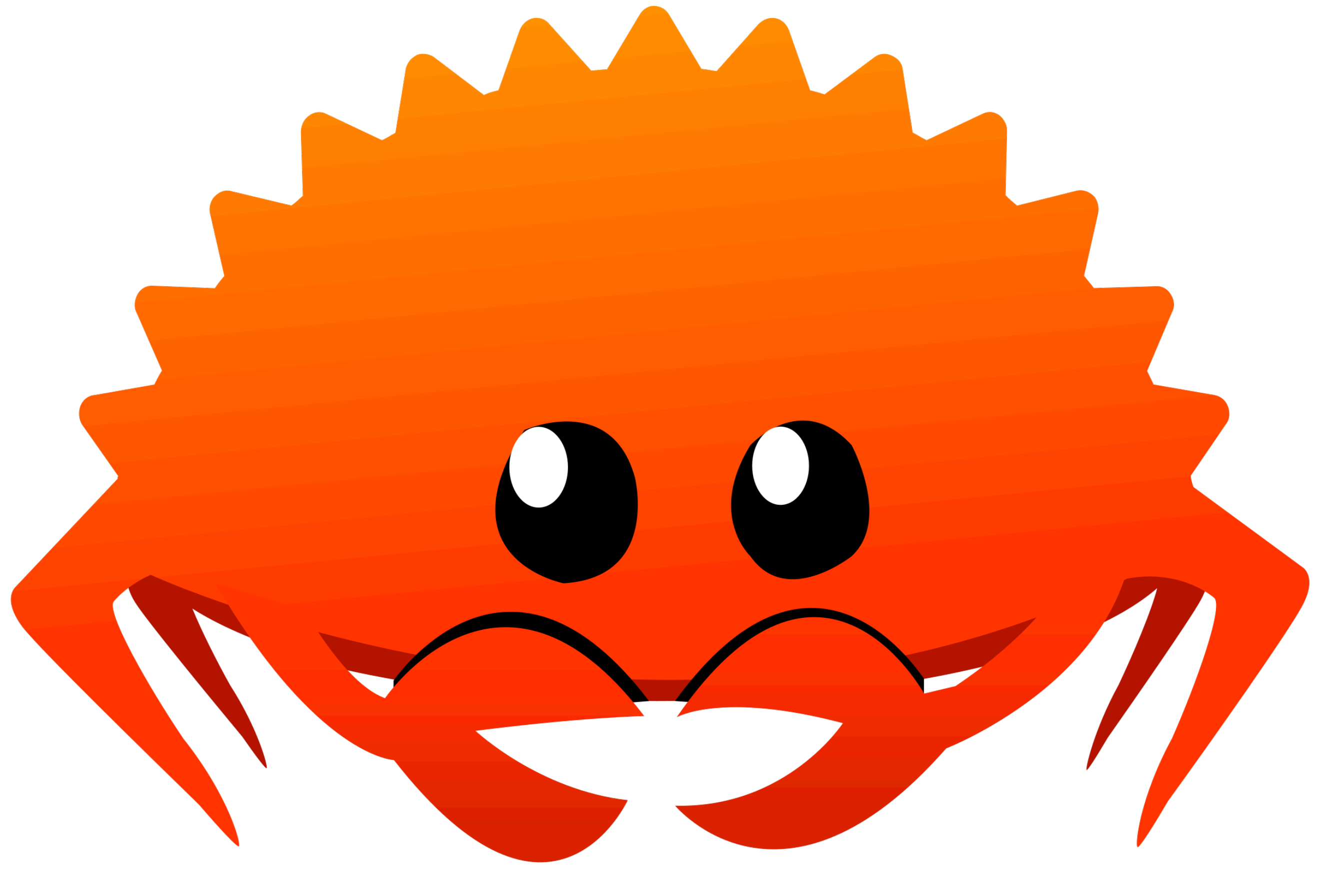

