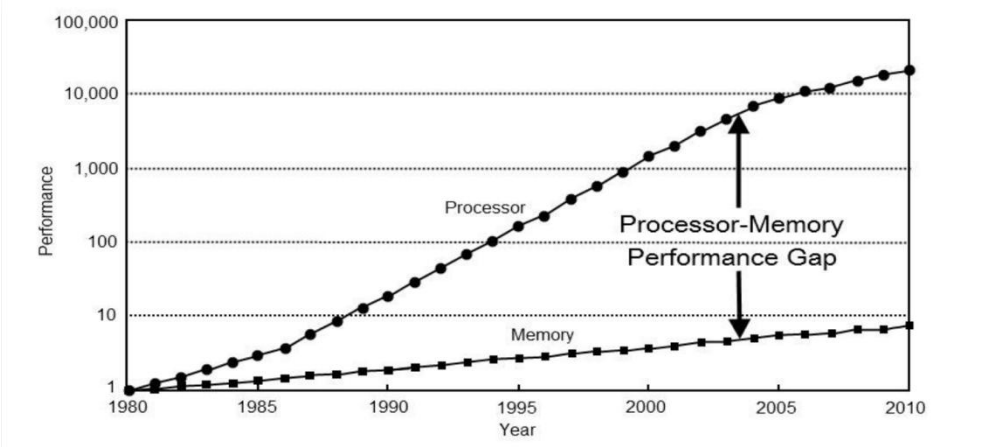
Introduction to Data-Oriented Design

So what is this Data-Oriented Design?

It’s about on shifting focus to how data is read and written

Why should we care?

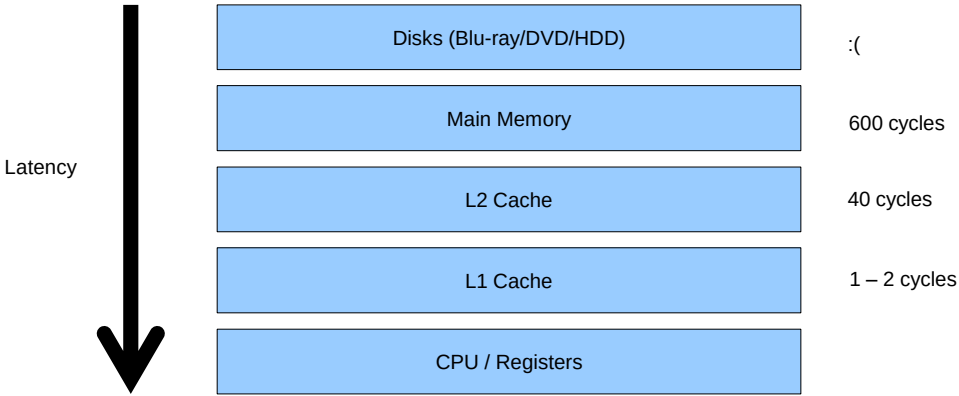
Performance



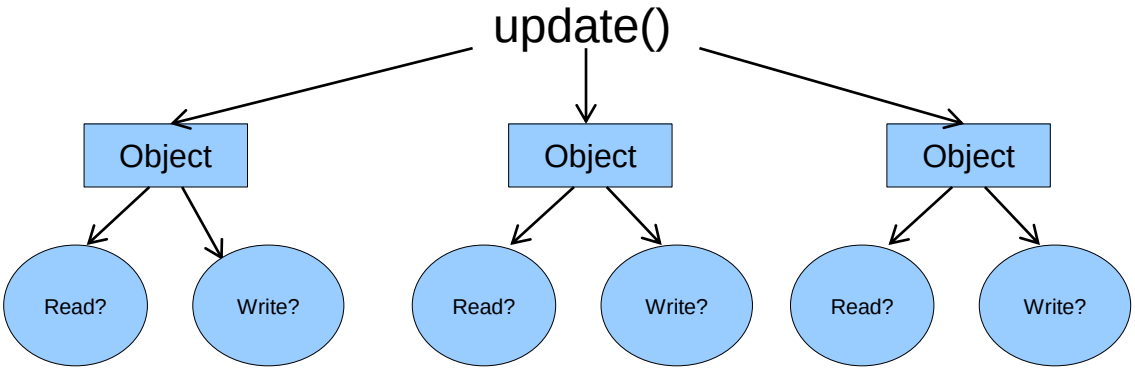
A read from memory takes ~600 cycles at 3.2 GHz

