

Newtonian N-Body Simulator

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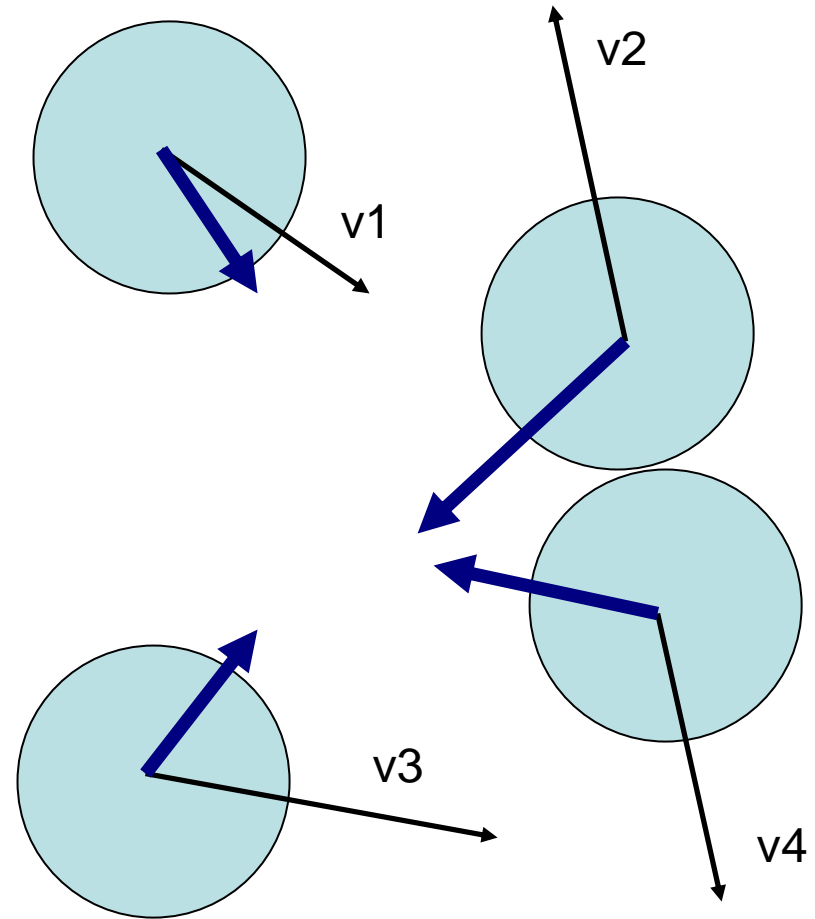


Project Overview...

N-body problem

- Masses
- Locations
- Velocities
- Geometries
- Other Properties

No closed form.

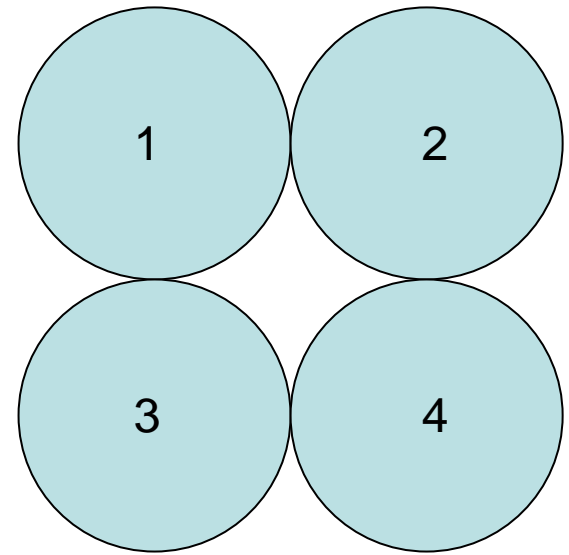




Iterative Solution...

- n objects
- $(n-1)$ interactions
- $n(n-1)$ total interactions
- Equal and Opposite Forces
- $\frac{1}{2} n(n-1)$ full steps:

$$O(n^2)$$



1	:	2, 3, 4
2	:	3, 4
3	:	4



Parallel Processing...

