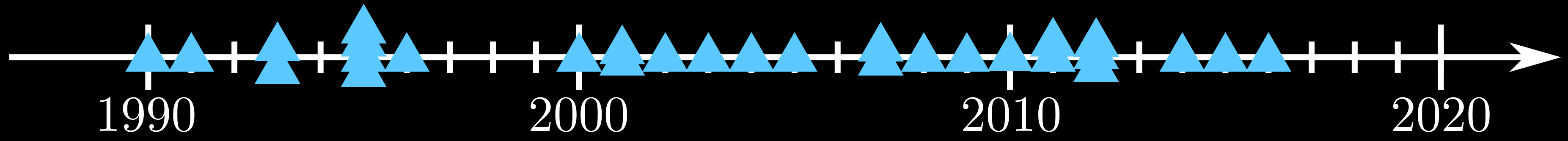
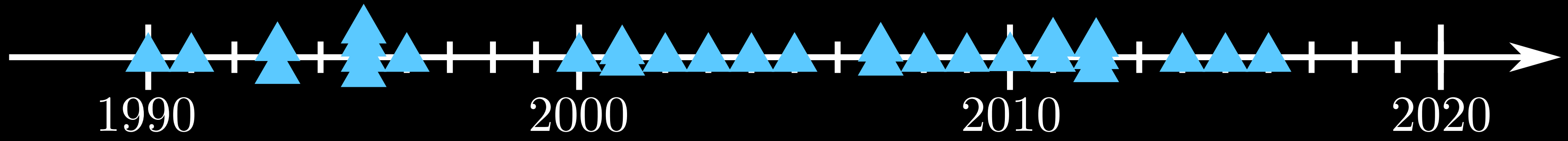
Spade - An HDL Inspired by Modern Software Languages

Frans Skarman

Linköping University


1990
2000
2010
2020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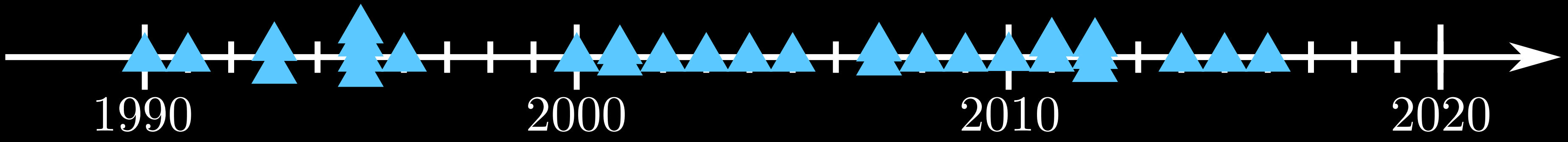
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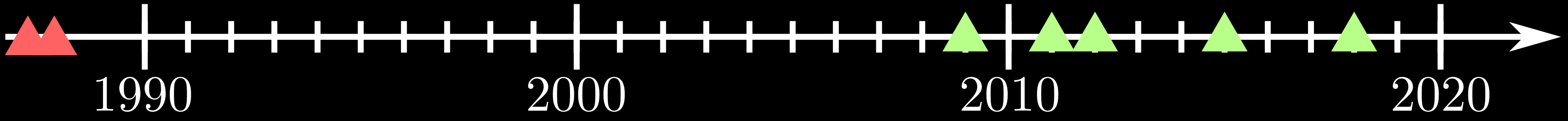
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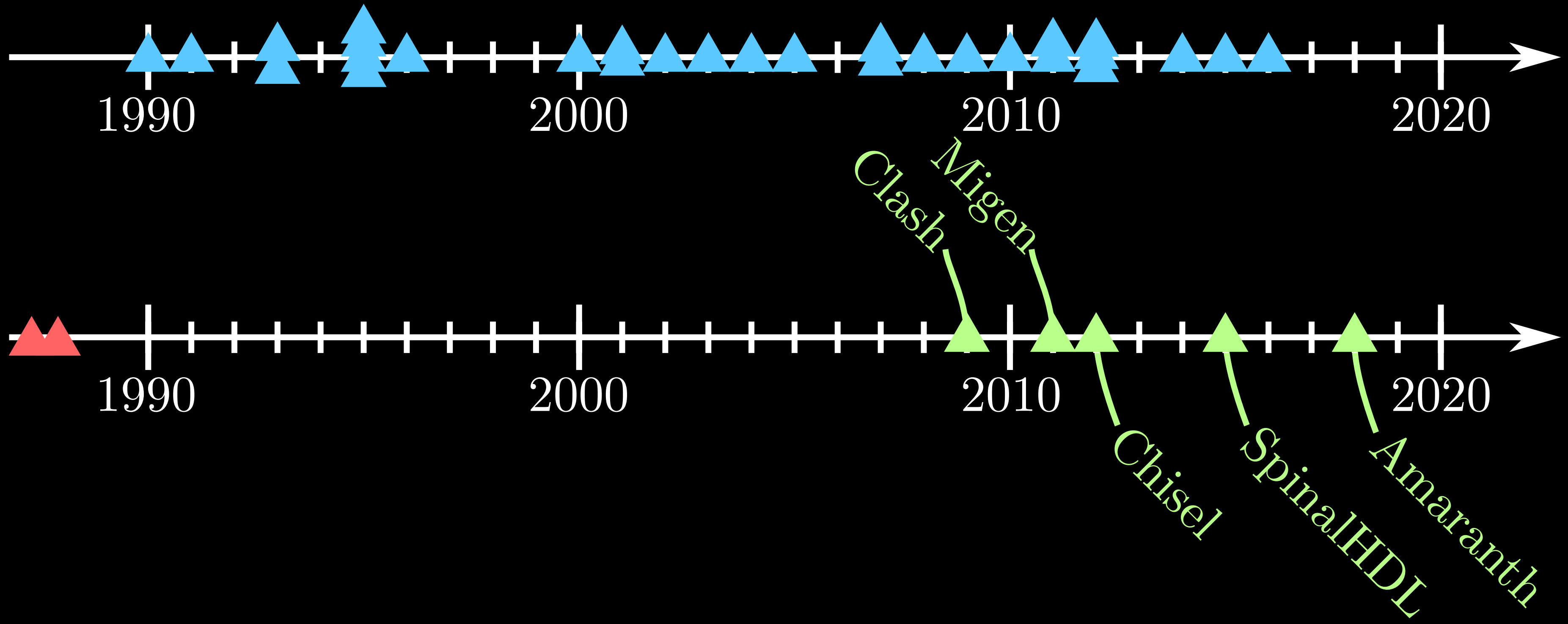
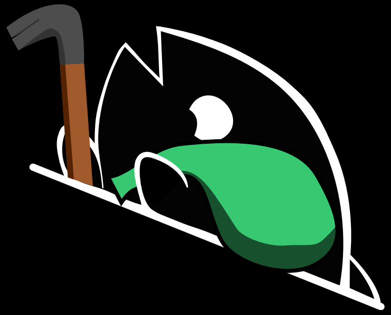