A read from memory takes 40 cycles at 300 MHz

Performance

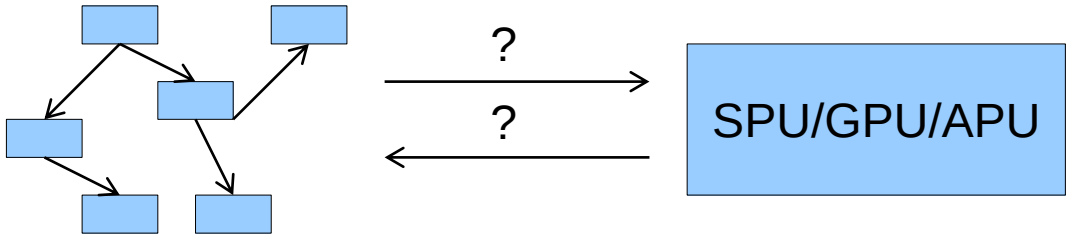


Multithreading



- **Cannot** multithread without knowing how data is touched
- Adding locks always protects **data** not **code**

Offloading to co-unit



- If data is unknown **hard/impossible** to run on co-unit

Better design

- Data focus *can* lead to isolated, self-contained, interchangeable pieces of data and code
- This *can* make it easier to test data and code in isolation

Example - OOD

```
class Bot
{
   ...
   Vec3 m_position;
   ...
   float m_mod;
   ...
   float m_aimDirection;
   ...

   void updateAim(Vec3 target)
   {
     m_aimDirection = dot3(m_position, target) * m_mod;
   }
}
```

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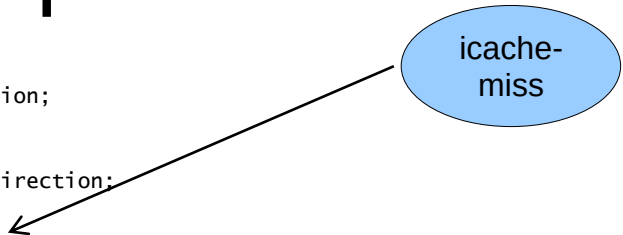

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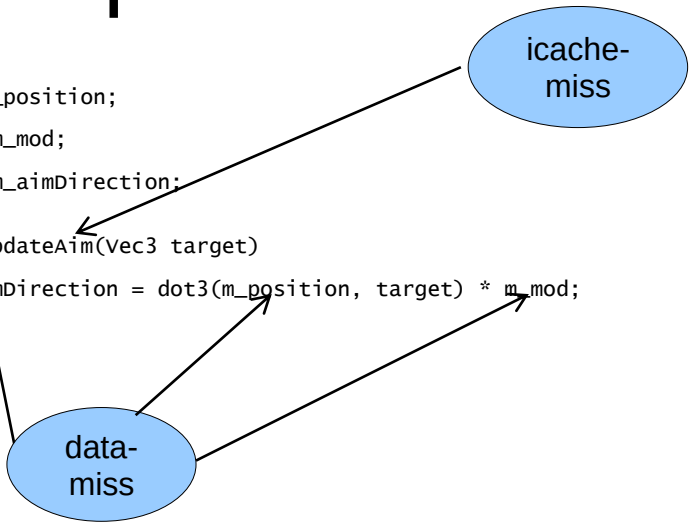

