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Experiment Plan as a Discreet System Equilibrium State

Normunds Kante[1], Mykola Kryshchuk[2], Jurijs Lavendels[3]
[1, 3] *Riga Technical University, Latvia*
[2] *National Technical University of Ukraine (Kiev Polytechnic Institute), Ukraine*

***Abstract* – The method of obtaining the plan of experiments in multidimensional space is considered in the paper. The method is based on assumptions of uniform distribution of charged particles in infinite space. To obtain the plan of experiments, the infinite multidimensional space is replaced with a hypercube whose surface models influence 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.**

***Keywords* – Charged particle interaction, experiment plan, Latin hypercube.**

I. Introduction

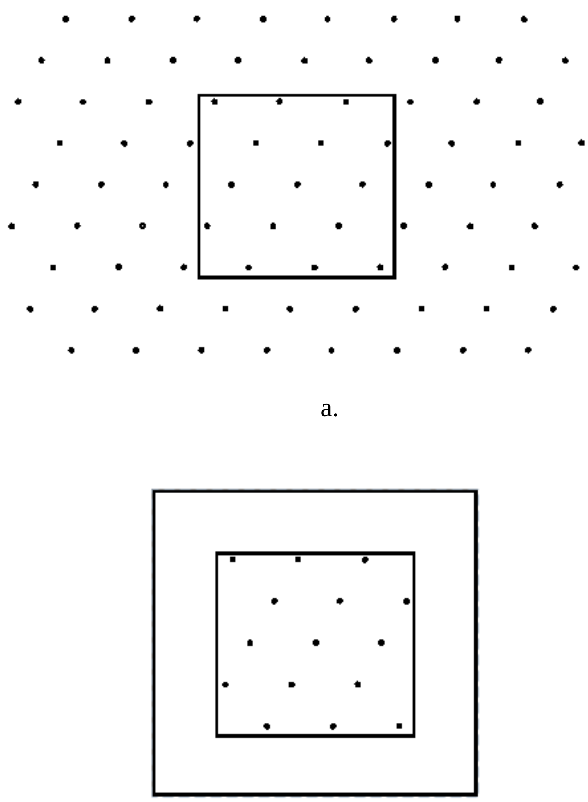
Computerised, mathematical modelling and metamodeling occupy increasingly important part in technical object and system development nowadays. Irreplaceable part of computerised modelling is an experiment plan [1].

Experiment plan obtaining is usually coordinated by using Latin hypercube methods [2] and [3]. Latin hypercube is often used to obtain an 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. Consequently, other approaches for obtaining experiment plan and computerised determination of discreet system's equilibrium state, which is analogous to experiment plan, are becoming increasingly topical [2]. In 1977, V. Eglājs suggested that charged particle coordinates in equilibrium state could be used as an experiment plan [4]. In this article, we discuss and compare two practicable alternative approaches for obtaining an experiment plan using charged particle equilibrium state in a discreet system.

II. Discreet System Equilibrium State and Experiment Plan Equivalence

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 either physically or 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. Figure 1 shows research schema for a two-dimensional (square) case.



a.

b.

Fig. 1. Substitution of infinite space with a model of a finite size.

a. Square as a fragment of an infinite two-dimensional space.
b. Square and its perimeter area as replacement of the infinite two-dimensional space.

Replacing infinite space with square creates a 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 (Fig. 1 a).
- Mirror – part of the space, which does not allow charged particles to leave the space, which is restricted. by the square (Fig. 1 b.).