All 2-Body Interactions

calculated simultaneously involves:



Multiplication



Division



Addition



Subtraction



Square Root

Fixed-point: 6k-
10k Slices

Floating (single):

- $\frac{1}{2}(n^2 - n)$ 2-body calculations (approx.)
- $(6k \text{ slices})(\frac{1}{2}(n^2 - n)) = 33k \text{ slices} =$

All slices

→ **$n = 3.8 \text{ objects} \Rightarrow 3 \text{ objects}$**



Parallel Processing...

Stage Pipelining

- Only *one* 2-body interaction per cycle (after latency)
- Reuse of hardware
- Possibility of gigantic **latency** between frames
 - ➔ *Small by human standards*
 - ➔ *We can perform other calculations*
 - ➔ *Still better than a computer*



Simulator Design...

Calculate Gravitational Acceleration



Apply Accumulative Acceleration



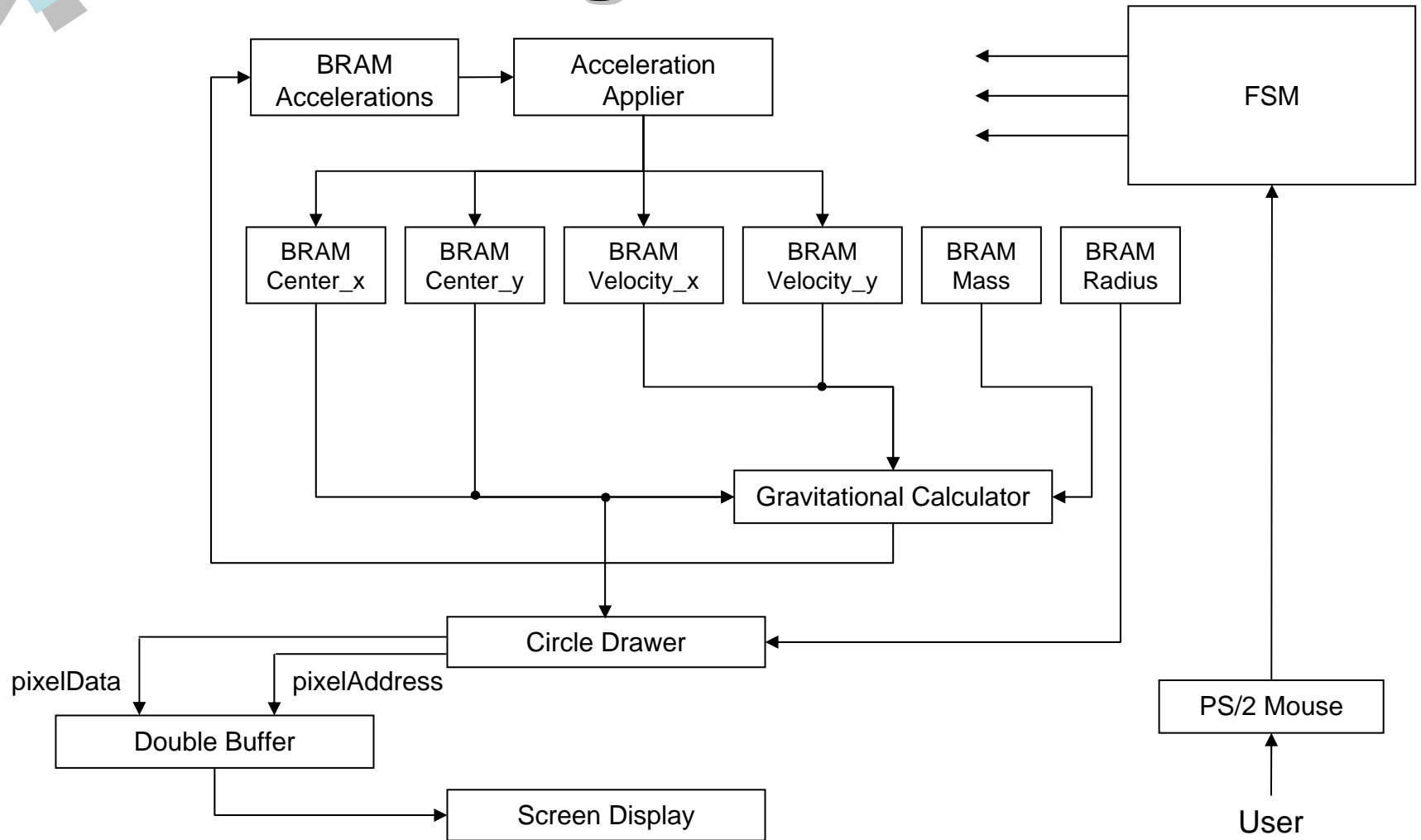
Draw the Graphical Data into a Double Buffer



Allow User Interaction with the PS/2 Mouse



Block Diagram...