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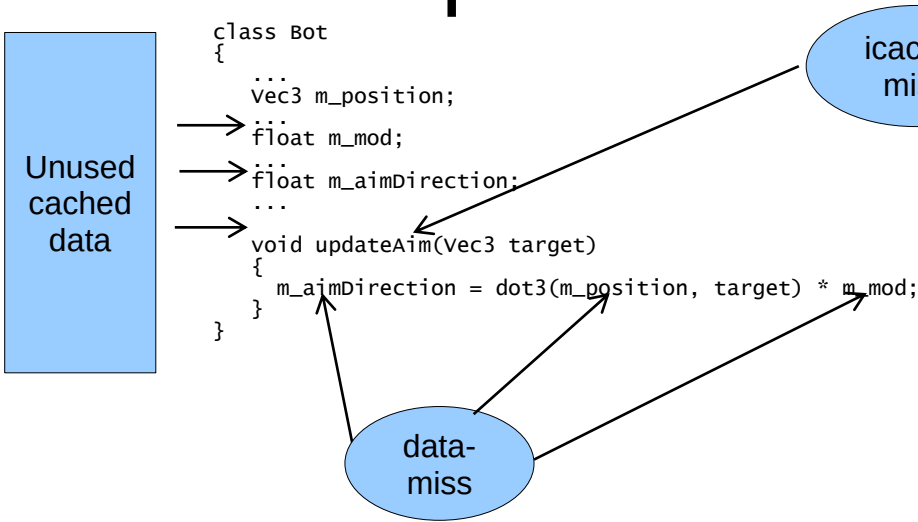
Unused cached data
class Bot
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Vec3 m_position;
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float m_mod;
...
float m_aimDirection;
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void updateAim(Vec3 target)
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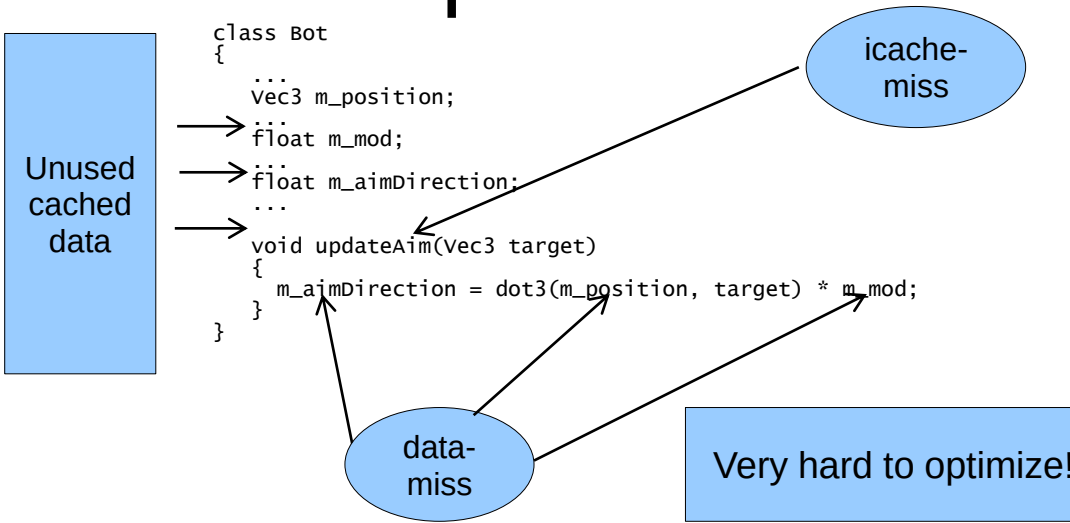
}
}
icache-miss
data-miss

Example - OOD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}
}
icache-miss
data-miss
Very hard to optimize!

