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Charged Particle Location Modeling Based Experiment Plan Acquisition Method

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Abstract

The method of obtaining the plan of experiments in multidimensional space is proposed. Our method is based on assumptions of uniform distribution of charged particles in infinite space. To receive the plan of experiments, the infinite multidimensional space is replaced with a hypercube whose surface models influence of infinite space. The software is developed and practical results, in two-dimensional space are acquired. There are no basic problems to carry out calculations in multidimensional space.

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Keywords: Experiment plan; Charged particle interaction; Latin hypercube

1. Introduction

Computerized, mathematical modelling and metamodeling occupy increasingly important part in technical object and system development nowadays. Irreplaceable part of computerized modelling is experiment plan[1].

Experiment plan obtaining is usually coordinated by using Latin hypercube methods[2,3]. Latin hypercube is often used to obtain experiment plan for an experiment with two to four independent parameters. As a result of the rapid development of modern technology the need arose to obtain experiment plan for experiments with eight to ten or more independent variables (ten-dimensional space), where Latin hypercube method loses its efficiency.

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Consequently, other approaches for obtaining experiment plan are becoming increasingly topical. In 1977 V. Eglajs suggested that charged particle coordinates in equilibrium state could be used as an experiment plan[4].

2. Main presumptions

Particles in n-dimensional, infinitely viscous space with certain particle density would interact with one another until reaching equilibrium state, at which point all movement would stop. At this time system would reach equilibrium state. Hypercube taken from this space would be a good experiment plan.

This type of solution is not realizable – not physically nor using the mathematical model. Practically, the equilibrium state can be researched using hypercube which contains charged particles and whose surface is replaced by the forces from the outside world that affect the hypercube. Fig. 1 shows research schema for two-dimensional (square) case.

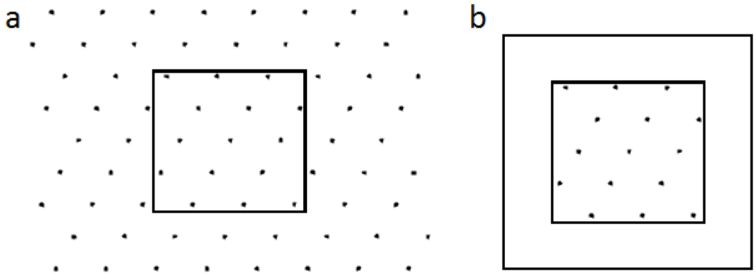

Fig. 1. (a) Square as a part of infinite two-dimensional space; (b) Square whose perimeter replaces the infinite space.

Replacing infinite space with square creates methodical mistake in the system, which needs to be evaluated. In this paper we analyse two methods for replacing an infinite space:

- Wallpaper – part of the space, which infinitely repeats itself (see Fig. 1a)
- Mirror – part of the space, which does not allow charged particles to leave the space, which is restricted by the square (see Fig. 1b)

3. Calculation schema

Calculation is made for each particle by determining place where the particle is located at its equilibrium state as shown in Fig. 2.

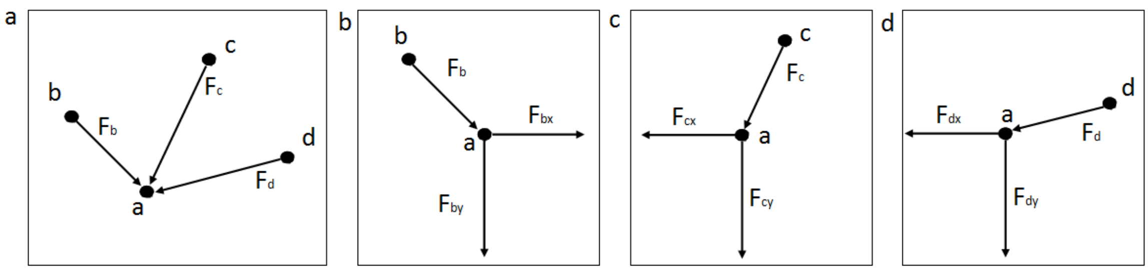

Fig. 2. Finding the equilibrium state of a charged particle.

To determine the location where particle should be moved to, we need to find the following for a-particle[5]:

- All forces which affect the particle - F_b, F_c, F_d. (see Fig. 2a)
- Components x and y of each force – F_{bx},F_{by}, F_{cx}, F_{cy},F_{dx},F_{dy} (see Fig. 2b, 2c, 2d)
- Cumulative force F_x which is affecting the particle

$$F_x = F_{bx} + F_{cx} + F_{dx} \tag{1}$$

- Cumulative force F_y which is affecting the particle

$$F_y = F_{by} + F_{cy} + F_{dy} \tag{2}$$

- Collective force F which is affecting the particle

$$F = \sqrt{F_x^2 + F_y^2} \tag{3}$$

- Primary displacement of the particle

$$F_{ai} = C\frac{1}{r_{ai}^2}, \tag{4}$$

where
i – index of the element,
C – coefficient,
r – distance of the particle,
a – displacement of the particle,

- In each subsequent step displacement is reduced by half.

In each step displacement is situated in the direction of the force (see Fig. 3).

