Expert System Design of Two Electrostatic Lenses Column by Mixing Dynamic Programming and AI Techniques

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Abstract

This paper have shown an expert system design by using optimization methods for the Focused ion beam FIB optical system, by mixing the dynamic programming procedure and artificial intelligence technique to build an intelligent agent. CADION ANALYZER has been designed as an interpretation expert system, written in Java expert system shell (JESS) and Visual Basic.Net for optimizing and analyzing calculation processes for two electrostatic lenses column. By using such rule based engine, the optimized axial potential distributions for electrostatic fields undergo the constraints have been used in the two – lens optical column setup FIB.

Keywords: Fuzzy Logic Expert System, Software Engineering, Smart Systems, Artificial Intelligence, Ion Microscopes

1. Introduction

The increasing demand for smaller structures for fundamental physics research as well as for faster and higher density electronic circuits pushed the fabrication technology in recent years to dimensions in the nanometer-scale region. For the fabrication of structures with extremely small details both pattern definition and pattern transfer play a crucial role. The ion-beam lithography system is widely used for the pattern definition [1]. As will be shown in the present work, a simulation and optimization procedure have used to design lenses with relatively large overall dimensions of the order of a few millimeters and medium resolution of the order of (30 – 100) nm. It is aimed for finding the potential distribution that minimizes the aberration integral, at the same time satisfying the differential equation of the paraxial rays, also the constraints imposed by practical requirements.

In the present procedure, a database was established to provide storage and retrieval of calculated optical properties (i.e. spherical and chromatic aberration coefficients) to optimize potential distributions (for electrostatic lenses) according to dynamic programming procedure mixed with an expert system, which has been built according to artificial intelligence technique rule-based system. It maintains a collection of knowledge nuggets called facts. This collection is known as the knowledge base, which is our relational database. By using a Jess (i.e. Java Expert System Shell) programming language and a class modules in VB.Net **[2, 3]**, the present work expert system has been created and setting up the user interface.

Our rule based expert system written in Jess is a data-driven program where the facts are the data stored in our knowledge base that stimulate execution via the inference engine. This engine decides which rules should be executed and when. Therefore, the present expert system automatically performs the field calculation and ray tracing, depending to the stored data base (i.e. jess knowledge base) and the following two factors:

1. The facts of the function to be analyzed (i.e. electrostatic potential distribution).
2. The rule of dynamic programming procedure solutions, which obey the constraints.

The subroutines comprise of our full package (CADION) which is stand for (Computer Aided Design for ION system) has described as a class module program written in jess and visual basic .net ,where designed as one simulator as follows:

a- Accomplished program for the fourth order **Runge –Kutta** method, also this is used for computing trajectories when the initial conditions are given. The full details and outputs are given in a tabulated form (set of data) inside the PC stored as one database.

b- Accomplished program to analyze all set of stored data, such a program is called (**CADION ANALYZER**"**SMART SYSTEM**"), it analyses all optimized field distributions (i.e. electrostatic fields), and it has an ability to select the best formulae fitted to the optimization procedure (i.e. dynamic programming).This analyzer is involving both techniques (artificial intelligence and dynamic programming),also it has a search engine depending on the SQL statements (i.e. SELECT statement).The programming language is used classified into two categories: [1.JESS – "java expert system shell "and" 2.visual basic .Net" as it to make the user interface], also this program is a rule based expert engine and SQL server connector for the expert system used.

c- Accomplished program for computing spherical and chromatic aberration coefficients, this is done by using **Simpson's rule** integration method.

d- Accomplished program to draw both (2 & 3 Dimensions) all kind of inputs as optimized field distributions (presented electrostatic fields).

e- Accomplished program to fit the data according to the least square fitting method.

f- Accomplished program to convert and read all outputs into another application, Visual Basic Application programs as an Excel sheets were used in this investigation. This program has a search engine to facilitate work with multi formulae that could be stored in the CADION **Analyzer** database.

g- Accomplished program to calculate and plot all outputs into another GUIs, aberration spot size diagrams were plotted and analyzed in this investigation.