Example - OOD

Lets say we call this code 4 times (4 diffrent Bots)

```
void updateAim(Vec3 target)
{
  m_aimDirection = dot3(m_position, target) * m_mod;
}
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void updateAim(Vec3 target)
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}
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iCache – 600

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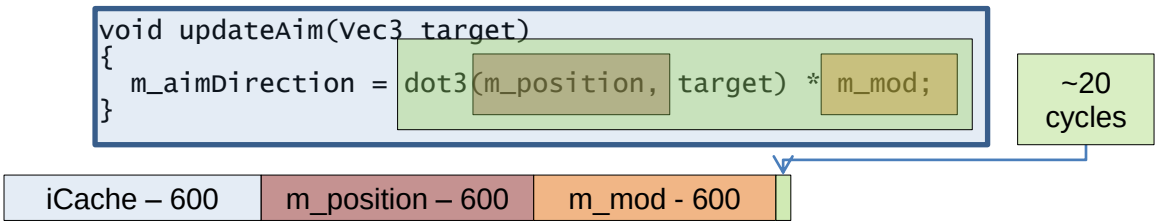

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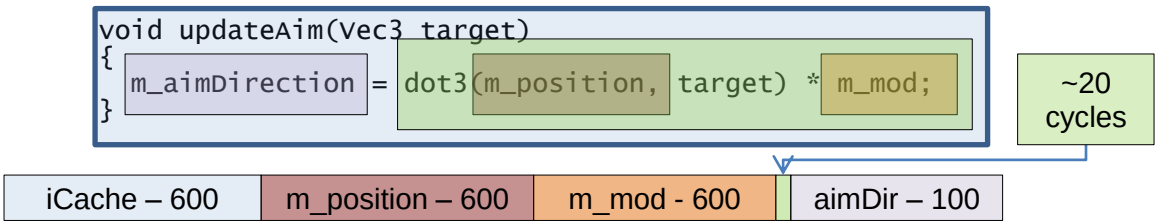

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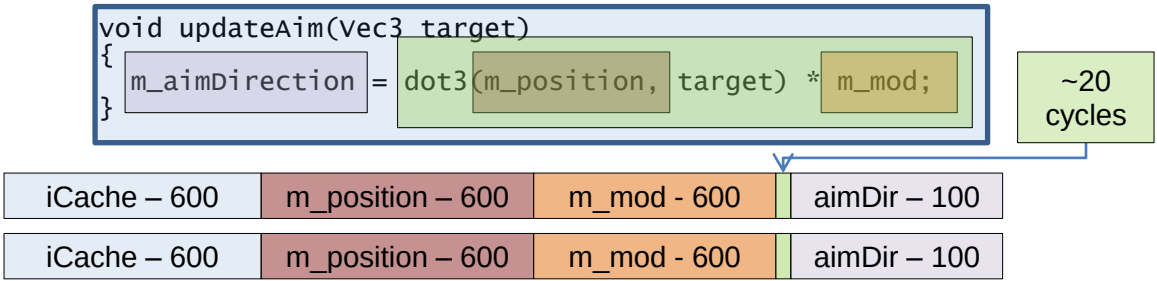

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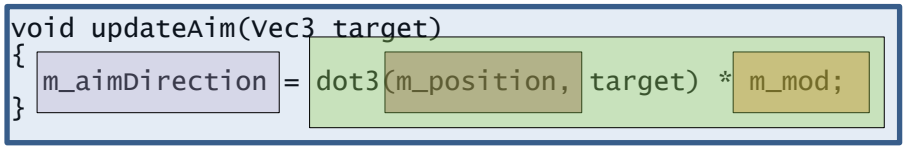

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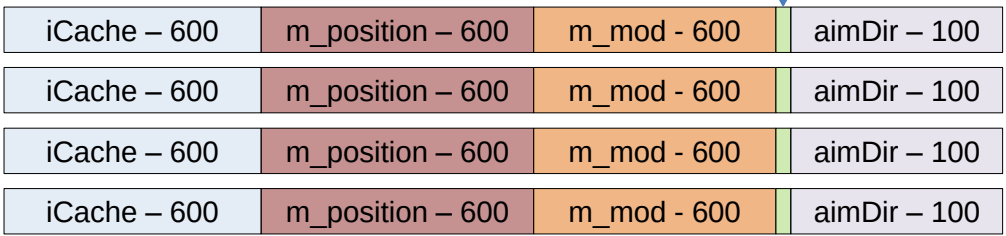
Lets say we call this code 4 times (4 diffrent Bots)

```
void updateAim(Vec3 target)
{
  m_aimDirection = dot3(m_position, target) * m_mod;
}
```

~20 cycles



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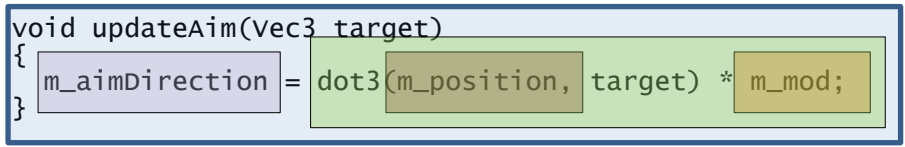

~20 cycles

iCache – 600	m_position – 600	m_mod - 600	aimDir – 100
iCache – 600	m_position – 600	m_mod - 600	aimDir – 100
iCache – 600	m_position – 600	m_mod - 600	aimDir – 100
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Example - DOD

Example - DOD

- Design ”back to front” and focus on the output data

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- Design ”back to front” and focus on the output data
- Then add the *minimal* amount of data needed to do the transform to create the correct output

Example - DOD

