FPGA Based Particle Engine for Textile 3D Surface Modeling and Simulation

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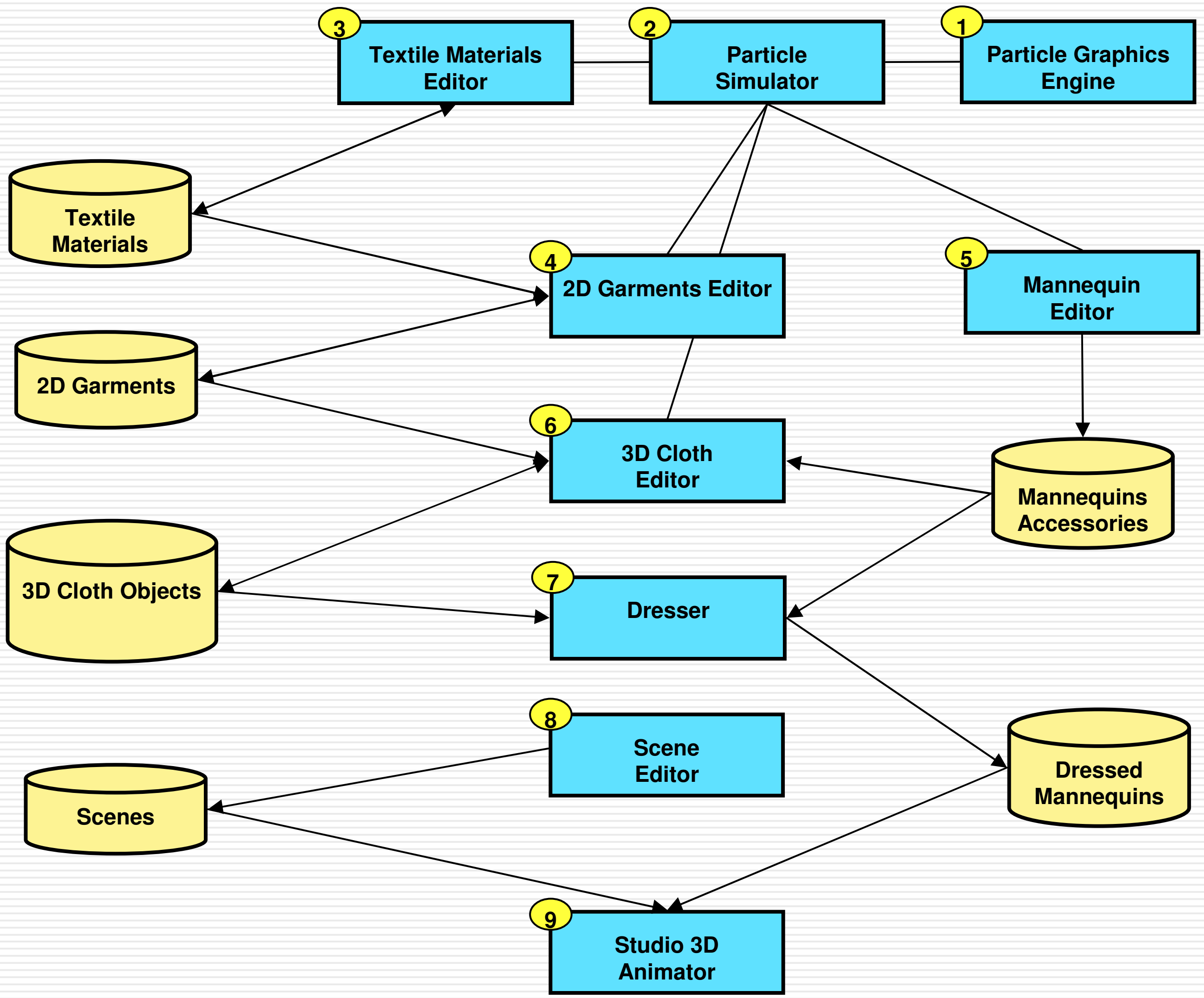
Fashion design

- Objectives
  - Development and experimentation of a virtual 3D studio
  - Research in fashion textile design
  - Allows a designer to achieve by a natural manner the modelling and the simulation of the textile materials and objects