III. Determination of Discreet System Equilibrium State

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

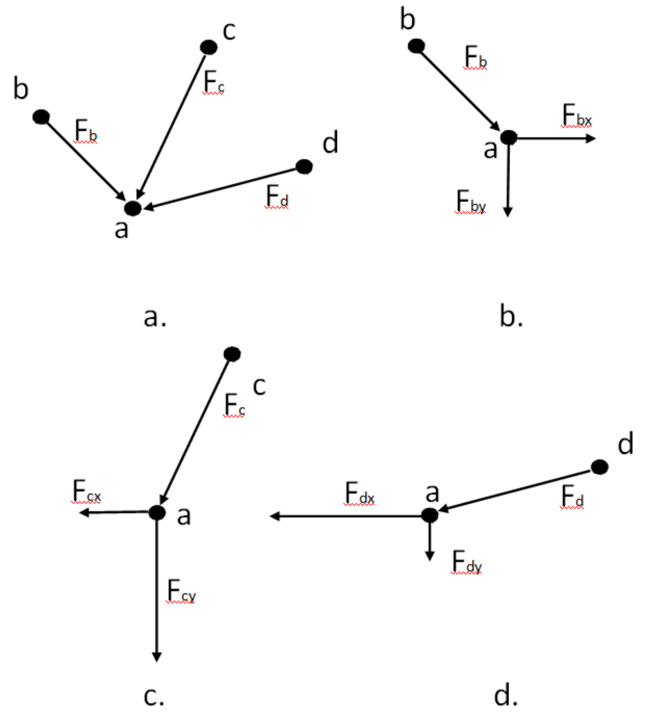


Fig. 2. Finding the equilibrium state of a charged particle.

To determine the location where particle should be moved to, we need to find the following for particle **a**:

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

$$F_x = F_{bx} + F_{cx} + F_{dx} \quad (1)$$

- Cumulative force F_y which is affecting the particle

$$F_y = F_{by} + F_{cy} + F_{dy} \quad (2)$$

- Collective force F which is affecting the particle

$$F = \sqrt{F_x^2 + F_y^2} \quad (3)$$

- Primary displacement of the particle

$$F_{ai} = C\frac{1}{r_{ai}^2}\text{, where} \quad (4)$$

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 (Fig. 3).

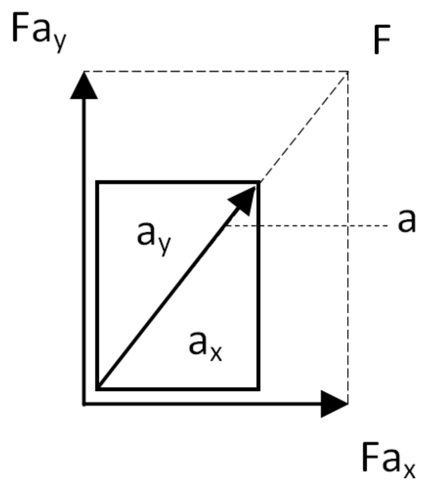


Fig. 3. Determination of displacement a_x and a_y

$$\frac{F_{ax}}{F} = \frac{a_x}{a} \quad (5)$$

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

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.

IV. Infinite Schema Replacement Method "Wallpapers"

A square that contains a certain number of particles is isolated. 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.

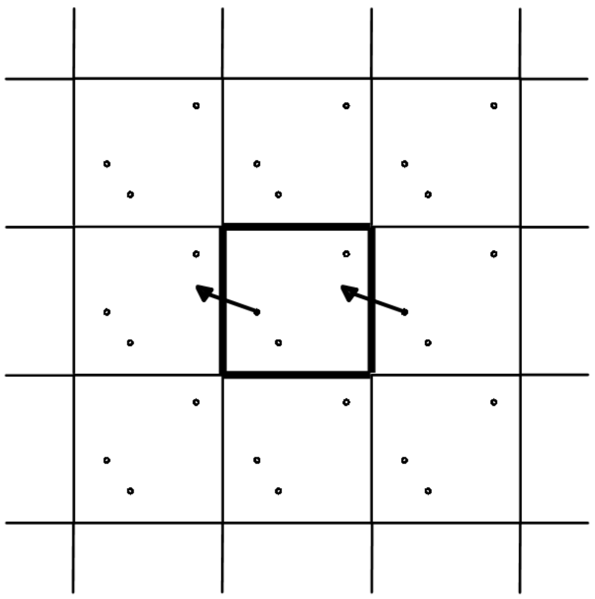


Fig. 4. Replacement method "Wallpapers".

Any displacement of a particle means that all corresponding particles also move the same distance in the same direction at 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. Figure 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.

V. Infinite Schema Replacement Method "Mirror"

A square is isolated, which contains a certain number of charged particles. The major problem in this method is not to let the 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 to leave the calculation area as shown in Fig. 5.

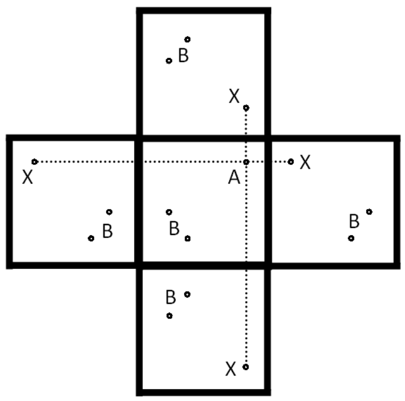


Fig. 5. Replacement method "Mirror".