1990
2000
2010
2020
Clash
Migen
Chisel
SpinalHDL
Amaranth

Stealing From Software

- **Fearless** refactoring

Stealing From Software

- Fearless refactoring
- **Abstractions** for hardware



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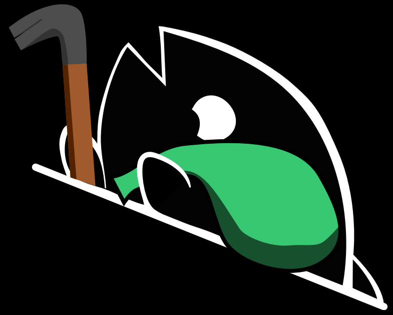
- Fearless refactoring
- Abstractions for hardware
- **Low** performance overhead

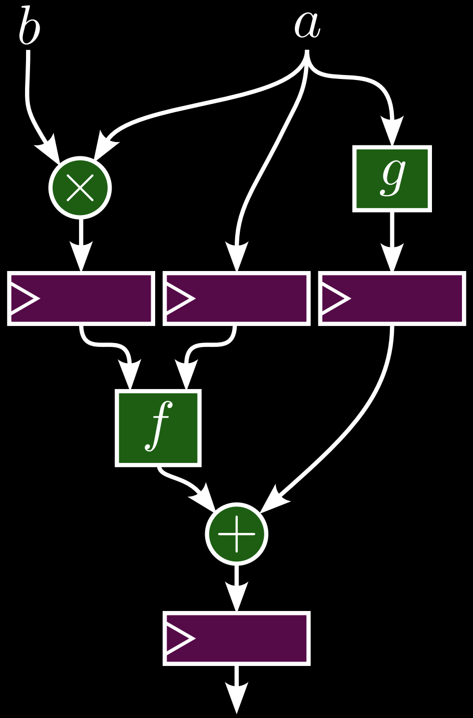


Stealing From Software

- Fearless refactoring
- Abstractions for hardware
- Low performance overhead
- Great **tooling**

Pipelines

```
pipeline(2) X(clk: clock, a: int<32>, b: int<32>)
    -> int<33> {
    let x = g(a);
    let produt = a*b;
reg;
    let sum = x + f(a, product)
reg;
    sum
}
```



