MATERIAL POINT METHOD(MPM)

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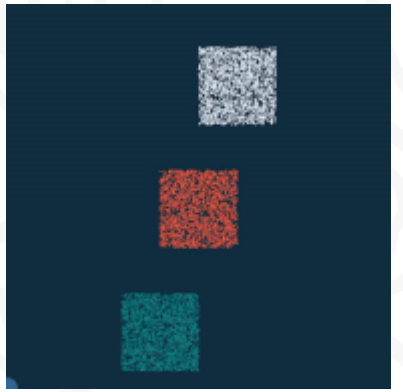
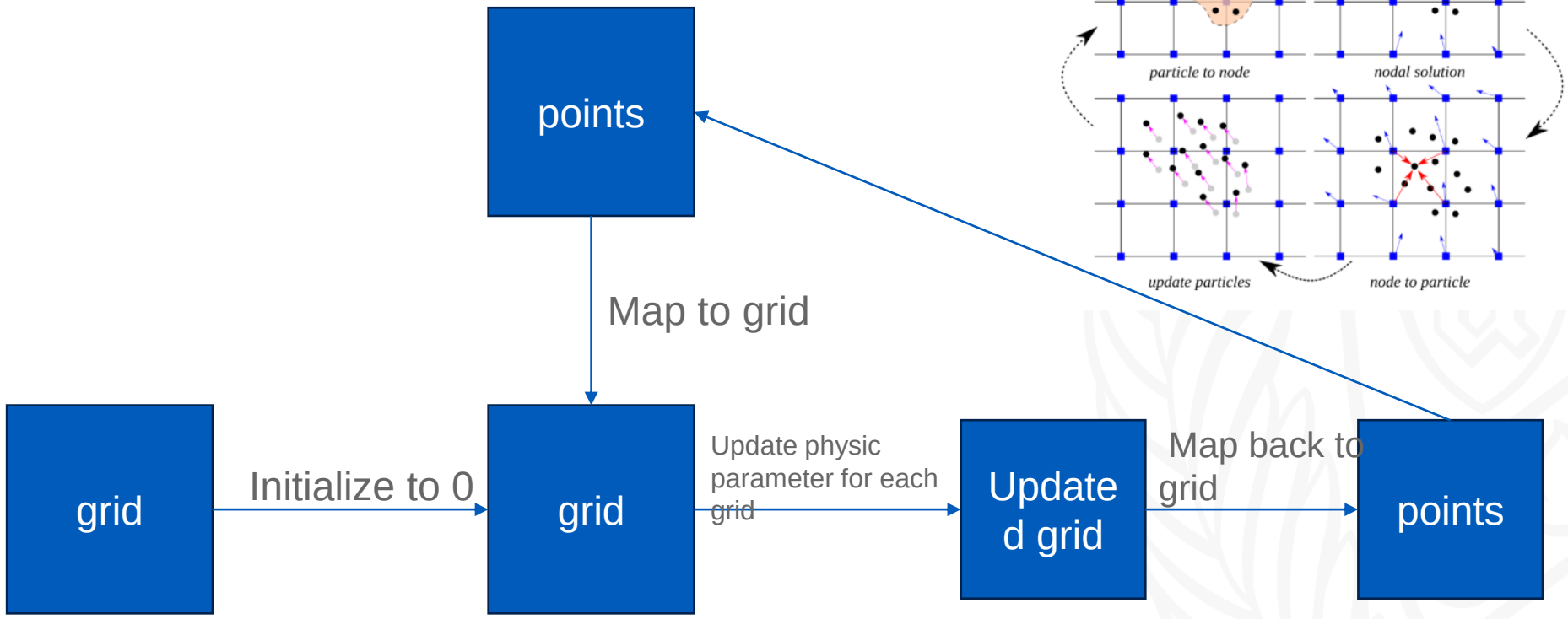
What is Material Point Method:

- It is a numerical technique used to simulate the behavior of solids, liquids, gases, and any other continuum material. (Wikipidia, Material point method)