A – Particle whose displacement is being calculated.

X – Mirror images of particle *A* that do not allow particle *A* to leave the calculation area.

B – Another particles that are not used in calculation.

VI. Practical Results

The described methodology was practically implemented. Calculations were carried out according to the practical experiment plan. The results are shown in Figs. 6 and 7.

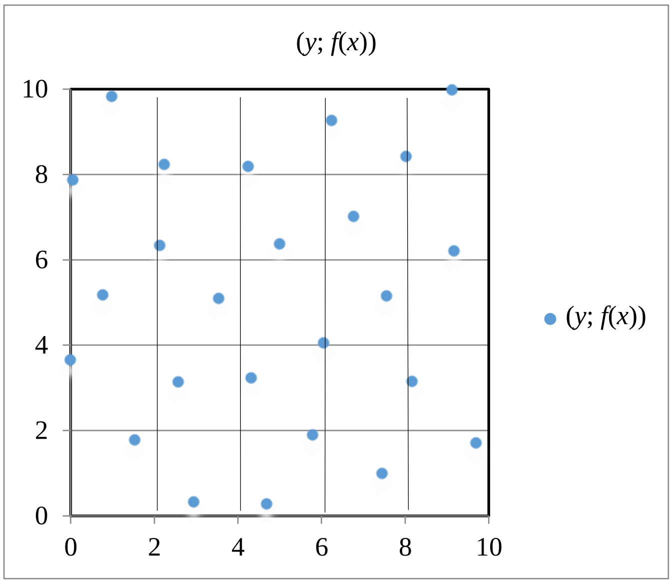


Fig. 6. Calculation result example of replacement method "Wallpapers".

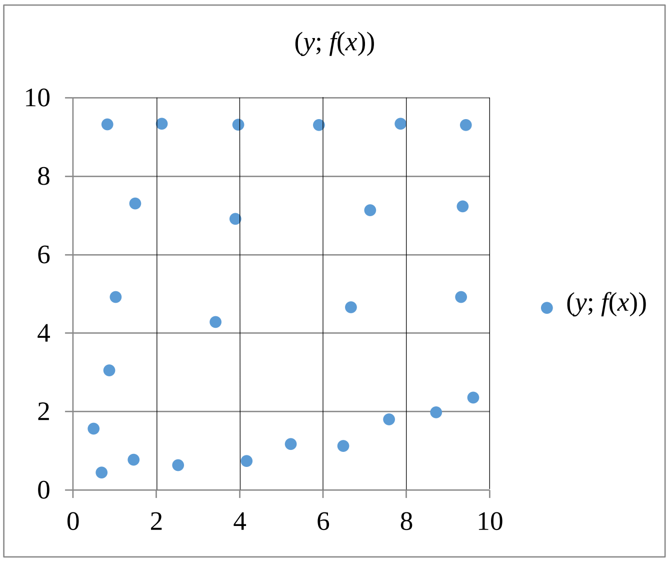


Fig. 7. Calculation result example of replacement method "Mirror".

We can see that the calculation method "Wallpapers" has given a better result than "Mirror". It should be noted that the method "Wallpapers" is not completely realisable for all possible numbers of particles. It was empirically detected that if particle count was not optimal, the number of phantom rings should be increased to create an appropriate 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” should be improved.

VII. Conclusion

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

The developed method was realised and approbated in the two-dimensional case. It is also easily applied to a larger number of dimensions.

The method can also be used to create an experimental plan for unevenly distributed particles. In this case, charge of the particle should be defined as a function of coordinates.

The obtained results are interesting and the work should be continued.

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Normunds Kante received B. sc. ing. degree in 2015 from Riga Technical University (RTU), Faculty of Computer Science and Information Technology. At present, he is the 2nd-year student of the Master study programme “Computer Systems”. His current research interests include experiment plan obtaining methods in discrete systems.
E-mail: normunds.kante@rtu.lv

Mykola Kryshchuk holds Dr. sc. ing. degree. He is a Professor at the National Technical University of Ukraine, Department of Automation and Control in Technical Systems. His current research interests include computation methods for simulation processes in solid objects.
Address: 37 Prospect Peremogy, Kiev 03056, Ukraine
Telephone: +(38) (044) 2366913.
E-mail: krys@ukr.net

Jurijs Lavendels holds Dr. sc. ing. degree. He is a Professor at Riga Technical University. His current research interests include computation methods with discretisation and algebraisation for design and modelling of physical processes.
E-mail: jurijs.lavendels@rtu.lv