```
void updateAims(float* aimDir,const AimingData* aim,
                Vec3 target, uint count)
{
  for (uint i = 0; i < count; ++i)
  {
    aimDir[i] = dot3(aim->positions[i],target) * aim->mod[i];
  }
}
```

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What has changed?

Example - DOD

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What has changed?

Only read needed inputs

Example - DOD

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What has changed?

Only read needed inputs	Write to linear array

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What has changed?

Only read needed inputs	Write to linear array
Loop over all the data	

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iCache – 600

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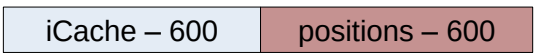

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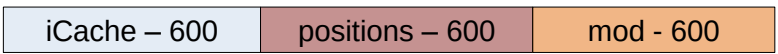

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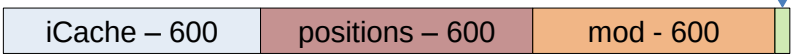

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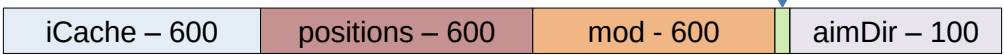

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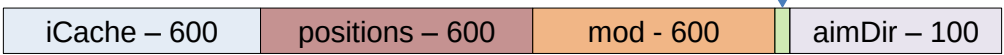

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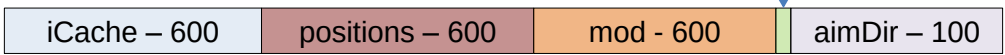

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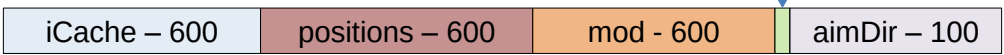

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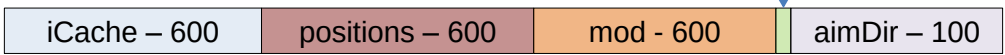

1980

Data layout OOD vs DOD

pos0	pos0	pos0	pos0
mod0			
aimDir0			

Pos1			
mod1			
aimDir1			

pos0	pos0	pos0	pos0
pos1	pos1	pos1	pos1
pos2	pos2	pos2	pos2
pos3	pos3	pos3	pos3
mod0	mod1	mod2	mod3

aimDir0	aimDir1	aimDir2	aimDir3

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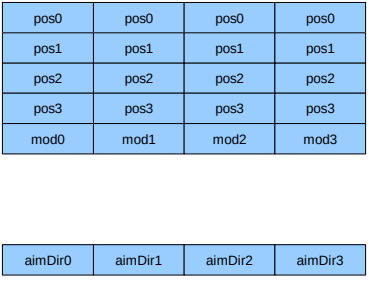
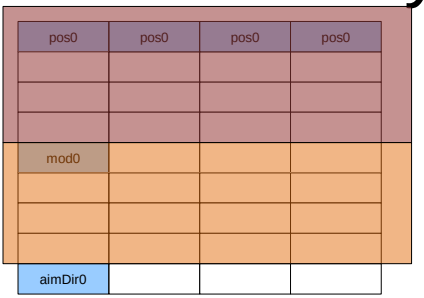
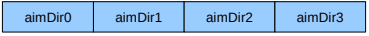
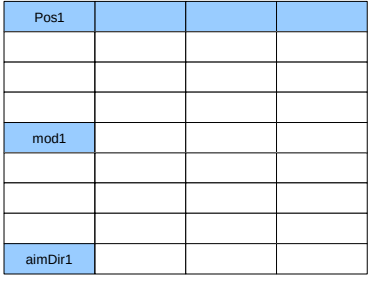


Each color block is one 128 byte cache line

Data layout OOD vs DOD







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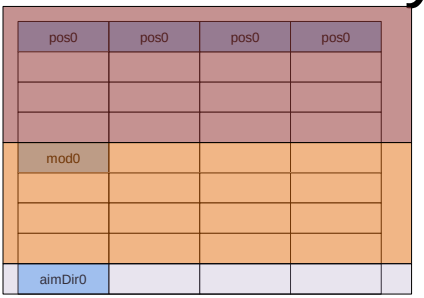

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pos1	pos1	pos1	pos1
pos2	pos2	pos2	pos2
pos3	pos3	pos3	pos3
mod0	mod1	mod2	mod3

aimDir0	aimDir1	aimDir2	aimDir3

Pos1			
mod1			
aimDir1			