The spherical and chromatic aberration coefficients have been calculated within the CADION simulations, which gives the main indications for building the electrodes design of each model. Different cases of electrostatic lenses have investigated in this work. Many factors and variables have to be calculated to make sure any of results among the others were corrected. Those factors have used optimizing process supported by artificial intelligence technique. So that, considerable amount of errors have obtained were neglected in the accumulation of data. Obviously, most of the formulae were optimized in the CADION simulator subroutines. To make fitted comparisons, a well known and more updating simulator, **SIMION** software package primarily used to calculate electric fields and the trajectories of charged particles in those fields when given a configuration of electrodes with voltages and particle initial conditions has been used for importing data resulted by CADION stored database to computerized manipulation the precise results. Adding that plotting and configuring the electrostatic lenses electrodes in three dimension profiles. Figure 1 is shown the schematic diagram and the optimization steps of this investigation.

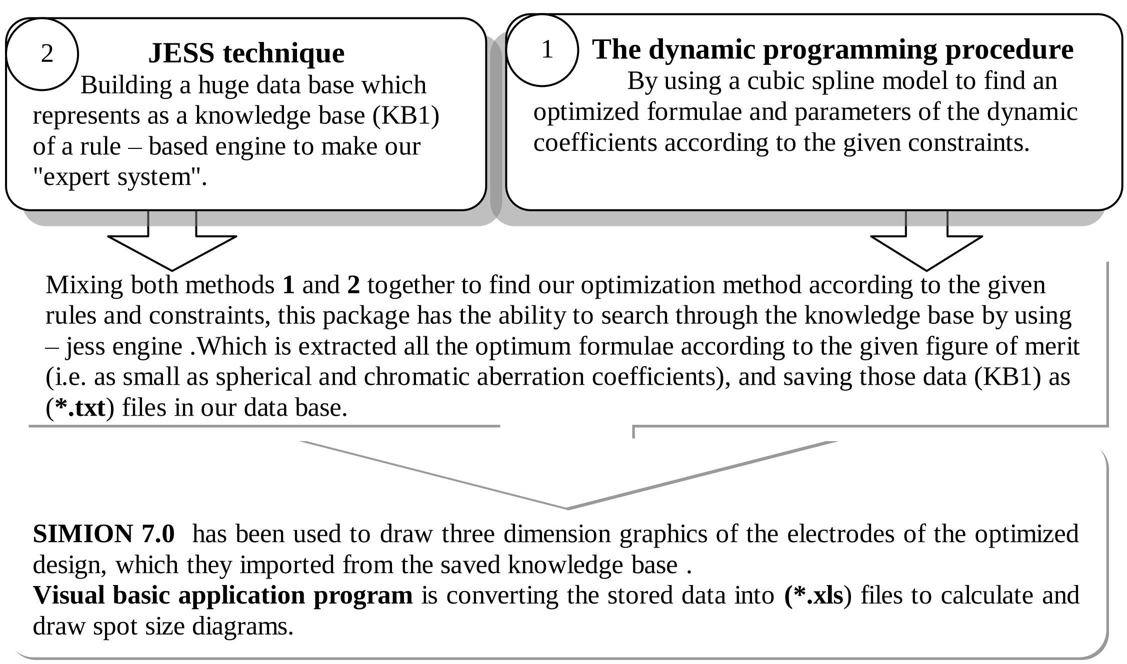


Figure 1. Shows the schematic diagram of the present work

In 1990's symbolic computing has become a promising aid in different kinds of decision making and building expert systems. These were the first attempts in this technique, programs are appearing that are able to deduce rules from a database without actually carrying out numerous amounts of numerical calculations [4].Present software (CADION) has adopted this technique with the aid of dynamic programming procedure, in order to maintain such smart database (i.e. expert system); the system contains database tables impeded inside the subroutines. Focused ion beam setup design needs to create by using full computational package to be smart for getting the configurations and parameter calculations likewise. Figure 2 is shown the present software flowing data diagram and its subroutines.