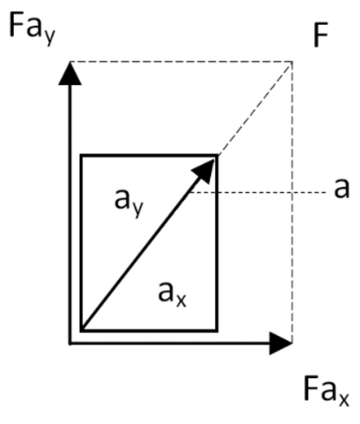

Fig. 3. Determination of displacement a_x and a_y.

$$\frac{F_{ax}}{F} = \frac{a_x}{a} \tag{5}$$

$$\frac{F_{ay}}{F} = \frac{a_y}{a} \quad (6)$$

where

a_x – displacement on x axis,
a_y – displacement on y axis,
F – collective force,
Fa_x – force on x axis,
Fa_y – force on y axis,
a – displacement of the charge.

Each particle is moved until the necessary precision is reached or displacement no longer lessens the force that is affecting the particle, or energy level of the entire system no longer decreases.

4. Infinite schema replacement method “Wallpapers”

A square is isolated which contains a certain number of electrons. This square is surrounded by squares of the same size and the same particle positioning. One, two or more phantom rings can be placed around the calculation space.

Fig. 4 shows that when the displacement is great enough for the particle to leave the square, this particle moves to one of the phantom squares thus replacing the particle that moved out of the square. This dislocation is represented by arrows.

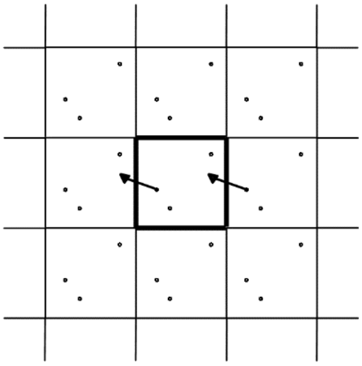

Fig. 4. Replacement method "Wallpapers".

Any displacement of a particle means that all corresponding particles also move the same distance in the same direction with the same speed. This means that when calculating displacement of each particle, phantom of the particle is also taken into account. Phantom particles are taken into account when calculating the displacement, but particles that are further away are not taken into account because resulting cumulative force from all sides is equal to zero.

5. Infinite schema replacement method “Mirror”

A square is isolated which contains a certain number of charged particles. Major problem in this method also, is not to let particle leave the calculation area.

Therefore, a mirror image of each particle is made that is used in calculation and does not allow the main particle leave the calculation area as shown in Fig. 5.

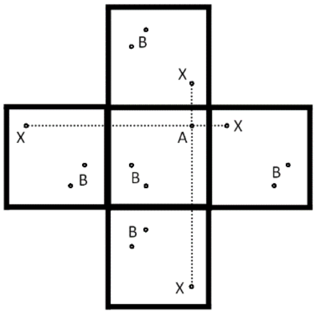

Fig. 5. Replacement method "Mirror".

A – Particle whose displacement is being calculated.
X – Mirror images of particle A which do not allow particle A to leave the calculation area.
B – Another particles that are not used in calculation.

6. Practical results

Describe methodology was practically implemented[5]. Practical experiment plan obtaining calculations were made. The results are shown in Fig. 6 and Fig. 7.

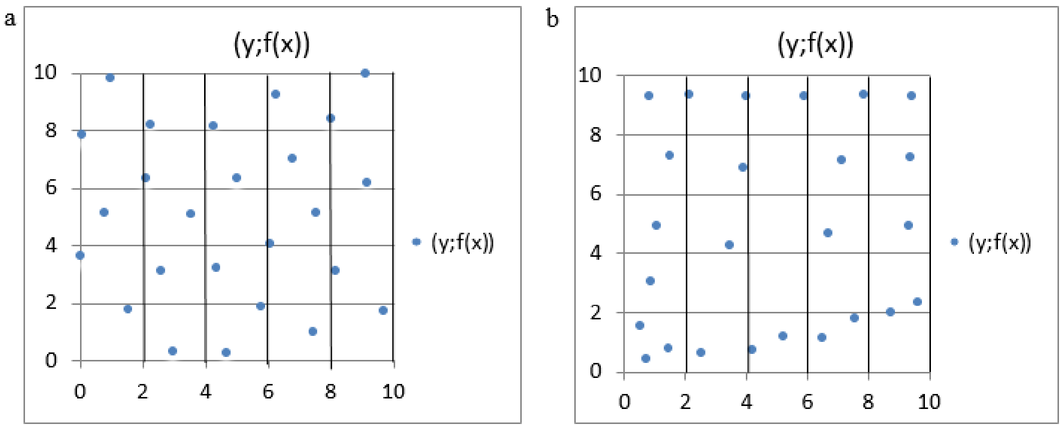

Fig. 6. (a) Calculation method "Wallpaper"; (b) Calculation method "Mirror".

We can see that calculation method “Wallpaper” has given a better result than “Mirror”. It must be noted that method “Wallpaper” is not completely realizable for all possible numbers of particles. It was empirically detected that if particle count is not optimal, the number of phantom rings must be increased to create a good experiment plan. Experiment plan obtaining method “Mirror” does not work efficiently enough. It was empirically detected that by changing the parameters of a particle, the particle can be centred in the square or “pushed” to the side of it. Implementation of “Mirror” must be improved.

7. Conclusion

Experiment plan obtaining method based on charged particle behaviour modelling was practically implemented. Implemented software is practically usable in conjunction with other methods.

Developed method was realized and approbated in the two dimensional case. It is easily usable also for larger count of dimensions. Method is also usable to create experimental plan for unevenly distributed particles. In this case charge of the particle must be defined as function of coordinates.

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