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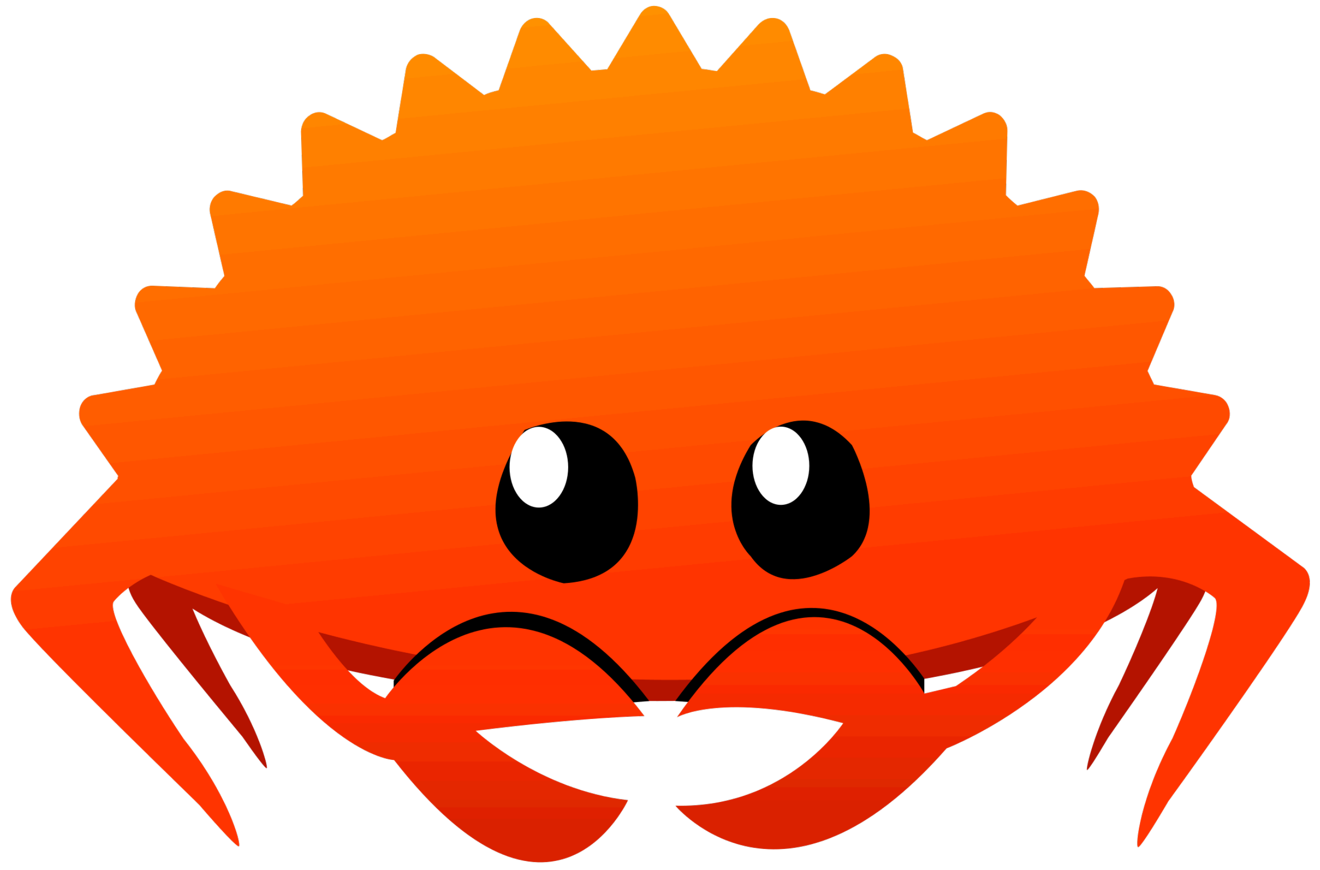