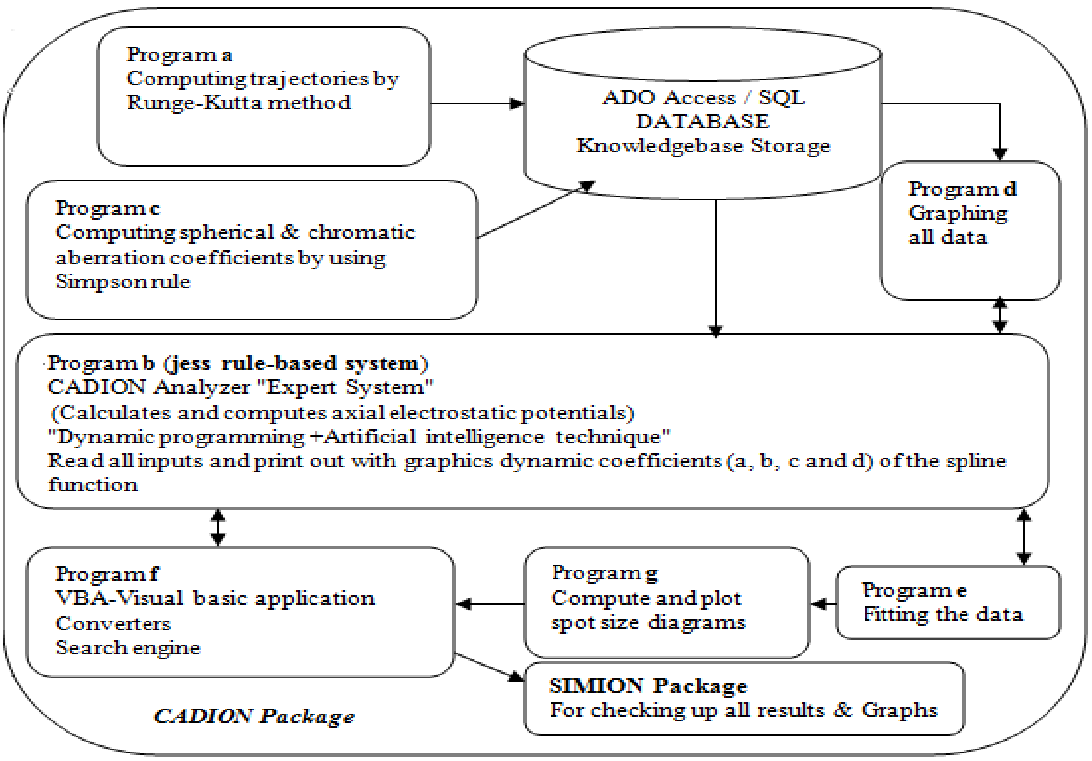


Figure 2. Represents the schematic data flowing diagram of the present software (CADION)

In recent years, most of researchers have interested in optimizing optical instruments and devices as a nano scale devices. Also, they attempted the design and optimization of electron lenses and systems according to the analysis method with the aid of computer programs. Also, symbolic computing has become a promising aid in different kinds of decision making .Expert systems that have built in knowledge in the form of symbolically represented facts and rules. **Steve et al** described a novel method of determining potentially successful starting designs by utilizing expert systems algorithm which operates on a database of previously well-designed optical systems **[5]**.Also, **Xiaogang Chen et al** developed a small expert system used in lens design **[6]**.

According to **Szilagyi**, who introduced the dynamic programming approach **[7]**, and more recently to **Ahmad et al** which have introduced a computer aided design of an electrostatic FIB system consisting of three electrostatic lenses, approximated by the spline lens model **[8]**. Our rule-based has been used in the present procedure (i.e. jess rule based) is the typical dynamic programming recursive formulation as **[9]**:

$$F_n\,(n, s, x) = g\,|R\,(n, s, x),\, F^*_{n-1}(s')| \qquad (1)$$

where n is an integer denoting the stage of the problem, s is an integer denoting the state of the system at n, s' is an integer denoting the state of the system at stage n-1 resulting from the decision x, x is the decision being evaluated at stage n , R(n,s,x) is the immediate return associated with making decision x at stage n when the state of the system is s , F*n-1(s') is the return associated with an optimal sequence of the decision at stage n-1 when the state is s' and g is the minimal function. Figure 3 shows the computational grid for the dynamic programming procedure with the aid of artificial intelligence technique. It defined the domain of existence of the solution for the sought distribution function E (z) (i.e. electrostatic field).