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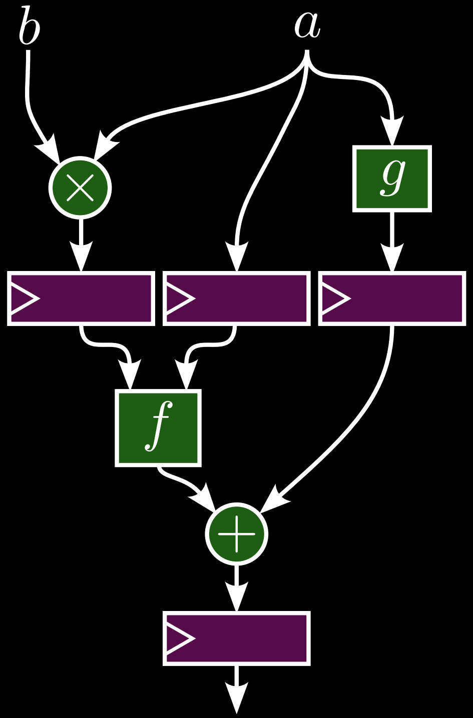

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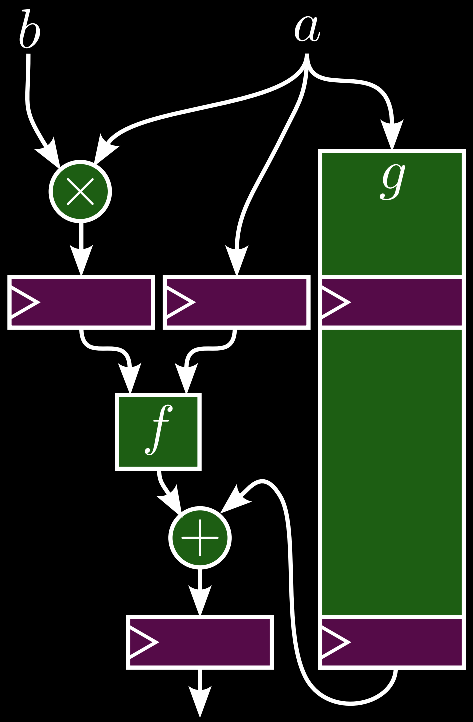

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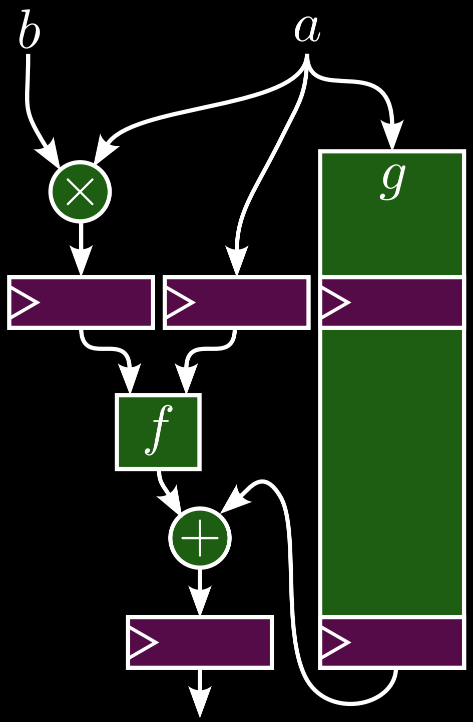

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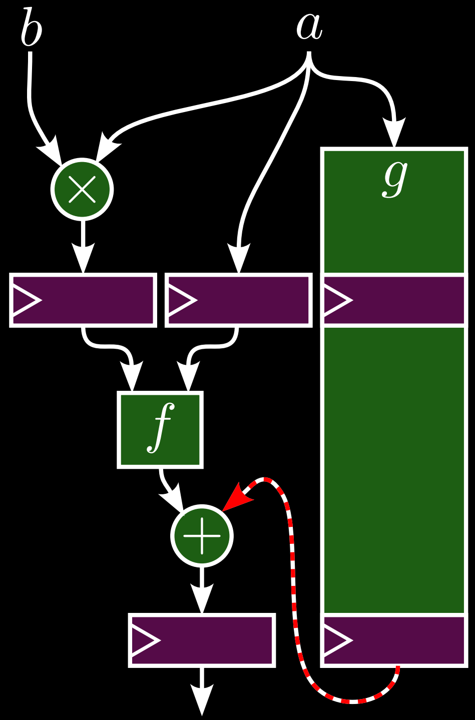