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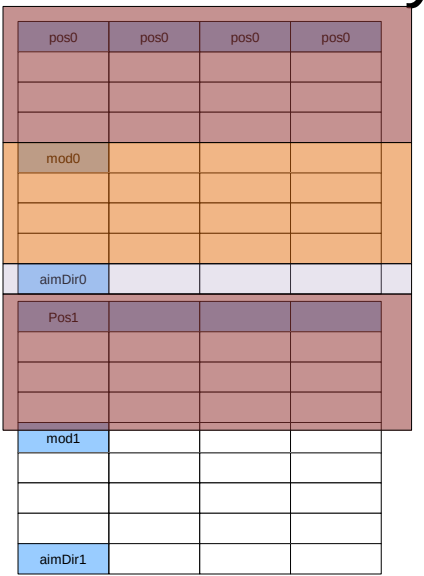
Data layout OOD vs DOD



pos0	pos0	pos0	pos0
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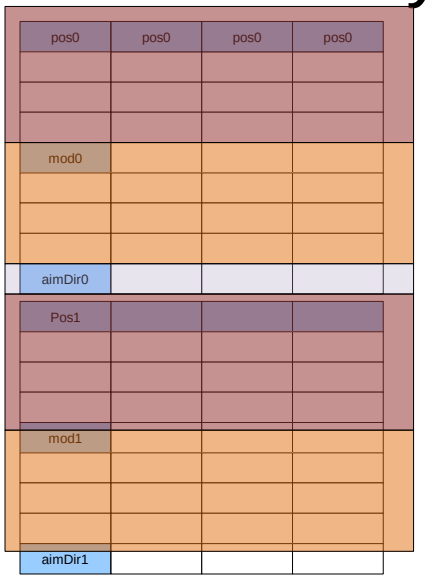

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Data layout OOD vs DOD

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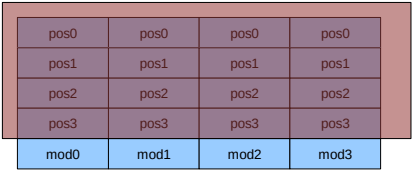

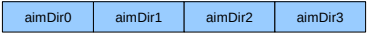

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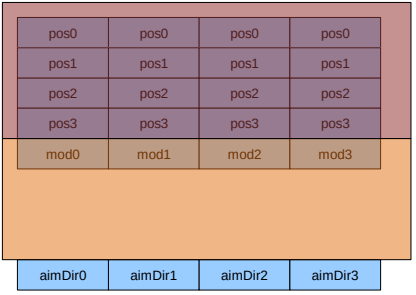

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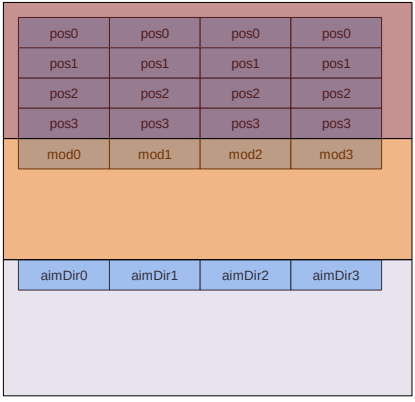

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- Optimize for data first then code
- Most code is likely bound by memory access
- Not everything needs to be an object

Remember

Remember

- We are doing games, we know our data.

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- We are doing games, we know our data.
- Pre-format. Source data and native data doesn’t need to be the same

Example: Area Triggers

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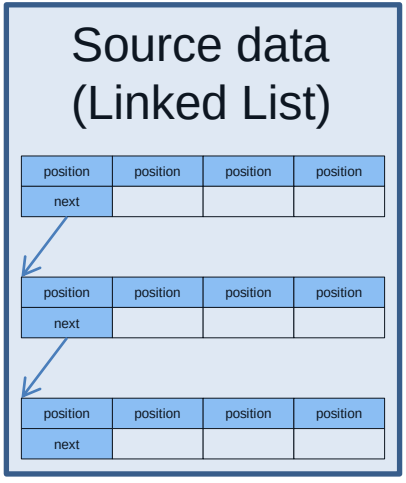