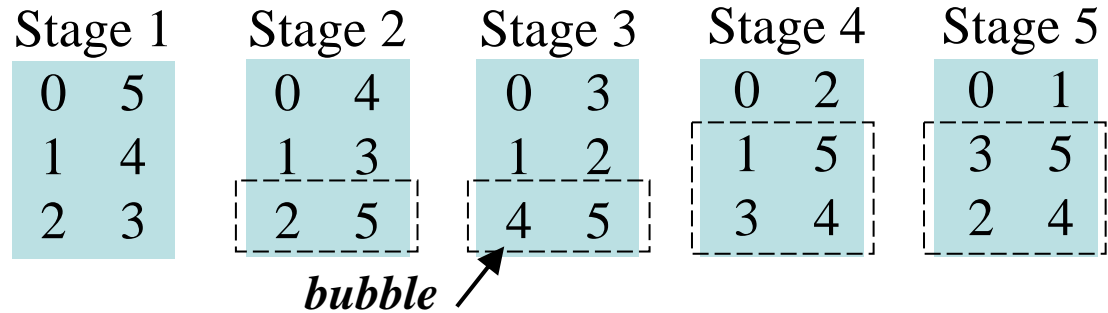


Parallel Processing...

Stage Pipelining

0 :	1	2	3	4	5
1 :		2	3	4	5
2 :			3	4	5
3 :				4	5
4 :					5
<i>Primary</i>					<i>Secondary</i>

n objects = (n-1) stages
where n is even

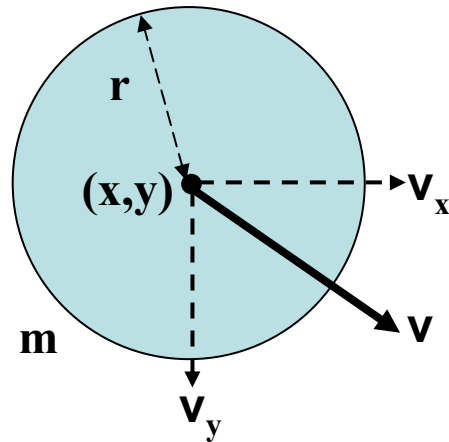


Analysis

- 0 → **Primary** for all stages (never *Secondary*)
- 1 → **Primary** for all except the last stage
- n → **Secondary** for all stages (never *Primary*)
- **bubbles per stage** = $\text{floor}[\text{stage number} \div 2]$



Data Representation...