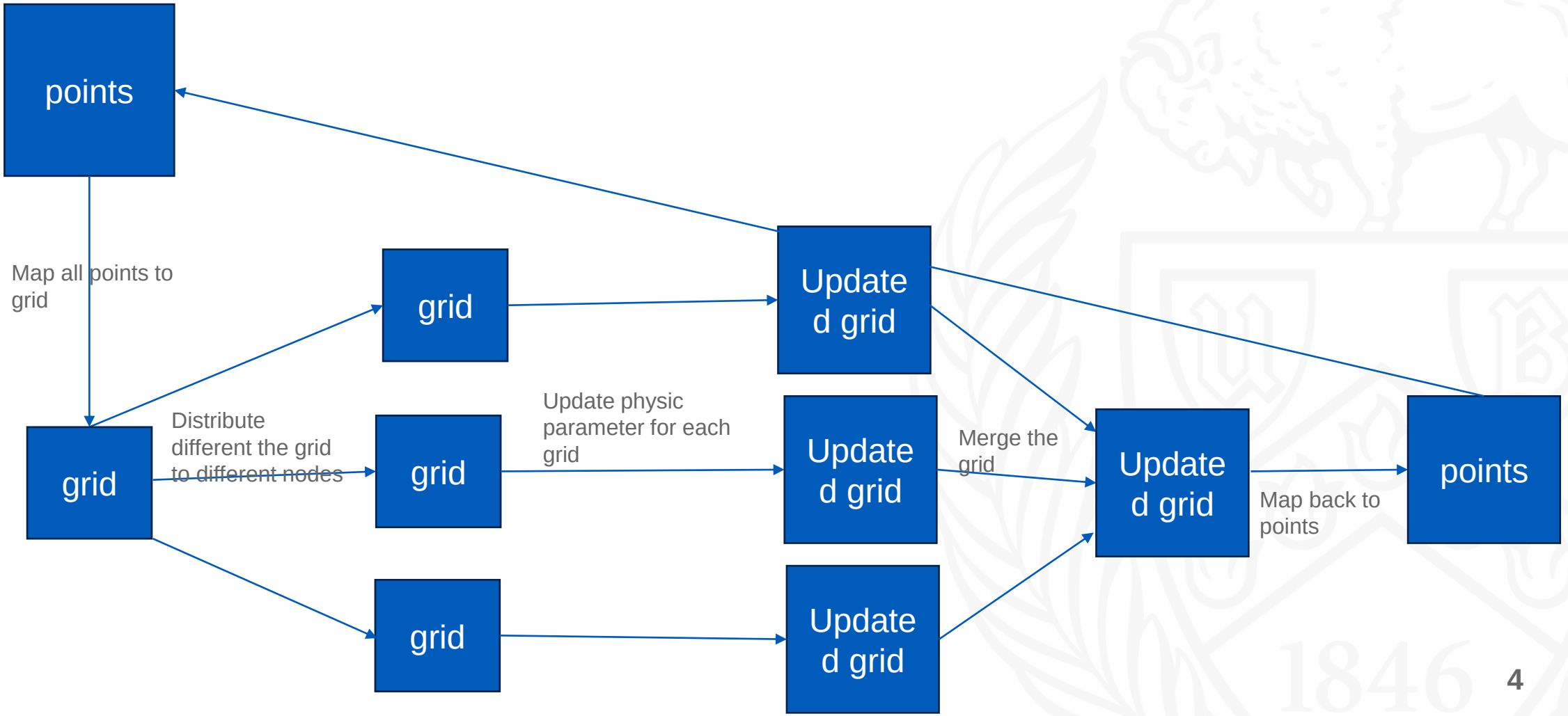
- In another word, it provides a way to simulate the material points movement and their velocity and position.