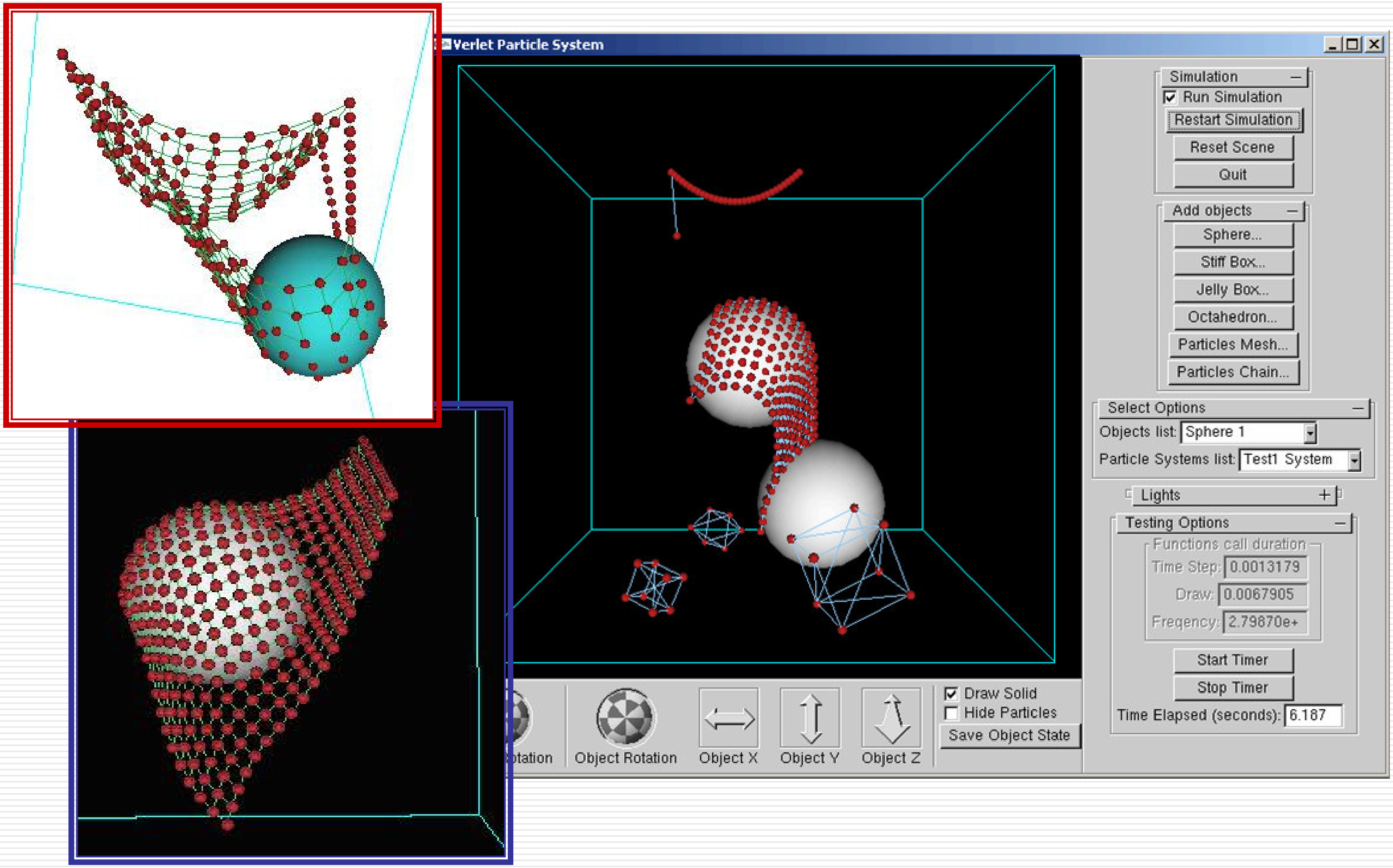
Modelling and simulation of 3D textile surfaces

- Objectives
  - Simulation of the physical characteristics of the textile materials (elasticity, rigidity, transparency) but also their association with the material's chromatic composition
  - Modelling and editing of the 2D garments considering the current trends in fashion
  - Design of clothing items and their presentation on models
  - Configuring the surrounding environment (colours, textures, lights and shadows) for viewing the static or dynamic models
  - Experimenting interaction techniques and the implementation of software tools for virtual 3D operations: cutting, fitting, sewing and laying out material pieces on the models.

