Particle gravity method:
a feasibility study to apply gravity method with a mesh-free model

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To better image the underground structures or fluid movements, reservoir simulation studies have been brought forward from a commonly-used grid model to a non-classic particle model. The conversion of a model unit would lead reservoir studies with a higher level of freedom and reservoir simulations could, in turn, deal with more complex reservoirs without any constraint of grids in the space. The current numerical techniques for gravity are now constrained by grid or prism-based methods and the shift from the gridded space to particles could be a breakthrough to an integrated analysis with both reservoir simulations for the kinematic behavior of materials and the gravity for the potential energy distribution. For achieving the goal of the integrated analysis, we need to prove the concept of the integration.
The first question needs to be answered is that could we reproduce the gravity force of a simple prism by volume composed of particles? Because surface gravity surveys detect the gravitational force of attraction caused by underground mass bodies in vertical directions, the gravity force at every observation point is the sum of attraction force of the individual masses. As a result, the gravity of a prism can be expressed as a sum of gravity of point masses. Additionally, the gravitational attraction of a sphere appears as it of a point mass with magnitude equals to the sphere. Relating to our object in this abstract, the previous question is therefore transferred to how to best contribute the mass of a prism by point masses (particles) to better reveal the gravity force of the prism?
We tested various combinations of particles to represent the prism. At first, two natural choices are, condensed approach, where the prisms mass is condensed in its interface sphere center, and discrete approach, where the prisms mass is evenly divided to 8 pieces and every mass segment is placed to each corner of the prism. This forward calculation is conducted under 3 synthetic buried depths of the prism, which is 10 km, 100 km, and 1000 km, respectively. The results show that both approaches produce a quite close gravitational attraction force to the gravity force of the prism. Additionally, if we discretize the prism, the one we studied in the previous case, in an adequately fine mesh, this prism can be replaced by pixels of contrast mass values, where the integral of the pixels masses should be the mass of the prism. The result from this pixel approach shows that the finer the mesh, a closer gravity field can we recover from particles to prisms. The same process can be used to calculate gravitational force of any density bodies with arbitrary shape.
From the previous study, we know that it is possible to forward calculate the gravity force of a prism by volume composed particles. We then move a step further to apply this particle gravity calculation to some more complex synthetic cases. The first synthetic case is carried out from a two-body model, where a lighter and smaller object is buried in a deeper depth meanwhile a heavier and flatter object is buried in a shallower depth. The gravity force of particles depicts the gap in between the two objects as we can observe from the gridded model. The last synthetic model we ran is the SEG/EAGE salt body density model at a depth of 100 km below sea level. An overburden is moved from the background density (sedimentary rock) as a constant value before the calculation. The calculated gravity force shows a good consistency between a grid approach and a mesh-free approach.
To conclude, it is feasible for us to conduct gravity forward modeling with particles. Both the gridded and mesh-free models are capable of viewing some subtle features in between mass bodies. Particle gravity techniques have a higher level of freedom in the calculation.

Keywords: particle , gravity, simulation, integration