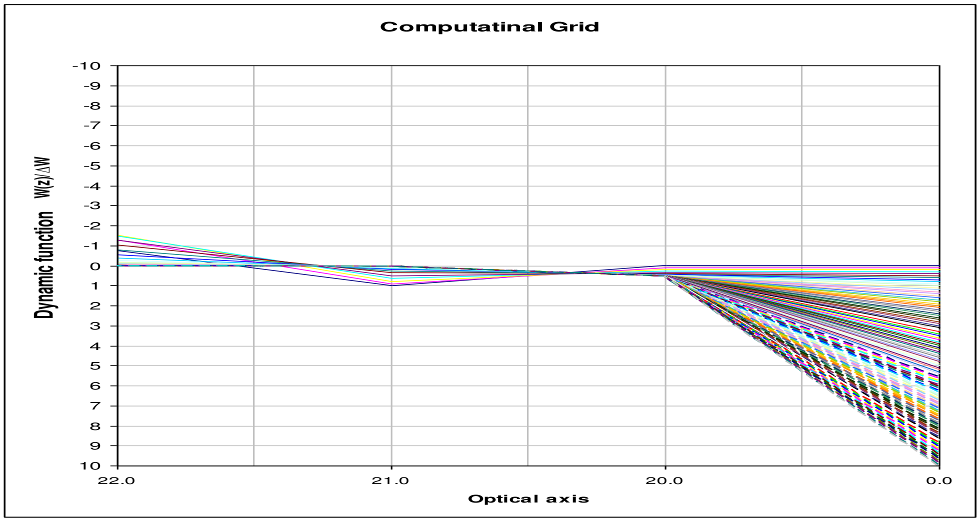


Figure 3. Represents computational grid of the dynamic programming procedure with the aid of artificial intelligence technique for electrostatic lenses defined over twenty intervals

2. Electrostatic lenses

Four types of the optimum axial potential distributions with its first derivative for the electrostatic lenses have been determined by using the dynamic programming procedure and artificial intelligence technique operated with the acceleration and deceleration modes depending on the constraints, which are shown in figures 4, 5, 6 and 7.Table 1 has given the optimized formulae and their dynamic parameters according to our rule based CADION ANALYZER (i.e. program "b") as in equation (1).

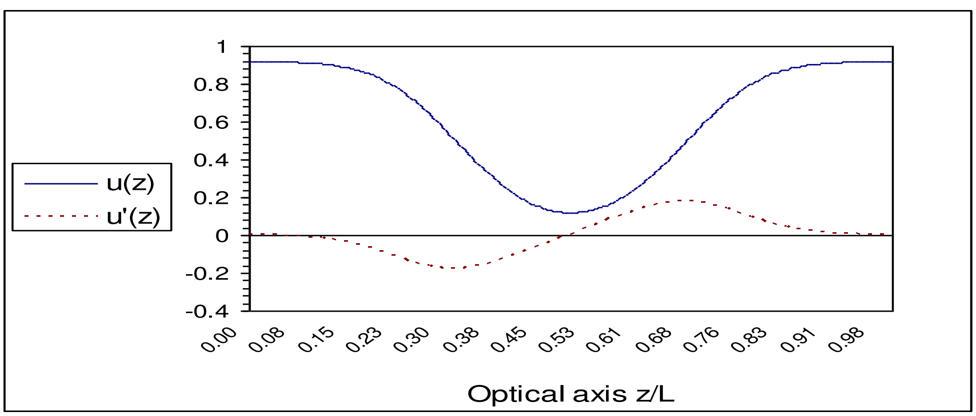


Figure 4. The optimum axial potential distribution and its first derivative u(z) and u'(z) respectively for unipotential lens (1) operated in deceleration mode

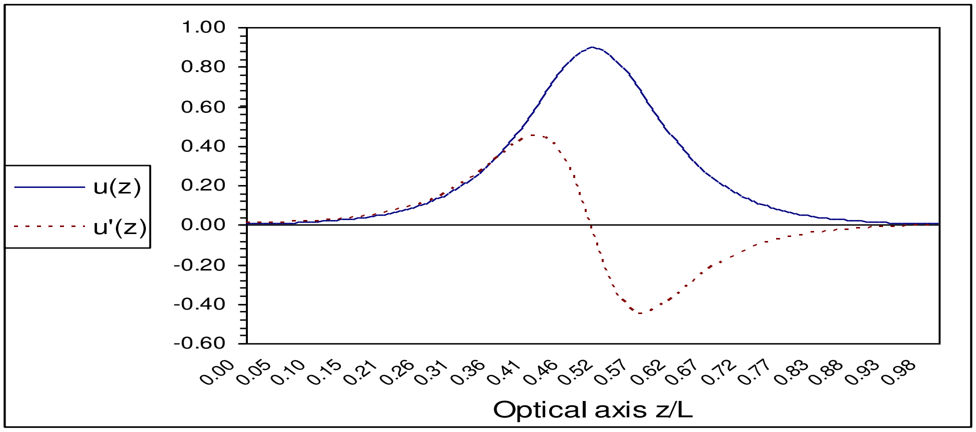


Figure 5. The optimum axial potential distribution and its first derivative u(z) and u'(z) respectively for unipotential lens (2) operated in acceleration mode