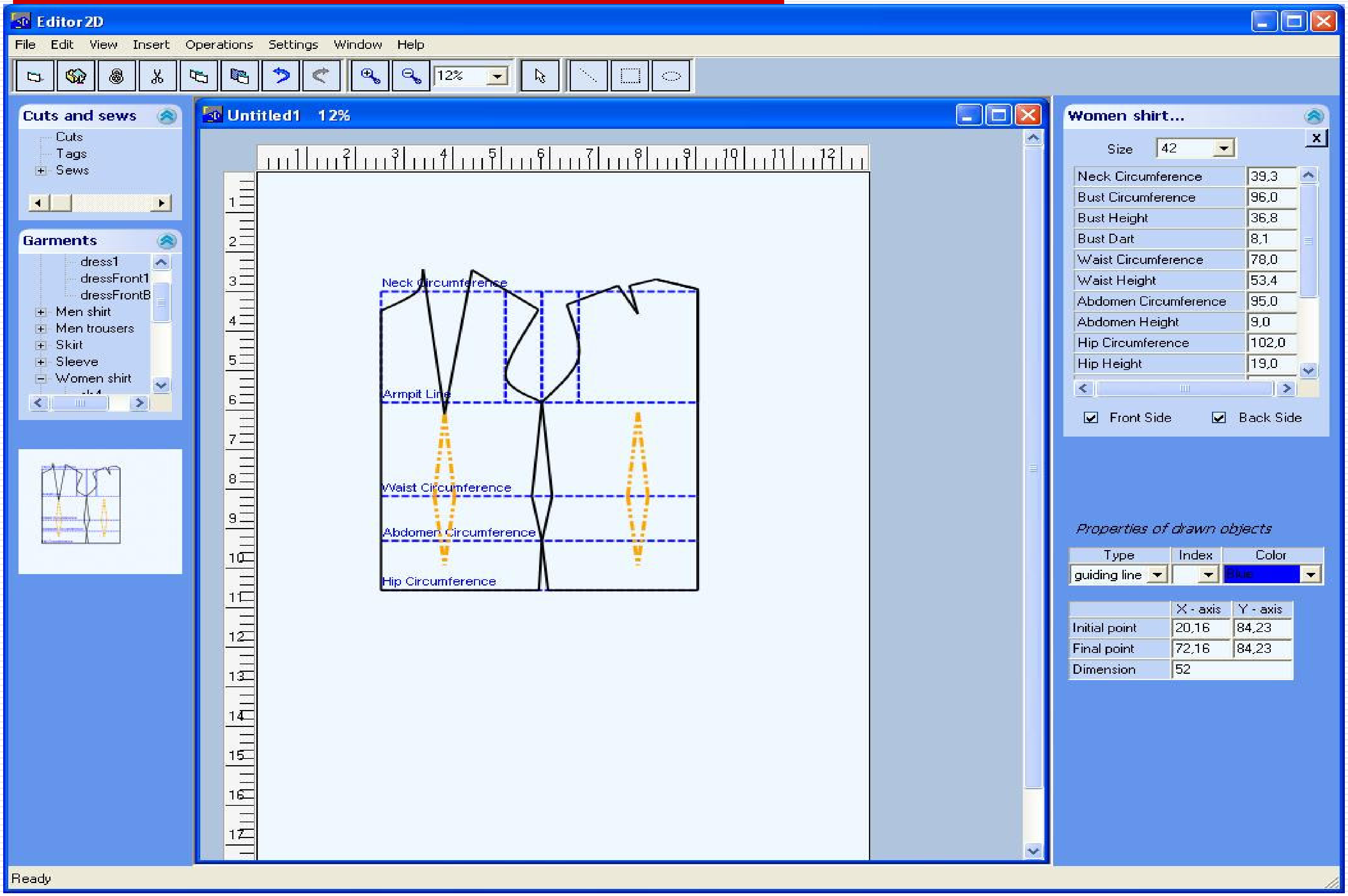
Software Platform Architecture



Particle based modeling of the textile 3D surface



Garments editor

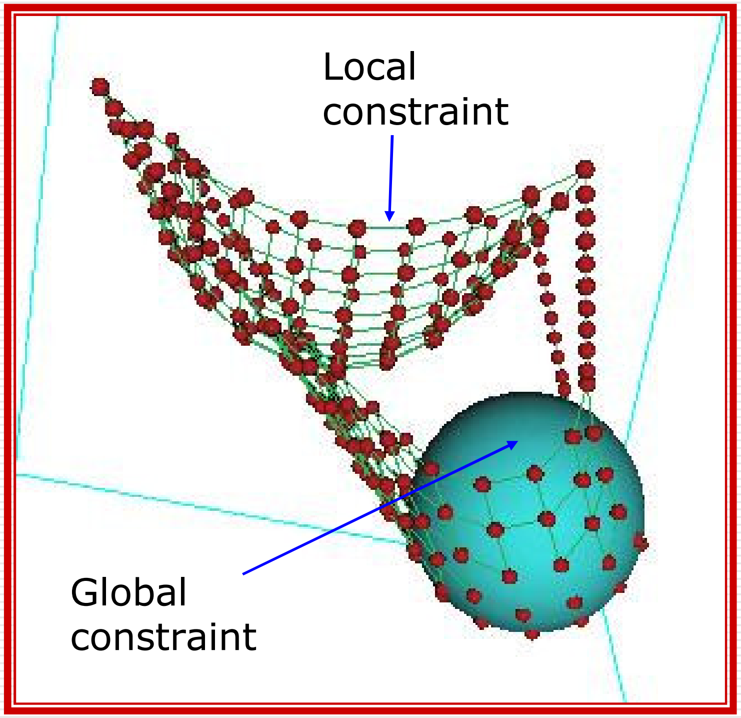


Main issues

- Expensive software computation
  - high memory data model
  - particle movement
  - force computation
  - constraint satisfaction
- Graphics presentation
- Animation
- User interaction
- Collision

Particle model execution algorithm

1. Force accumulation
2. Verlet integration
3. Global constraint satisfaction
4. Local constraint satisfaction



Considerations:

- Global constraint
  1. Sphere
  2. Box (axis aligned)
- Local constraint
  1. Rope (dist < L)
  2. Stick (dist = L)

Verlet integration

$$\mathbf{x}' = \mathbf{x} + \mathbf{v} \cdot \Delta t$$

$$\mathbf{v}' = \mathbf{v} + \mathbf{a} \cdot \Delta t,$$

Verlet integration

$$\mathbf{x}' = 2\mathbf{x} - \mathbf{x}^* + \mathbf{a} \cdot \Delta t^2$$

$$\mathbf{x}^* = \mathbf{x}.$$

Verlet computation:

next_pos = 2 crt_pos – prev_pos + a Δt

prev_pos = crt_pos

crt_pos = next_pos

Solution

- Particle engine
- Computation through hardware engine
- FPGA (Field Programmable Gate Arrays)
- VHDL (VHSIC Hardware Description Language)
- VHSIC (Very High Speed Integrated Circuits), 1980
- Xilinx (1984)

  technology and software tools, http://en.wikipedia.org/wiki/Xilinx

Research:

- design alternatives and the performance of an FPGA based particle engine

Particle model parameters

- Number of particles (N)
- Current positions of the particles (cpos)
- Previous positions of the particles (prev)
- Gravitational acceleration (g)
- Time step size (deltat)
- Number of iterative relaxations (R).
- The total number of time iterations (M)
- The number of global constraints (G)
- The set of global constraints (global).
- Number of local constraints (L)
- Set of local constraints (local)