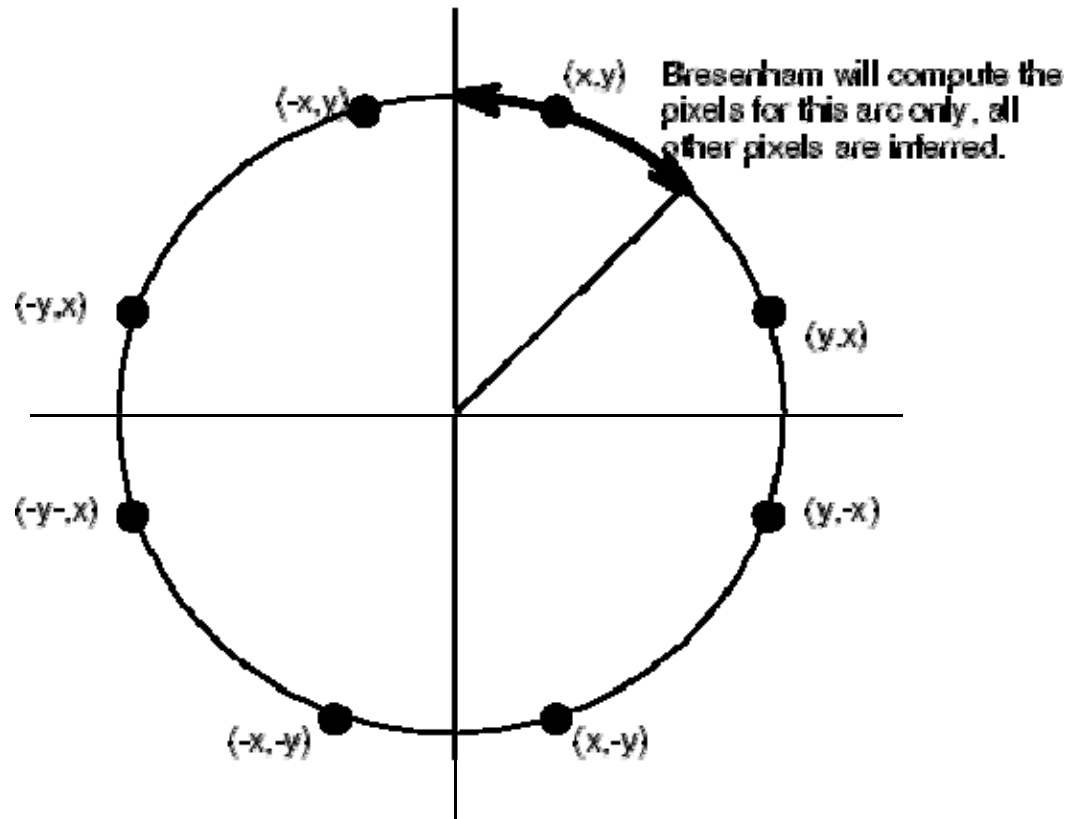
m	mass	} scalar
r	radius	
(x, y)	position: x and y	} vector
(v_x, v_y)	velocity: x and y	

- 144 of 512 x 36 BRAMs (cascaded for larger widths)
- Each number has its own BRAM.
 - *Single-precision floats (32 bits)*
 - *Range of magnitudes*
- 2 independent, synchronous read/write ports
 - *Limits parallel access to the data.*



Graphical Data...

Uses Bresenham's Circle Drawing Algorithm



(Courtesy of <http://glasnost.itcarlow.ie/~powerk/Graphics/Notes>)

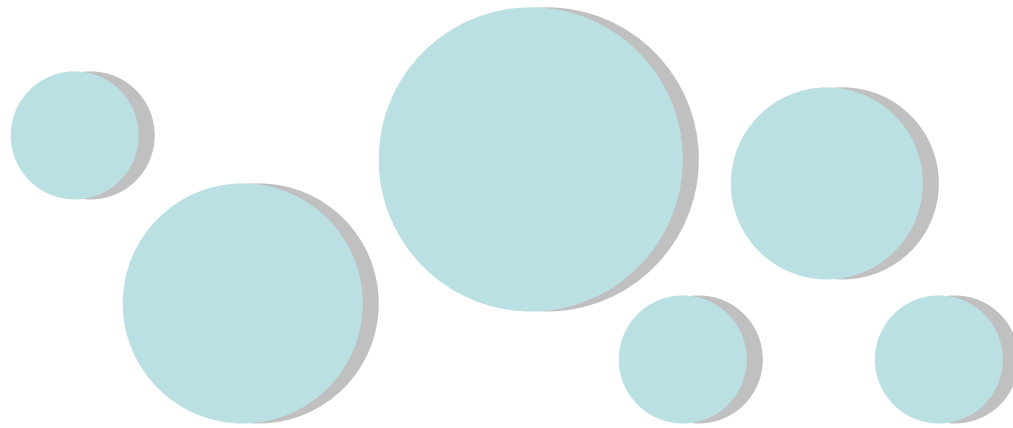


User Interaction...

- *Move object*
- *Add object*
- *Remove object*
- *Manipulate coordinate system*



(Courtesy of http://agumbo.com/logitech_mouse/page5/)



Questions & Answers...