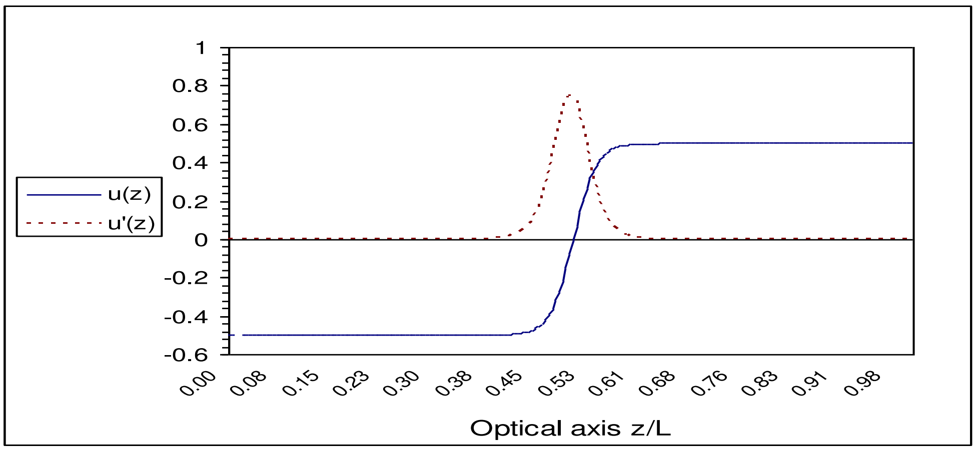


Figure 6. The optimum axial potential distribution and its first derivative u(z) and u'(z) respectively for immersion lens

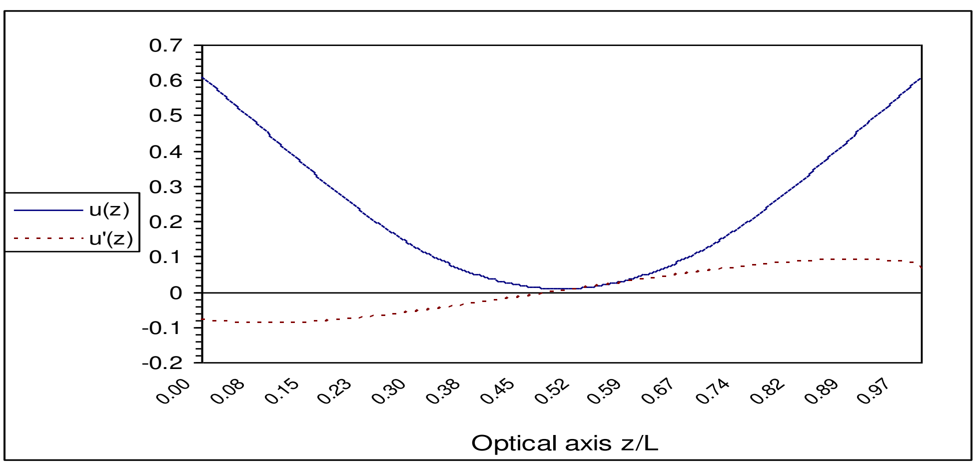


Figure 7. The optimum axial potential distribution and its first derivative u(z) and u'(z) respectively for diaphragm lens

Table 1. The optimized axial potential distributions with their dynamic parameters of the given electrostatic lenses.

Lens Type	Optimized Axial Potential Distribution Formula	Dynamic Parameters			
		a	b	c	d
unipotential lens (1)	a*tanh (b*z^c) +d	80	0.04	2	12
unipotential lens (2)	a*exp (-b*z^c)/cosh(z-d)	0.9	3	5	0
immersion lens	a*tanh(b*z^c)+d	0.5	1.5	1	0
diaphragm lens	a*tanh (b*z^c) +d	0.9	0.008	2	0.01

3. Two – lenses Column FIB (Focused Ion Beam) Setup

Demagnification of the beam size in the image plane is one of the most requirements of focused ion beam, which should be associated with low aberrations. The ion beam system consisting of two - lens system forming two collimated beams is taken the following setup as a result of present work rule based engine CADION ANALYZER of the following ion trajectories are shown in figures 8 and 9, respectively.FIB setup is taken the following lenses of Table 1 and show the electrodes configuration plotted in three dimensions by using SIMION 7.0 simulator of the two ion beam columns, respectively as follows:

1. Unipotential lens (1) **[einzel lens]** is operated under infinite magnification condition – immersion lens is operated under zero magnification condition as in Figure 10.