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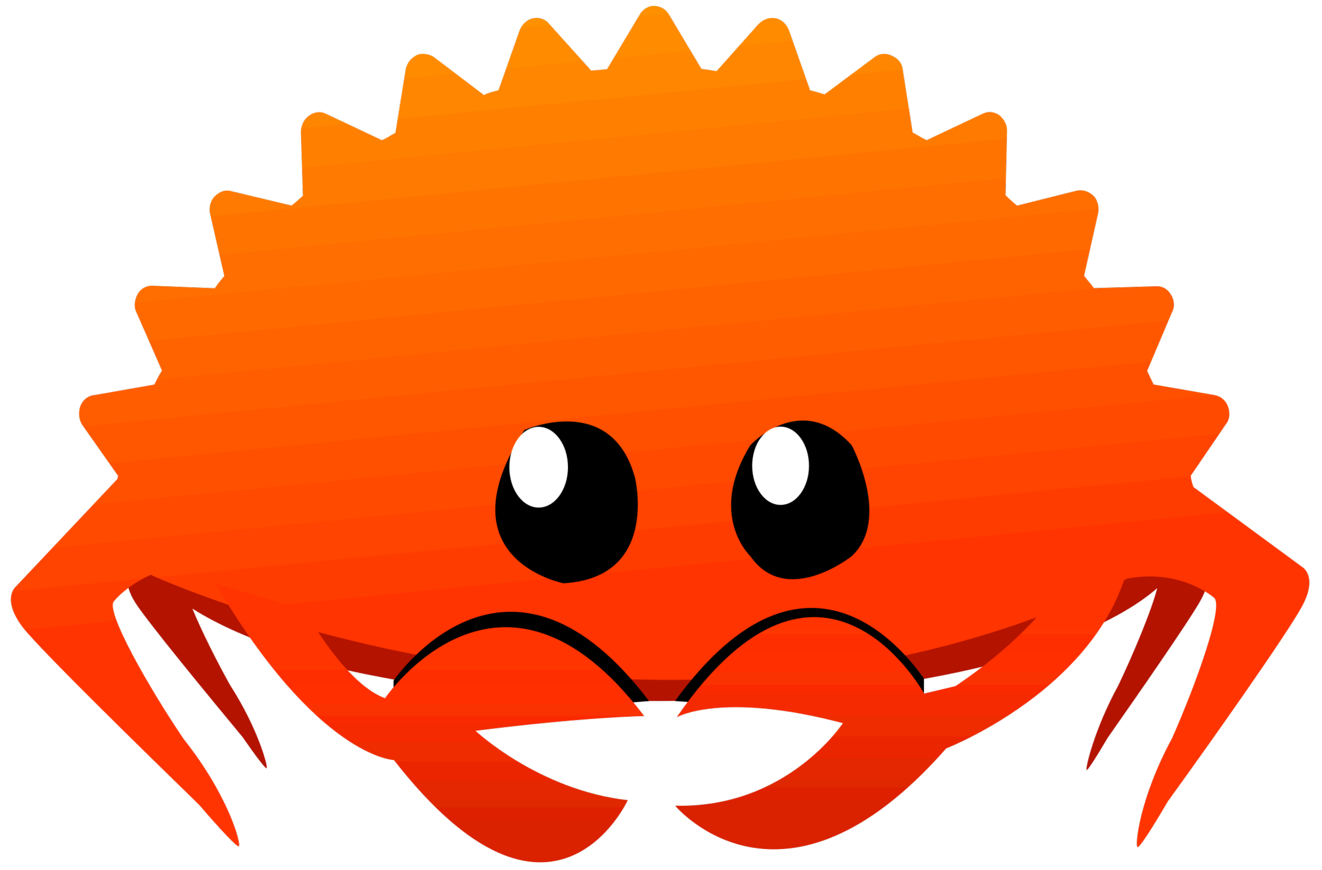

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- Moving to Rust required porting or rethinking several key ideas

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- …and, of course, webgraph

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- Requires collaboration from the underlying struct: the types you want to ε-copy must be type parameters

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- You cannot have references in the structure

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PR #1672
RustyYato trick

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// This is not possible directly--you need a helper
struct and T: CopyType<Copy = Zero/Deep>
impl<T: ZeroCopy> Deserialize for T { ... }
impl<T: DeepCopy> Deserialize for T { ... }
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#[derive(Epserde, Debug, PartialEq)]
struct MyStruct<A> {
    id: isize,
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// In this case we map the data structure into memory
let u: MemCase<MyStruct<&[isize]>> =
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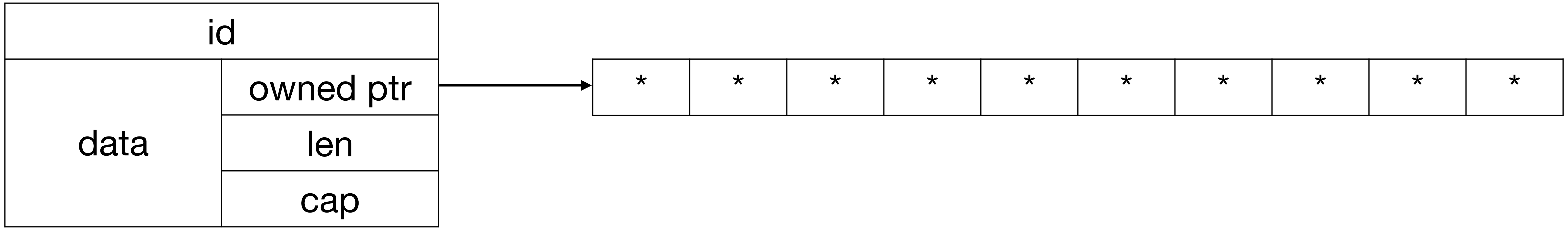
Construction time