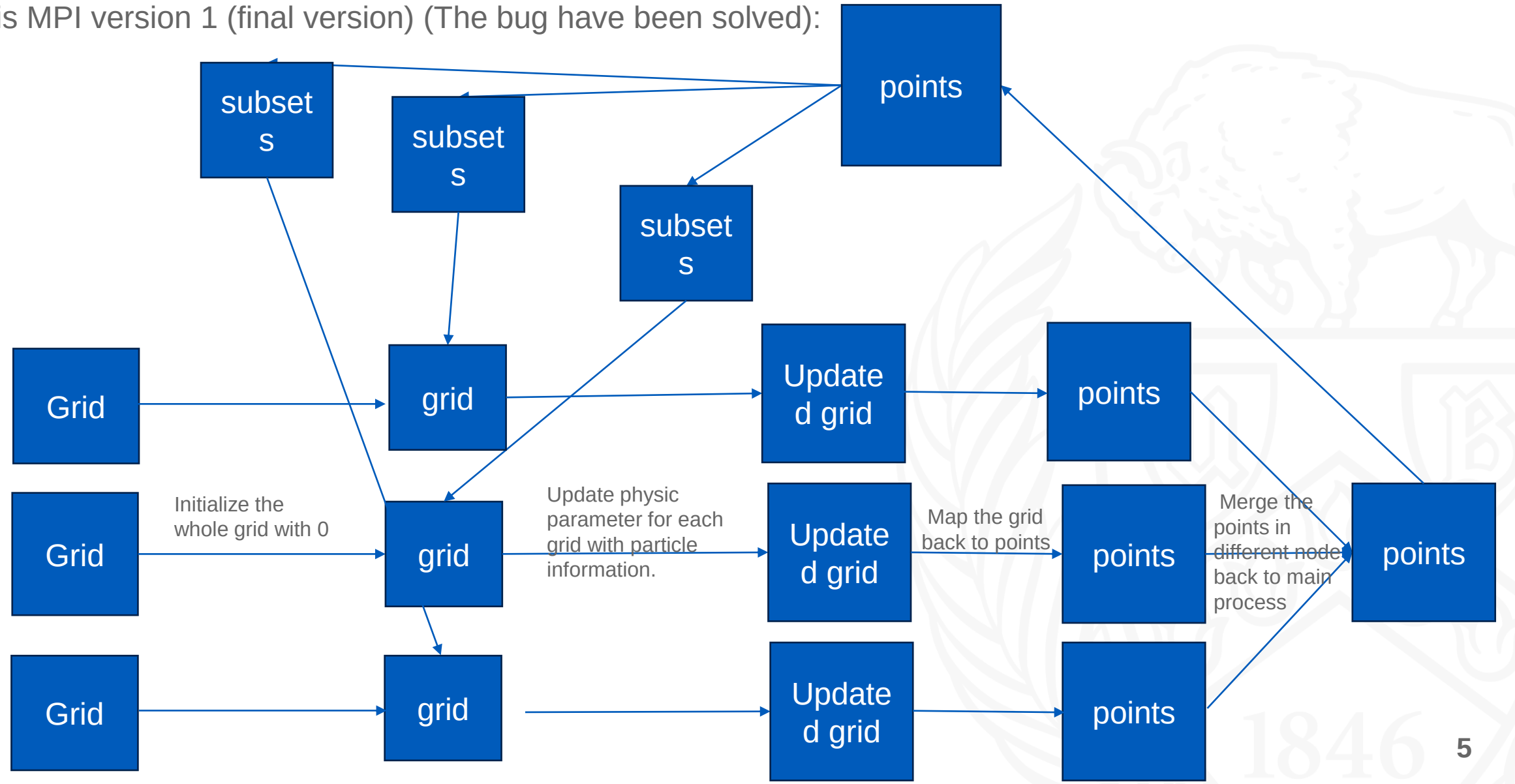
This is standard sequential version for MPM:



This is MPI version 2 (This version is difficult for scaling):