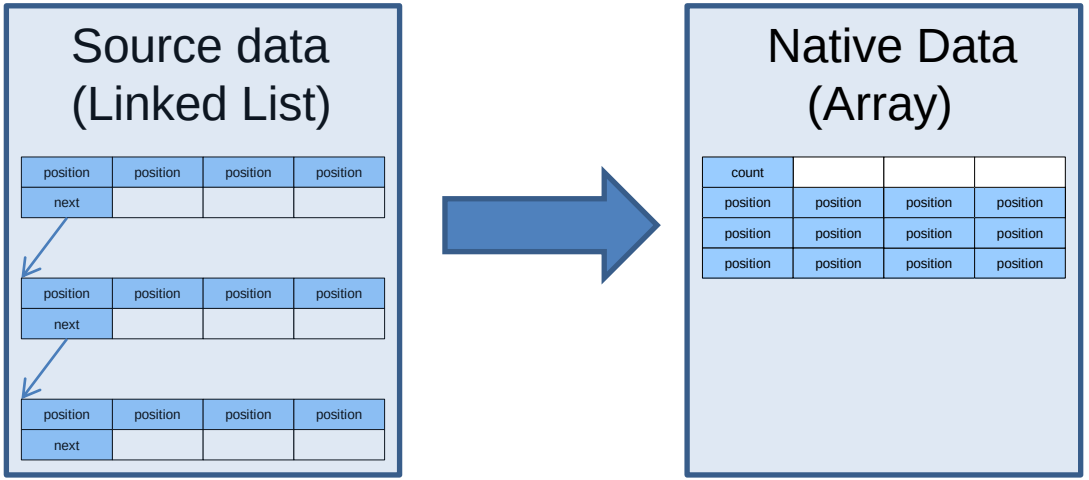


Example: Area Triggers



Example: Culling System

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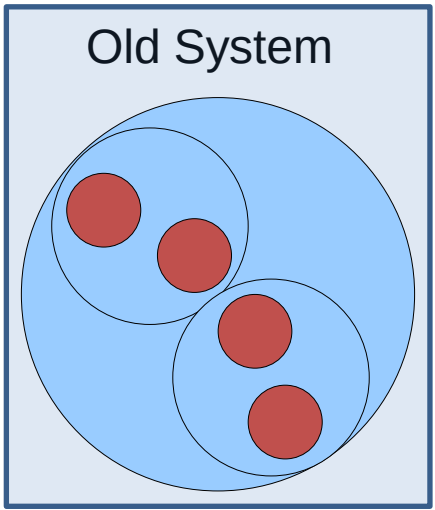
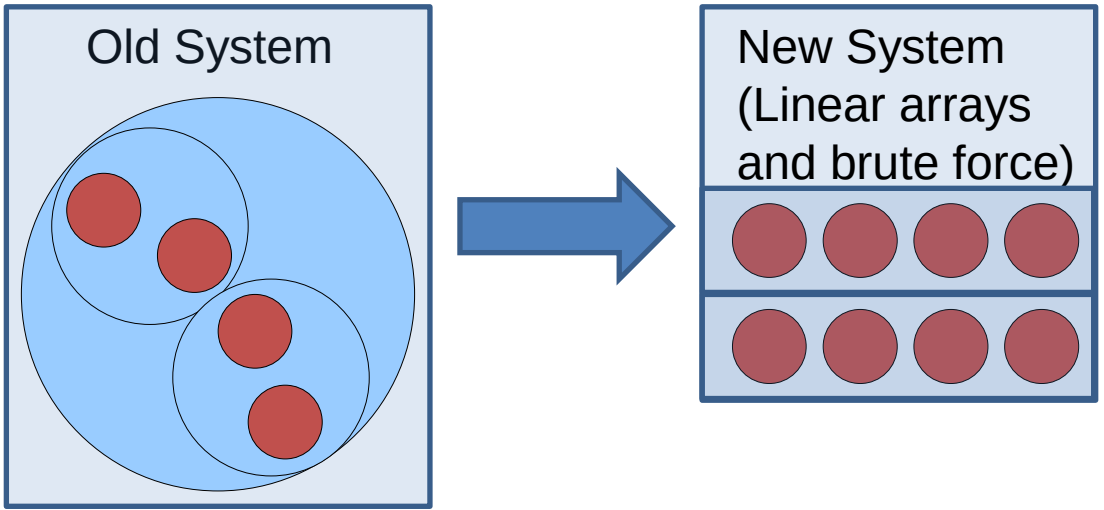
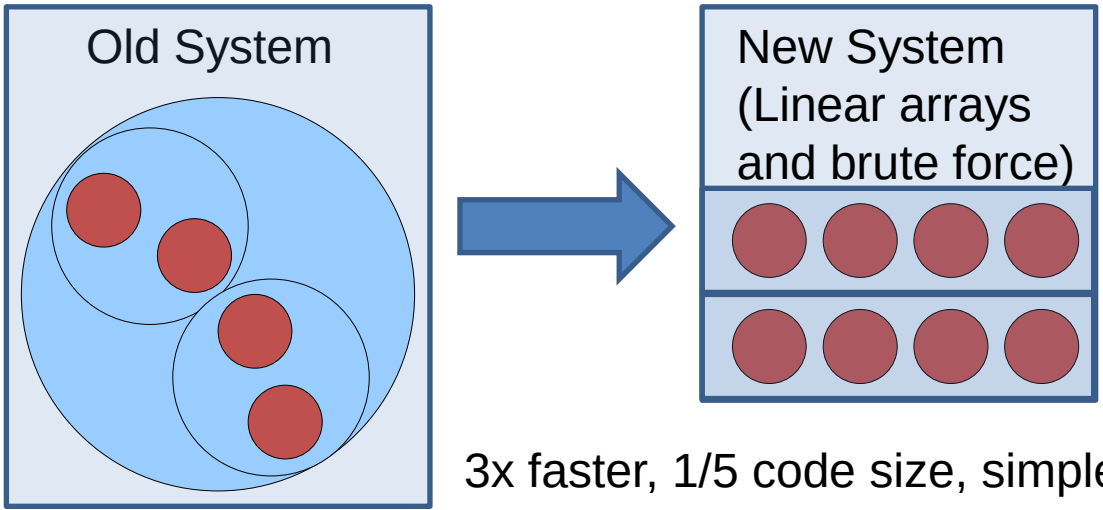


Example: Culling System



Example: Culling System

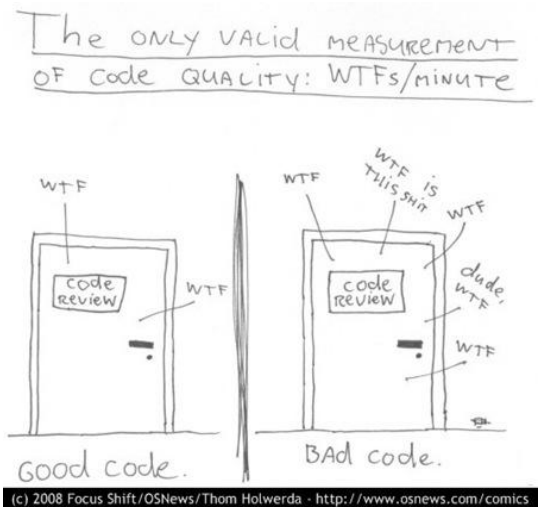


3x faster, 1/5 code size, simpler

Data Oriented Design Delivers:

Better Performance

Often simpler code



More parallelizable code

Questions?

Links

- **Data-Oriented Design (Or Why You Might Be Shooting Yourself in The Foot With OOP)**
  http://gamesfromwithin.com/data-oriented-design
- **Practical Examples in Data Oriented Design**
  http://bitsquid.blogspot.com/2010/05/practical-examples-in-data-oriented.html
- **The Latency Elephant**
  http://seven-degrees-of-freedom.blogspot.com/2009/10/latency-elephant.html
- **Pitfalls of Object Oriented Programming**
  http://seven-degrees-of-freedom.blogspot.com/2009/12/pitfalls-of-object-oriented-programming.html
- **Insomniac R&D**
  http://www.insomniacgames.com/research_dev
- **CellPerformance**

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