Commands to the particle engine

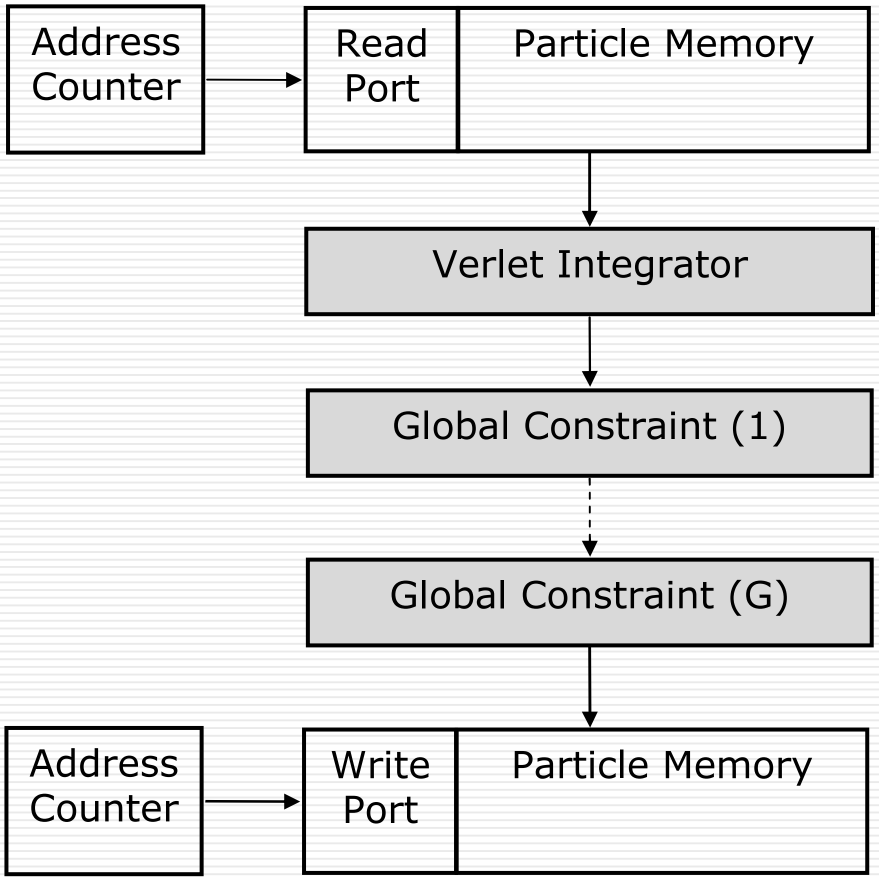
1. SET_GLOBAL: load the global constrains
2. SET_LOCAL: load the local constrains
3. SET_PARTICLES: load the initial positions of the particles
4. RUN_TIMESTEP: execute a simulation step
5. GET_PARTICLE: read the current positions of the particles

Implementation issues

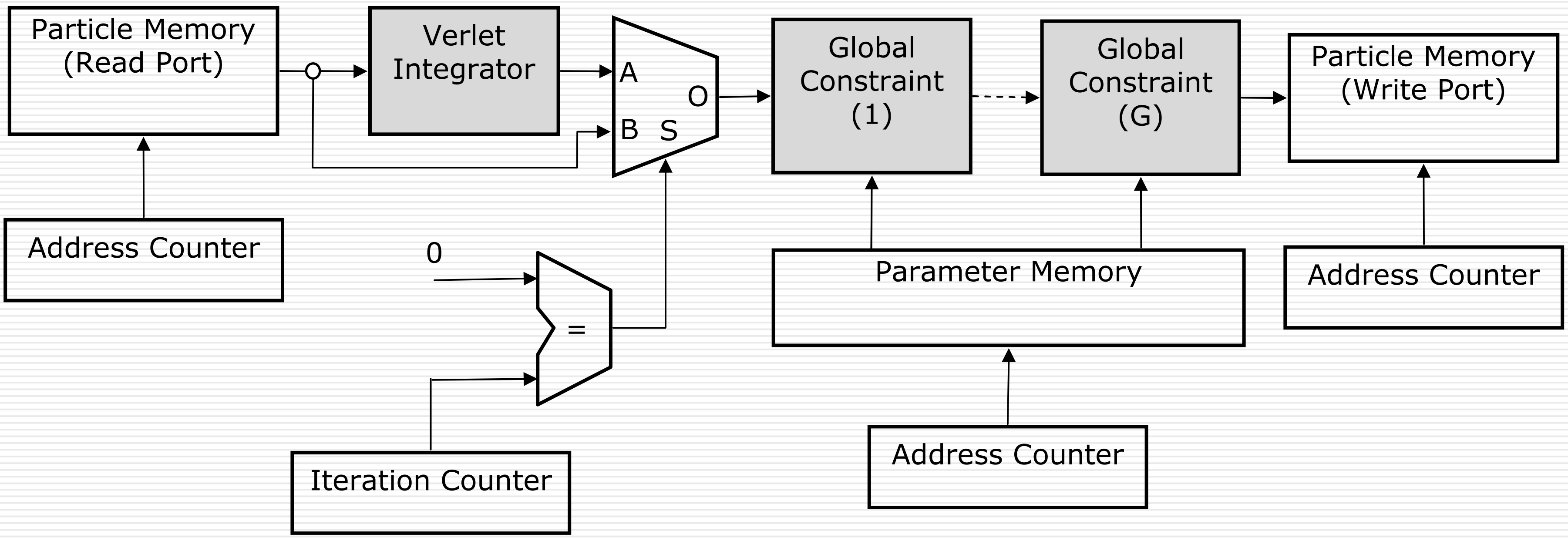
Parallelization, but with limitations:

- Spatial limitation of the design
  - cannot instantiate as many integration and constraint modules as the number of particles.
- Limited number of simultaneous accesses (read and write) to the particle memory.

Pipeline architecture



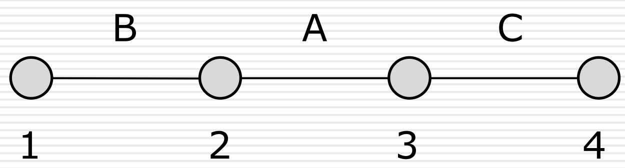
Particle engine - pipeline architecture



Extended version of the pipeline architecture for Verlet integration and global constraints.

Local constraints

Order of computation for the local constraints: A, B, D



A pipeline of length grater than 2 would fail, despite of the number of relaxation iterations.

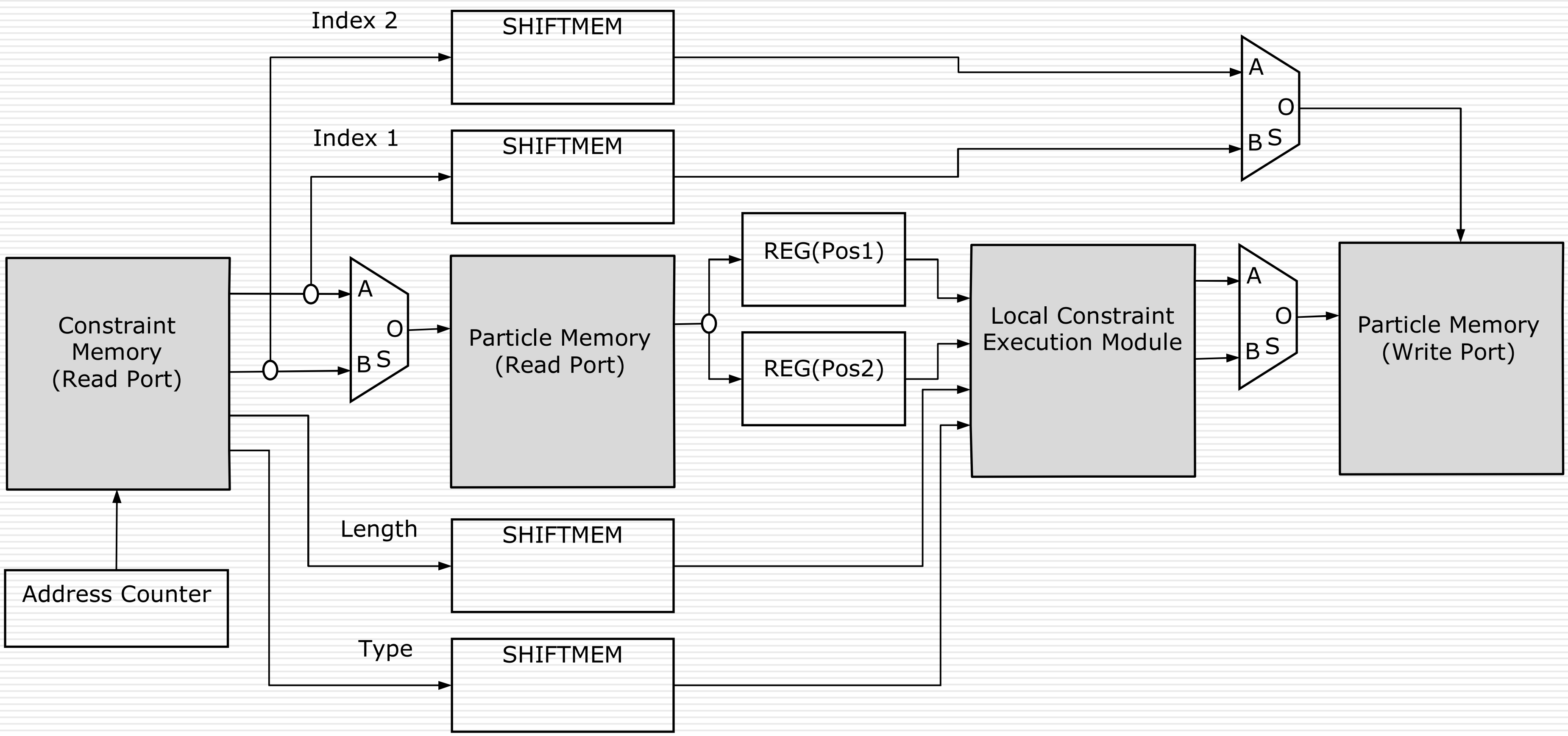
Local constraints

Solutions:

- Avoid the dependencies - detect the dependencies at runtime, followed by:
  - Stalling – delay the processing
  - Bypassing – pass the execution of another constraint

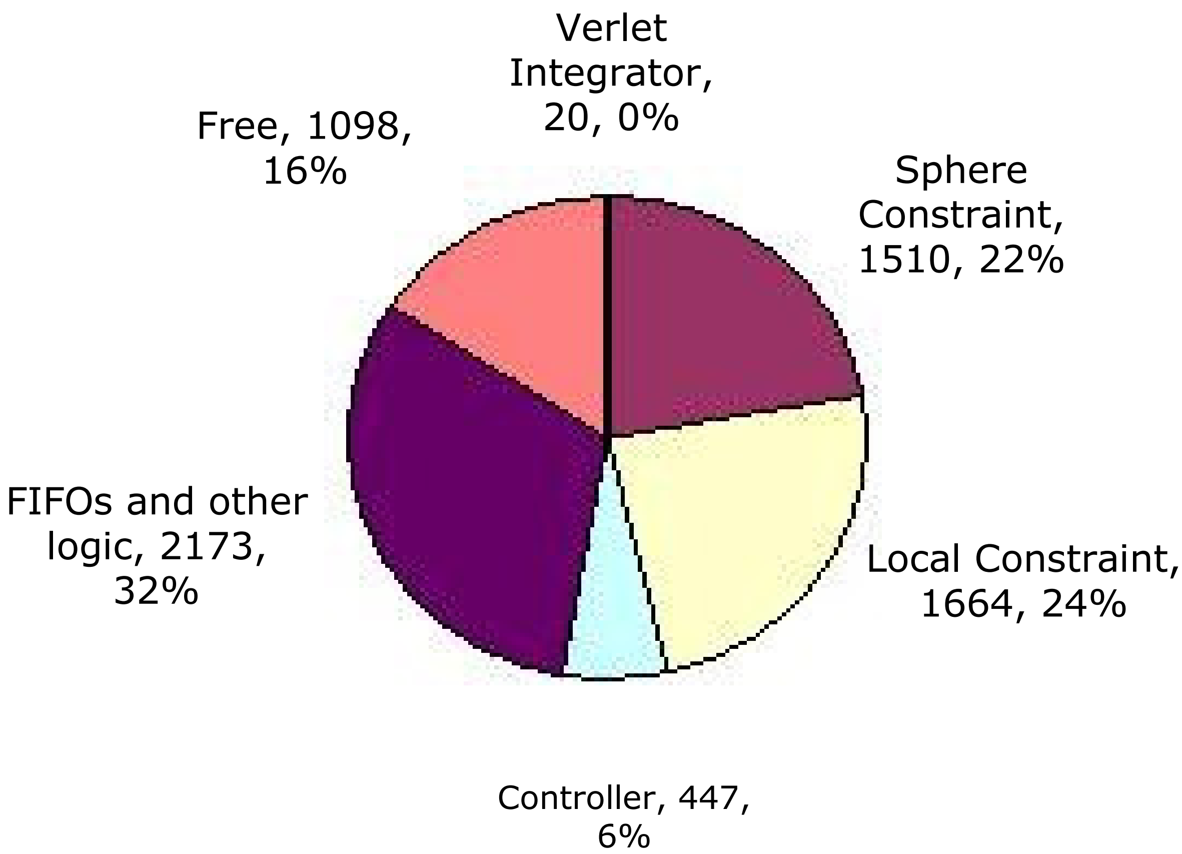
- Remove the dependencies before the execution (e.g. while the particles are loaded into the system):
  - Software environment - before the execution of the SET_LOCAL command.
  - Hardware system – during the execution of the SET_LOCAL command