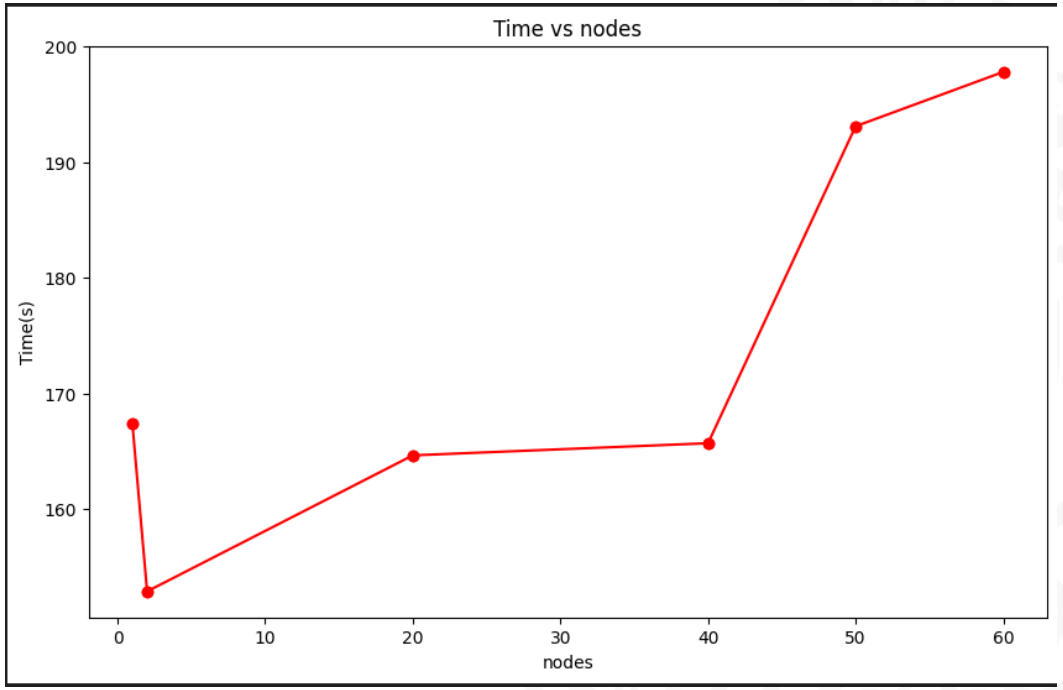


This is MPI version 1 (final version) (The bug have been solved):



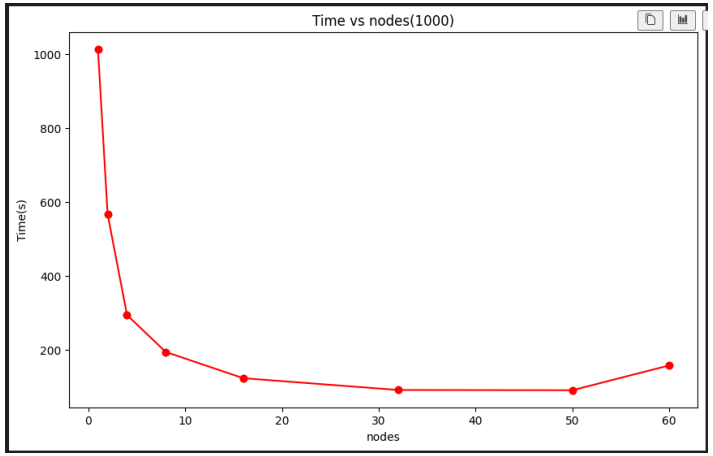
Weak Scaling (Each of the node will get 100 points):

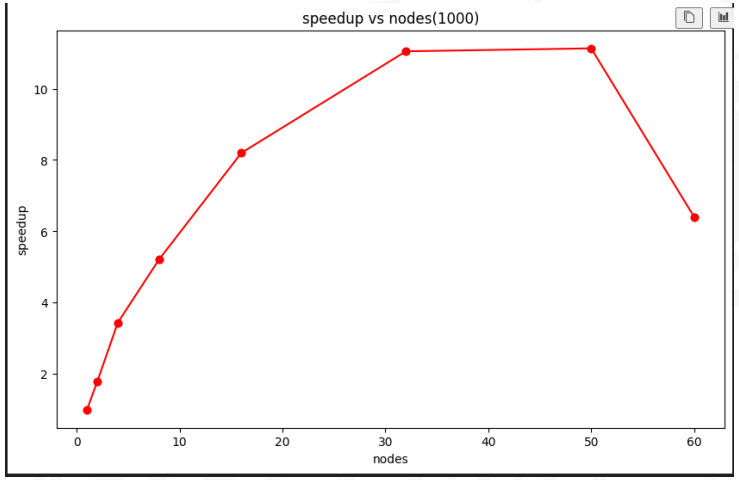
Number of node	Time(sec)
1	167.44
2	152.86
20	164.63
40	165.68
50	193.10
60	197.80