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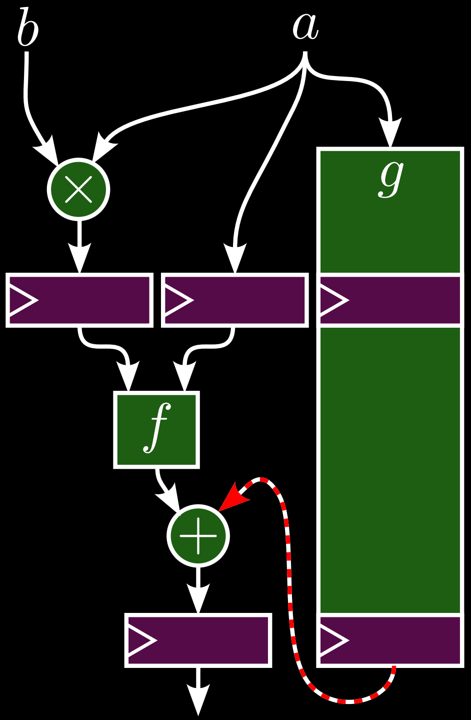
```
error: Use of x before it is ready
   --> src/main.spade:10:19
   |
10 | let sum = x + f(a, product);
   |             ^ Is unavailable for another stage
   = Requesting x from stage 1
   = But it will not be available until stage 2
```



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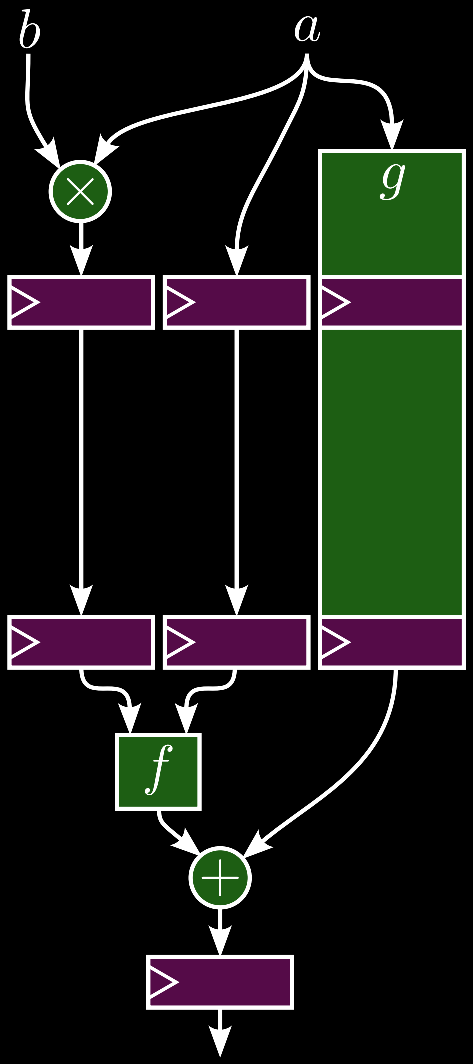

Pipelines

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pipeline(3) X(clk: clock, a: int<32>, b: int<32>)
    -> int<33> {
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reg;
reg;
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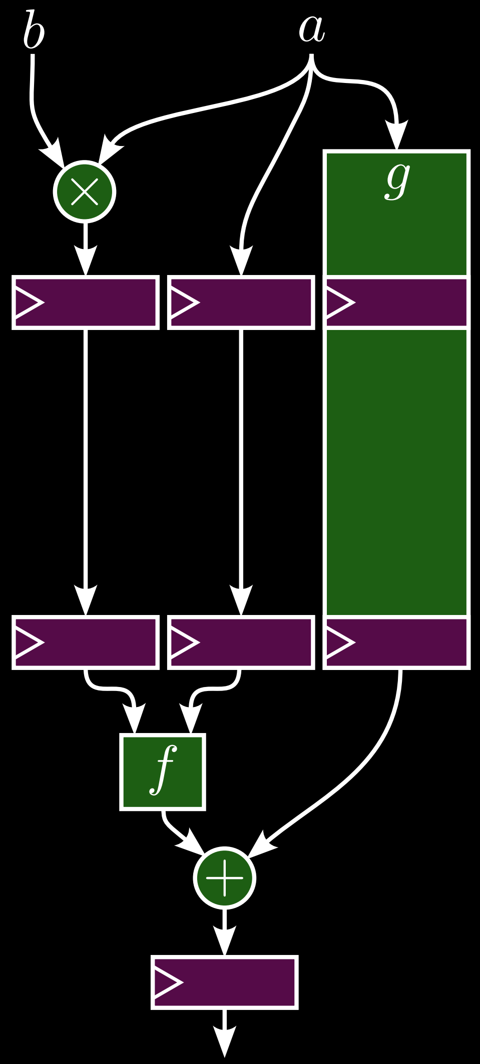
}
```



Demo?

CSI2

Camera protocol

CSI2

Camera protocol

- 1-4 lanes + clock

CSI2

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- Find SOT

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- Pixels after packet with header **`0x2A`**

Streams

- 1-4 lanes + clock
- Find SOT
- Merge lanes
- Look for packet headers
- Separate short and long packets
- Pixels after packet with header `0x2A`