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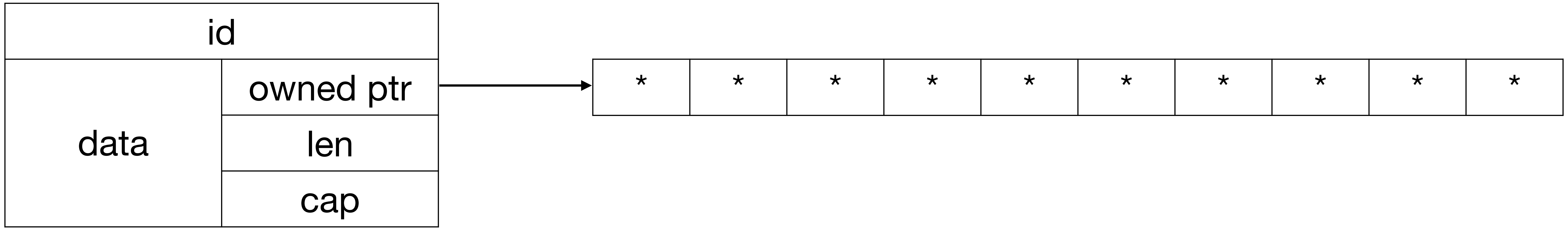

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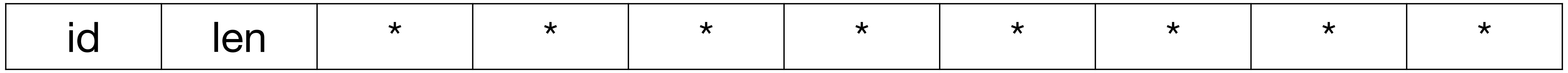

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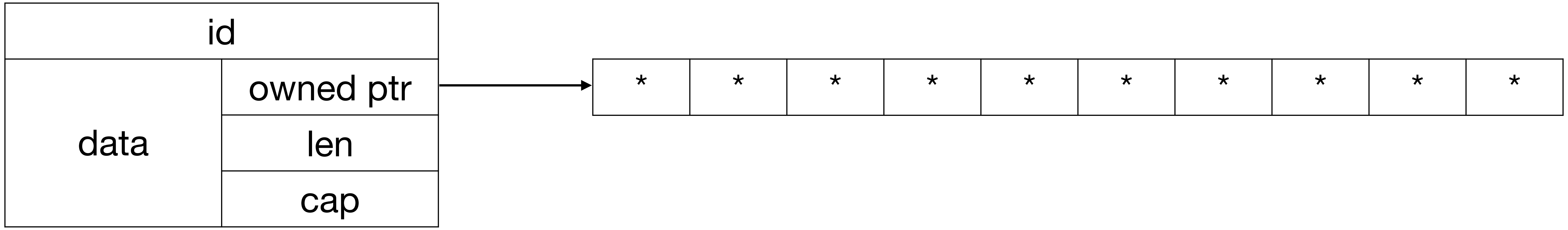