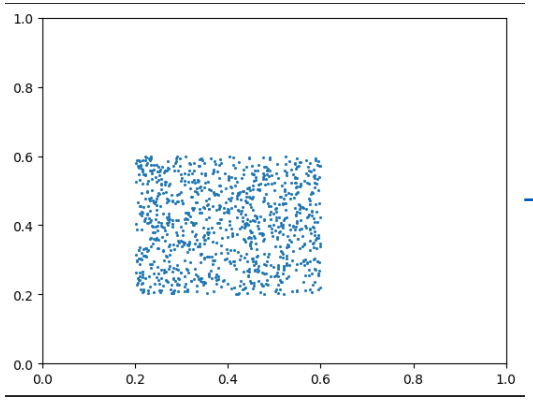


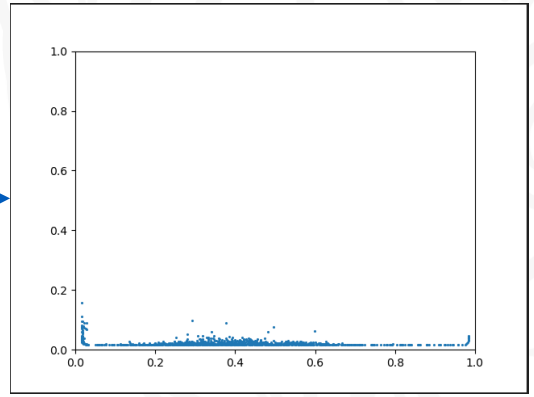
Result(Particle=1000, grid size is 128*128):

Number of node	Time(sec)
1	1013.62
2	567.02
4	294.55
8	194.59
16	123.65
32	91.75
50	91.07
60	158.18



