**1 Introduction**   
Hi Mehmed, hi everyone my name is Amadeusz and I am going to be presenting about Hardware implementation of the particle swarm optimization algorithm

**2. Introduction What is the Idea of Particle Swarm Optimization (PSO)**  
**Slide intro**The first slide is dedicated to introduction to and short general briefing about Particle Swarm Optimisation

**- Reflection of the idea is based on the observation of nature**

Especially of ants and bees was taken in to consideration during creation of PSO algorithm. In swarms of animals the welfare of single particles (also called agents) is not as important as the benefit of the whole system and the behaviour of the swarm is a result of the behaviour of particular members of the swarm  
  
**- Role of single particle (agent)**

Agents individually gain their own experience and pass it to other agents for further processing, this is how their work is bounded together. Other important factor is, each particle acquires the experience gained earlier by the overall swarm. This approach is one of the best ways of solving various problems. It reminds me of threads communication in parallel aspects of computer programs   
  
**- Reflection of the PSO in computers environment**As a reflection a single agent can be considered as a generic processing unit, which has its own computation capabilities and in the context of the overall group or network cluster, it is ale to perform even very complex tasks on behalf of the swarm or the network cluster.

**3. Movement of Particles in the PSO Algorithm**  
**Slide intro**In this slide I will demonstrate and go over the movement of particles in the PSO algorithm. There are few movement key factors worth mentioning  
  
**- Iterations**   
PSO might seem very complex, but it is a relatively a simple algorithm. Over certain number of iterations a set of variables associated with particular agents have their values adjusted to move the agents closer to on optimum solution (target). This helps new agents or agents situated far away from the target to find it over smaller amount of iterations. This is called swarm experience sharing.

**- Movement**   
The movement of particles in the PSO algorithm resembles the movement that takes place in the swarm. However, the particles in the PSO algorithm are abstract entities with in the abstract environment. For this reason, some effects that occur in this case are not present in real swarms. For example, particular units may fall on each other and occupy the same points in the input data space.

**- Mathematical description**The mathematical description of the behaviour of the swarm is also only a simpliﬁed model of the behaviour of real swarms.   
Full Mathematical particle data description has been reserved for the next slide.

**4. PSO algorithm Mathematical Data description**  
**Slide intro**  
Before moving on to actual sequential and parallel hardware implementation of PSO algorithm I though it would be worth to go through and explain Mathematical data description along with Computational Sequence of algorithm which will be explained in the next slide  
**- Particle**   
In the PSO algorithm, stands for particle  
- **Coordinates**  
Coordinates of particles own position in the input data space are expressed by   
- **Velocity**  
Information of particles own velocity is described as  
- **Personal best solution**  
A personal (own) best solution is expressed as = (as well as the information in which place this solution has been found)   
- **Global best solution**  
Global best solution is expressed as = with the information in which place this solution has been found

**-Each iteration** =   
**-Random values coming from uniform distribution** = and   
**-Personal acceleration coefficient** = **Social acceleration coefficient** = **Inertia coefficient** =  
  
-**Fitness function**The fitness function is in other words target function  
The parameters are modified in the course of the learning process, in accordance with relatively simple mathematical rules

**5. Computational sequence in the PSO algorithm**  
  
**6. Hardware model of the PSO algorithm and Parallel Data processing**

**Slide intro**  
jump in to first point  
 **- Parallel Processing and PSO Algorithm**

As we already know in systems based on PSO algorithm all particles change their position at the same time. For this reason authors of the paper considered it sensible to implement this algorithm using technologies that support parallel data processing such as FPGA or ASIC

**- FPGA platforms**

FPGA is field programmable gate array integrated circuit designed to be configured by user after manufacturing. The main attribute of FPGA is that it has a number of logic blocks that can be connected together to perform massively parallel, real time processing.

**- ASIC alternative**

Application Specific Integrated Circuits are special chips, which allow implementation for both analogue and digital functionalities. Authors of the research paper also considered them as an alternative, which could be used in hardware model , but by using ASIC they would have to deal with various physical problems, especially in case of the analogue approach.

**7. Transistor level approach of PSO algorithm**

**Slide intro**  
And therefore they focused on the transistor level approach mentioned in the first part of previous slide.  
  
**- Transistor level - More opportunities**

Transistor level approach offers more opportunities. One of them in my opinion most important one is the possibility to mix together analogue and digital blocks, which may lead to more flexible solutions. A pure analogue implementation is not practical.

**- Current-mode technique**

Current mode techniques has been considered because even basic operations and functions are quite complex. The current-mode technique facilitates the implementation of such operations as addition, subtraction, multiplication and comparison of signals. Such operations dominate in the PSO algorithm.

**- Problems with analogue realisation**

According to the research paper there a of typical problems with analogue realization is a reduced precision that results from the influence of the noise. Analogue circuits are also less robust against the physical problem described above.  
Authors of the paper resolved this problem by reusing implementation method from previous research projects.  
  
**8. Basic parallel operations and components used in proposed hardware model of PSO Algorithm p.1**

**Slide intro**  
This series of slides will be dedicated to explanation of how major calculation operations can be implemented at the transistor level  
  
**- Calculation of and signals**

One of the problems encountered by the author of the proposed hardware model is the necessity of the calculation of the fitness function. In the worst case it is assumed that the shape of this function is not known in advance. In this case the and values returned by this function has to be determined outside the chip on the basis of current positions of particles. Similar situation occurs when a swarm arrives in a new area, the map of which is not yet known.

**- Updating the velocities of the position of particles**

The calculation of the updates of the velocities (Δx factor) and the positions of particles require several basic operations, schematically shown in Fig.4. As it can be seen This block contains two summing, two subtracting and two multiplication blocks. The r, c and w signals are constants that in the proposed solution are represented by multi-bit digital signals. The r1 ·c1 and r2 ·c2 terms are kept in the memory as single constants.   
  
- At the end updated values of the x and the v terms substitute their previous values stored in analogue memory block associated with each particle.  
  
- The same circuit is also used to update the values of the and signals in the memory.

**9. Basic parallel operations and components used in proposed hardware model of PSO Algorithm p.2**

**-Parallel searching for best value among the**  **signals**

Operation of parallel searching for the best value among the signals are carried out by using a conventional Min or Max circuit (MIMA2)   
Search operation is performed by use of a binary three winner selection circuit. Simplified version is demonstrated by Fig5.   
Whole circuit is composed of MIMA2 blocks shown in FIG6. Multiple blocks allow for accelerated parallel search process to determine a single maximum or minimum value of two separate particles input.   
Best value is determined in steps at particular layers of the tree. At the first layer particular pbest i values directly compete in pairs. The winner from each pair is allowed to take part in the competition at the second layer.

**10. Basic parallel operations and components used in proposed hardware model of PSO Algorithm p.3**

**-Current mode comparator**

Finally the core block of this circuit is a current-mode comparator presented in figure 7   
The main role is of current mode comparator is to compare and value. This can be observed in figure 6

**11. Results and performance analysis**

Over here we can see estimates of parameters such as the hardware complexity (on the top) and the power dissipation of these components (on the bottom)

**12. Conclusion   
  
13. Questions**   
  
**14. References**