```
pipeline(7) csi2(clk, rst, lanes: [uint<8>; 2]) {
   let aligned = inst aligner(clk, rst, lanes);
 reg;
    let merged = merger(aligned);
 reg;
   let headers = merged
       .inst into_packet_headers(clk, rst);
 reg;
   let short_packets = headers
       .into_short_packets();
   let pixel_headers = headers
       .into_long_packets();
 reg;
   let raw_pixels = pixel_headers
     .inst into_pixel_stream(clk, rst, merged);
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Streams

```
struct LongHeaderStream {
  s: Option<Header>
}

impl LongHeaderStream {
  entity into_pixel_stream(..) -> PixelStream {

    reg(clk) num_left reset(rst: 0) =
      match self.s {
        Some(Header$(id: 0x2A, count)) => count,
        None => saturating_sub(num_left - 1)
      };

    PixelStream(
      if num_left > 0 { s.s } else { None },
    )
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}
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A language is nothing without its **tools**

Swim - The Spade Build Tool

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[libraries]
hdmi = {git = "..", branch="main"}
ulx3s_sdram = {path = "./deps/litedram"}
ecp5stubs = {git = "..", branch = "main"}

[plugins]
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[synthesis]
command = "synth_ecp5"
top = "main"
extra_verilog = [
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swim plugin litedram_setup
swim plugin litedram_generate
```

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Swim - The Spade Build Tool

Easy setup

```
cargo install swim
swim install-tools
git clone "git:gitlab.com/user/project"

swim upload
```

Conclusion

- **Fearless** refactoring
- **Abstractions** for hardware
- **Low** performance overhead
- **Tooling**

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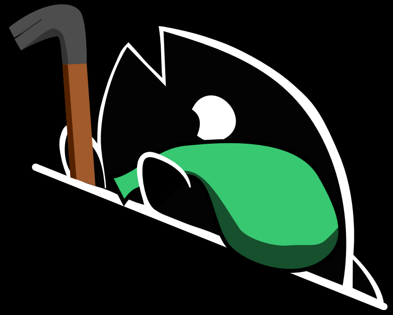

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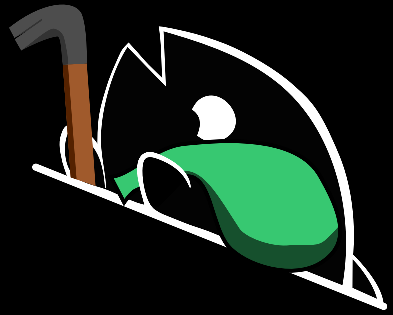

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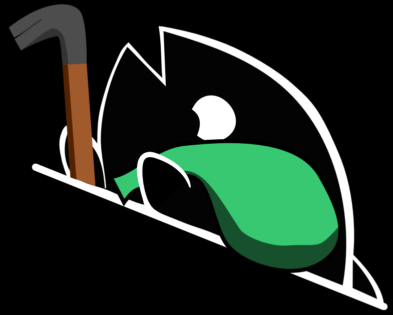

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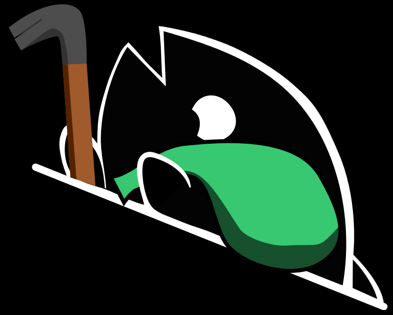

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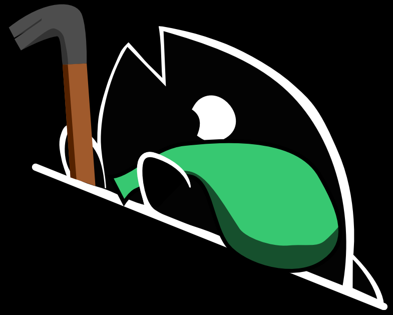

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  - Powerful **build system**
  - Purpose built **waveform viewer**

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LINKÖPING UNIVERSITY