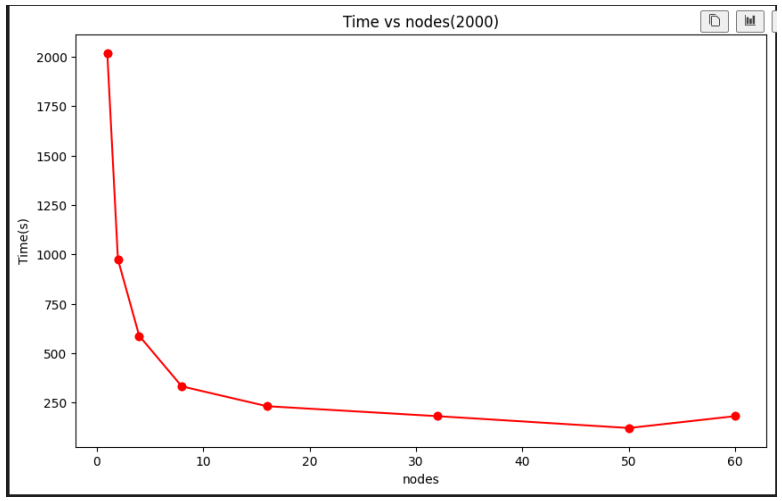


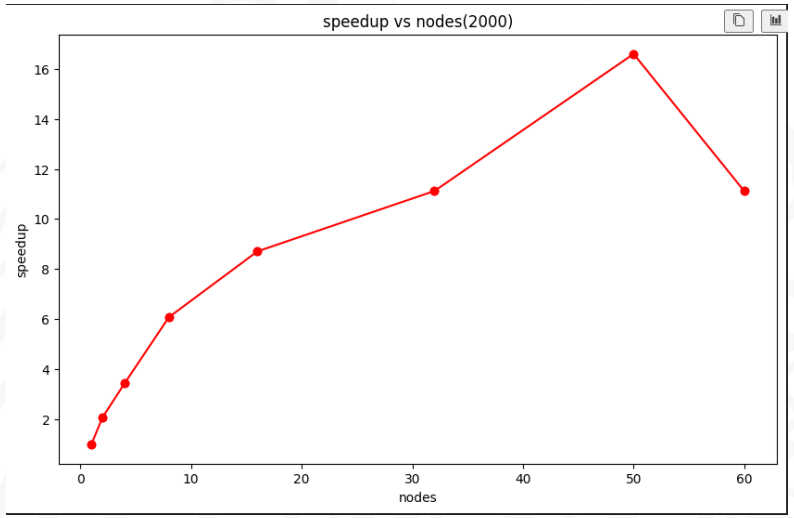


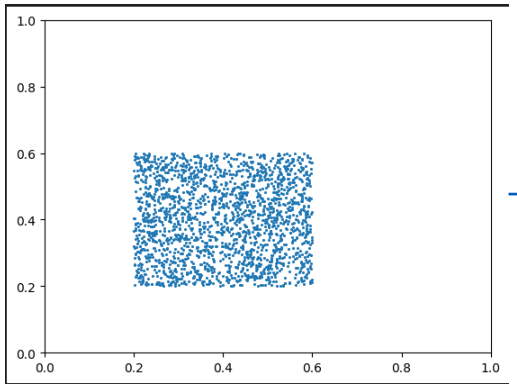


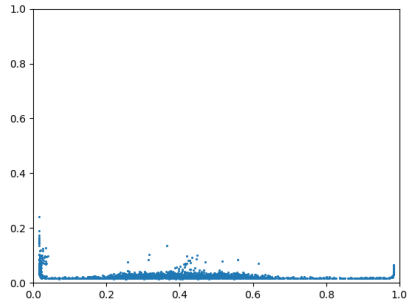
Result(Particle=2000, grid size is 128*128):

Number of node	Time(sec)
1	2019.06
2	974.93
4	587.92
8	332.32
16	231.95
32	181.59
50	121.65
60	181.70