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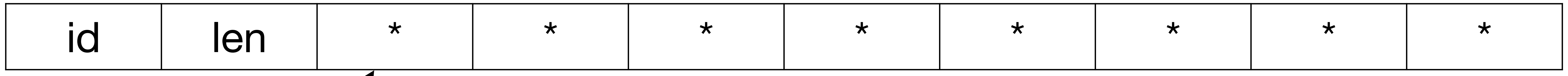
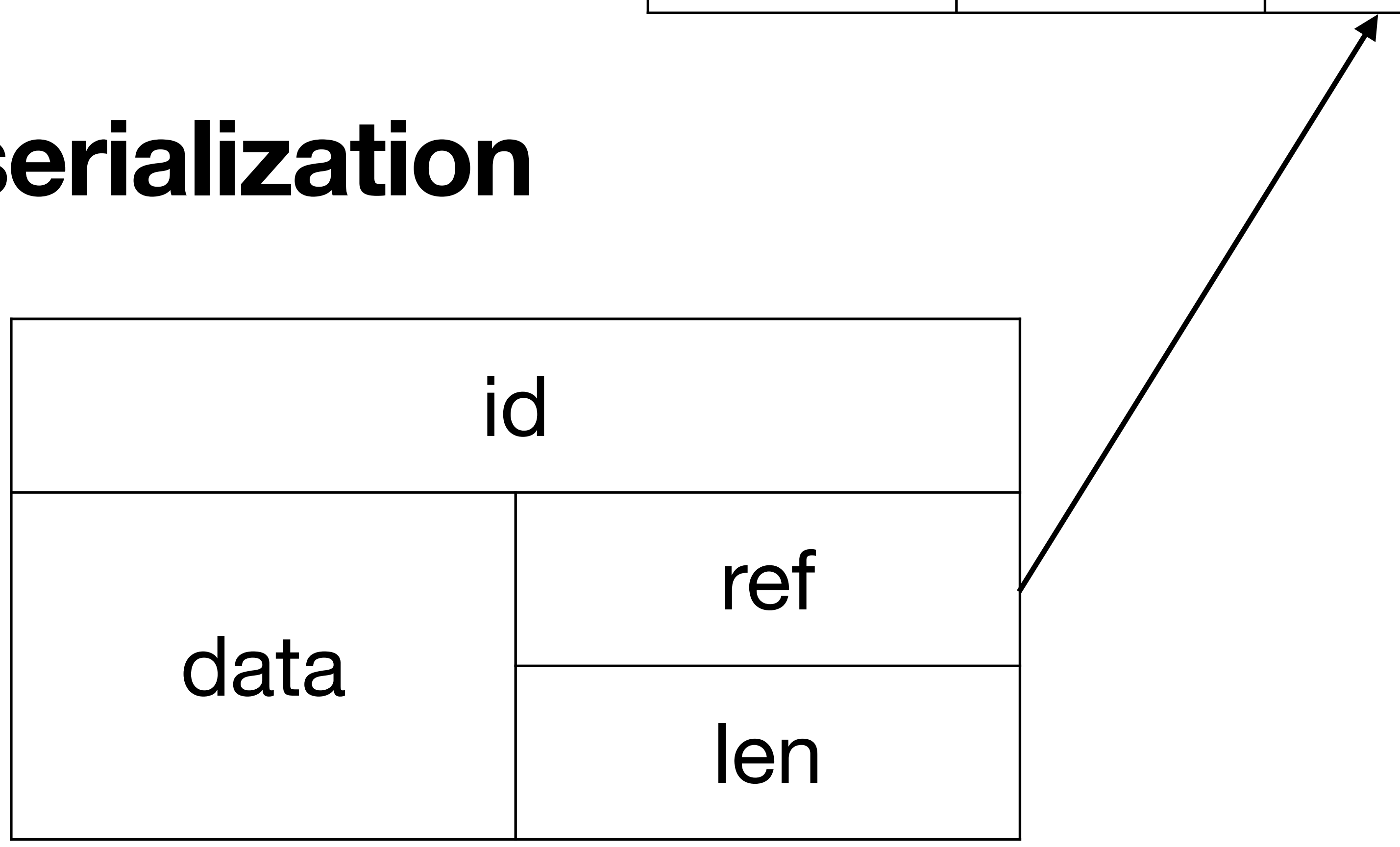


ε-deserialization



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- If you have several different such fields, you’ll have as many type parameters, which can become a nuisance
- If you think of your structure as a tree, only leaves reachable through a path of ε-serde–supporting type parameters will be zero-copied (given that they can be zero-copied)

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- High-
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```
Alloca
get_s
deep_s
size_
mem_s
```