Local constraint execution

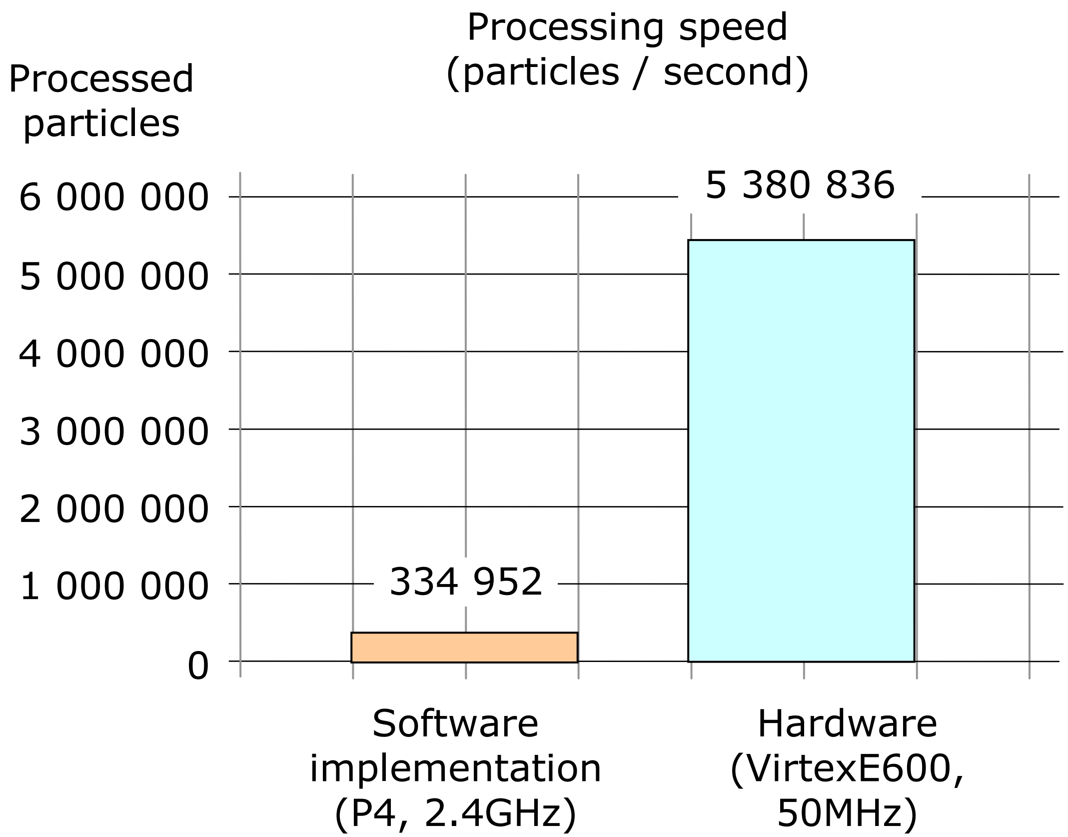


Pipeline architecture for local constraints execution.

Chip space usage



Software/hardware speed comparison



Thanks

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