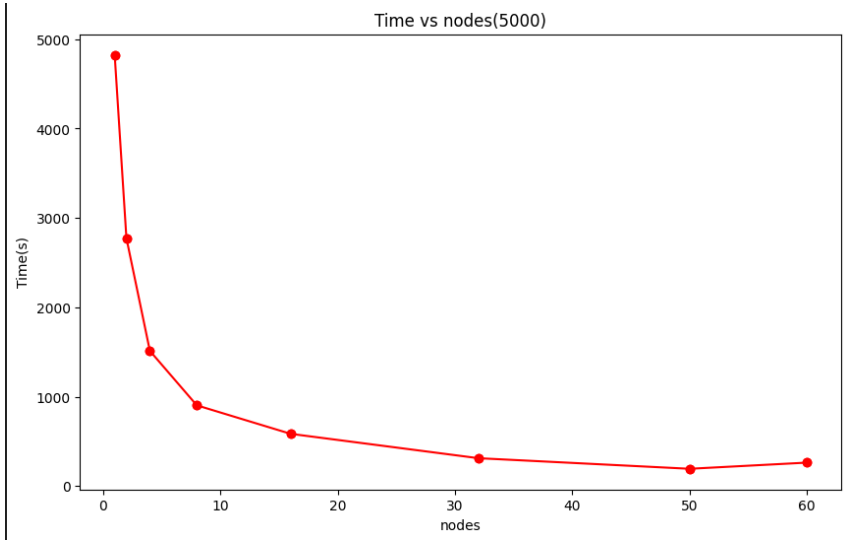


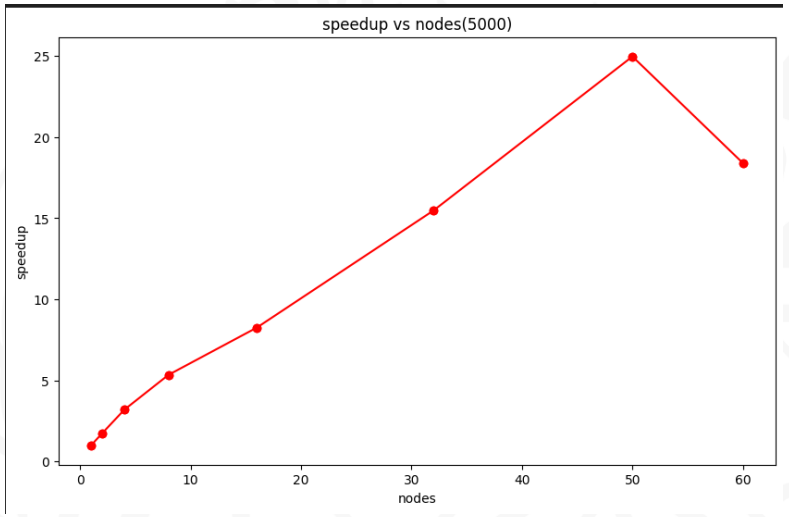


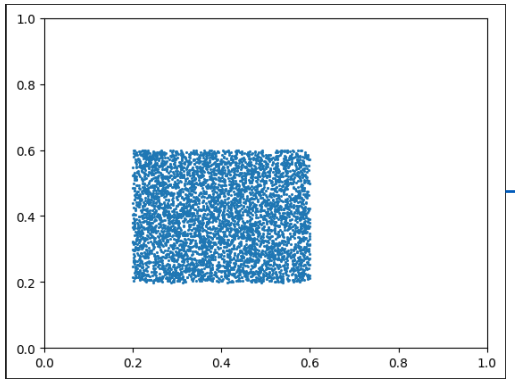


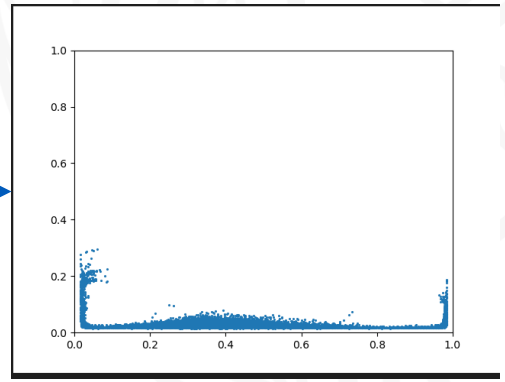
Result(Particle=5000, grid size is 128*128):

Number of node	Time(sec)
1	4823.23
2	2773.97
4	1512.10
8	902.94
16	584.12
32	311.52
50	193.10
60	262.10









Conclusion:

In conclusion, the performance is benefited from increase node number from the start. In addition, with the particle increasing, we can find the speedup increase as the particle number increasing (data size). Which means with proper number of node, more data will benefit more from the scaling.

And when the node number increased to around 50 to 60. The speedup will decrease. This means the running time is no longer benefited from increasing node number. One potential reason is the data transfer cost keep increasing as node number increased. And the communication overhead is too high which makes the performance reduced.

Future work:

- Can explore more complex simulate environment, such as mixture of liquid and solid.
- The second method to distribute the job may have better performance when grid size is very large, which is worth to explore.
- Reduced rate the broadcast the data may benefit the speed. Since the particle are not interact with each other. We can treat each particle as individual part and merge at the end, which allow us to reduce the rate for synchronizing the data.

Reference:

- https://www.taichi-lang.org/, Taichi library.
- https://www.math.ucla.edu/~cffjiang/research/mpmcourse/mpmcourse.pdf, The Material Point Method for Simulating Continuum Materials
- https://github.com/taichi-dev/taichi/blob/master/python/taichi/examples/simulation/mpm88.py, Taichi, MPM88
- https://en.wikipedia.org/wiki/Material_point_method, Wikipedia, Material point method.

Thank You