```
1.207 kB 100.00% ●: Struct<TestEnum, Data<alloc::vec::Vec<u8>>>
   16  B   1.33% ├╴a: readme::main::TestEnum
                 │ ├╴Variant: Unnamed
    8  B   0.66% │ ├╴0: usize
    1  B   0.08% │ ╰╴1: u8 [6B]
1.183 kB  98.01% ├╴b: readme::main::Data<alloc::vec::Vec<u8>>
  724  B  59.98% │ ├╴a: alloc::vec::Vec<u8>
  424  B  35.13% │ ├╴b: alloc::vec::Vec<i32>
   35  B   2.90% │ ╰╴c: (u8, alloc::string::String)
    1  B   0.08% │   ├╴0: u8 [7B]
   27  B   2.24% │   ╰╴1: alloc::string::String
    8  B   0.66% ╰╴test: isize
```

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- For example, there are 4^n binary trees, so it should be possible to represent a binary tree using $\log 4^n = 2n$ bits (Jacobson) instead of $2n \log n$

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let bits = bit_vec![1, 0, 1, 1, 0, 1, 0, 1];
let rank9 = Rank9::new(bits);
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- … and the last structure has also rank methods and access to the underlying bit vector

sux

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- Rust and intensional representations do not work very well together ATM

dsi-bitstream

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- A γ code read in less than 2ns (for data with the intended distribution)

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- Presently WR = u32 and WW = u64 are the best choice

webgraph

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- Graphs have *n* nodes numbered in [0 . . *n*).
- Access to the graph structure happens by enumerating pairs given by a node (usize) and a (possibly labeled) successor list (IntoIterator<usize>)

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    - Gap compression: lists are turned into gaps encoded via instantaneous codes
    - Reference: lists are partially copied from other nodes with similar successors
    - Intervalization: consecutive successors are stored as intervals
- Composition-based labeling
- Lender- (rather than Iterator-) based architecture, as we need to return items depending on the lender state

webgraph

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- An important change with respect to the Java version is that sequential enumeration of the arcs of a graph has no order guarantee
- Though there are marker traits to request that

webgraph

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- Basic trait: a SequentialLabeling

webgraph

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```
pub trait SequentialLabeling {
    type Label;
    type Lender<‘node>:
        for<'next> NodeLabelsLender<'next, Label = Self::Label>
    where
        Self: 'node;

    fn num_nodes(&self) -> usize;
    fn iter(&self) -> Self::Lender<'_>;
}
```

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- A sequential graph is a SequentialLabeling with usize labels

webgraph

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- Random access:

webgraph

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```
pub trait RandomAccessLabeling: SequentialLabeling {
    type Labels<'succ>:
        IntoIterator<Item = <Self as SequentialLabeling>::Label>
    where
        Self: 'succ;

   fn num_arcs(&self) -> u64;
   fn labels(&self, node_id: usize) ->
        <Self as RandomAccessLabeling>::Labels<'_>;
   fn outdegree(&self, node_id: usize) -> usize;
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```

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- A random-access graph is a RandomAccessLabeling with usize labels

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```
pub trait Lender {
    type Item<'this>
    where
        Self: 'a;

    fn next(&mut self) -> Option<Self::Item<'_>>;
}
```

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```
pub trait Lending<'a, __ImplBound = &'a Self> {
    type Lend: 'a;
}

pub trait Lender: for<'a /* where Self: 'a */> Lending<'a> {
    fn next(&mut self) -> Option<<Self as Lending<'_>::Lend>;
}
```

webgraph

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```
pub trait NodeLabelsLender<'a, __ImplBound = &'a Self>:
    Lender + Lending<'a, __ImplBound, Lend = (usize, Self::IntoIterator)>
{
    type Label;
    type IntoIterator: IntoIterator<Item = Self::Label>;
}
```

Performance

Graph	Nodes	Arcs	Avg. Degree	b/arc	Size (comp.)
dblp-2010	326K	1.6M	4.95	6.78	1.4MB
hollywood-2011	2M	229M	105.00	4.89	140MB
enwiki-2023	4.2M	101M	24.93	13.55	267MB
in-2004	41M	1.1G	27.87	1.41	250MB
webbase-2001	118M	1G	8.63	2.78	399MB
twitter-2010	41M	1.4G	35.25	13.90	2.5GB
eu-2015	1G	92G	85.74	1.19	13GB
swh-2023	34G	491G	14.38	3.07	176GB

	Java	**Rust**	**speedup**	**Java**	**Rust**	**speedup**
Graph	*Random access* (ns/arc)			*BFS visit* (ns/node)		
dblp-2010	96	50	× 1.92	604	220	× 2.75
hollywood-2011	51	27	× 1.88	7520	2620	× 2.87
enwiki-2023	61	31	× 1.97	1450	734	× 1.98
in-2004	70	37	× 1.89	735	369	× 1.99
webbase-2001	114	73	× 1.56	665	322	× 2.07
twitter-2010	73	38	× 1.92	2650	1270	× 2.09
eu-2015	24	17	× 1.41	1580	971	× 1.63
swh-2023	104	47	× 2.21	1140	359	× 3.18

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- And my students, without whom we would be far behind schedule

Questions?