2. Diaphragm lens is operated under infinite magnification condition – immersion lens is operated under zero magnification condition as in Figure 11.

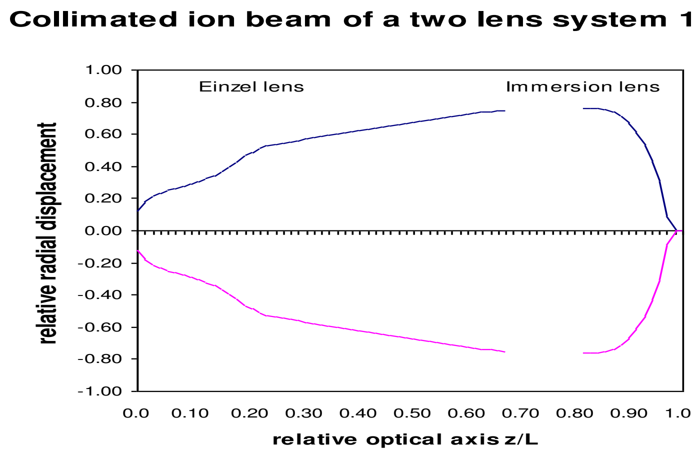


Figure 8. The ion beam trajectory for a two-lens system (1)

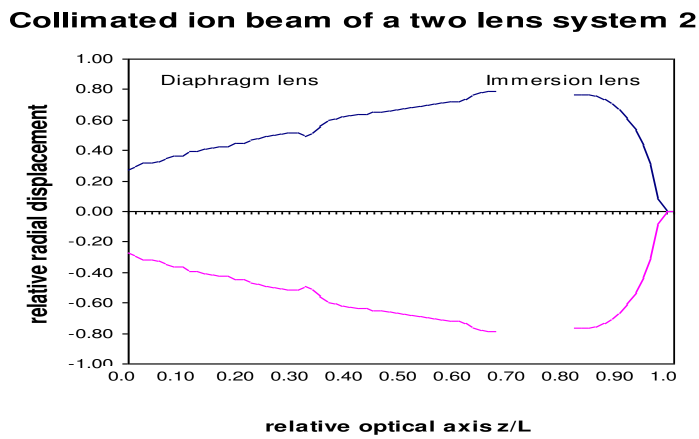


Figure 9. The ion beam trajectory for a two-lens system (2)

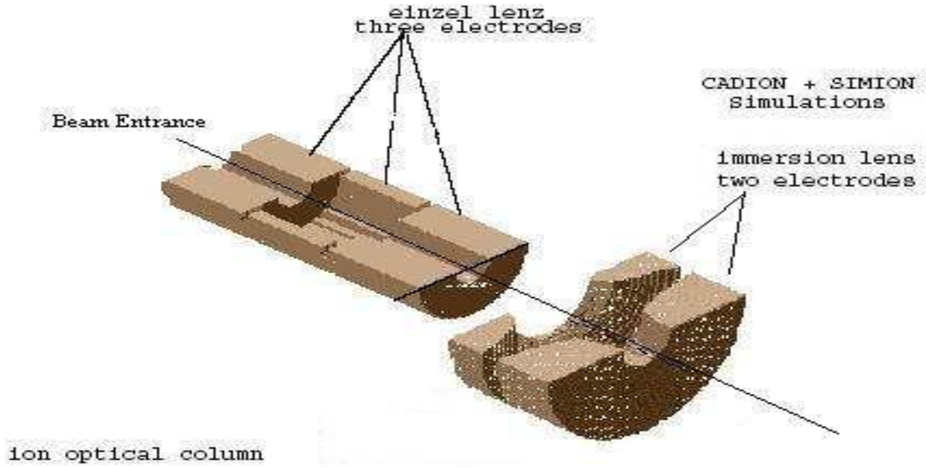


Figure 10. The electrodes configuration for a two-lens system (1) with collimated beam between focusing elements

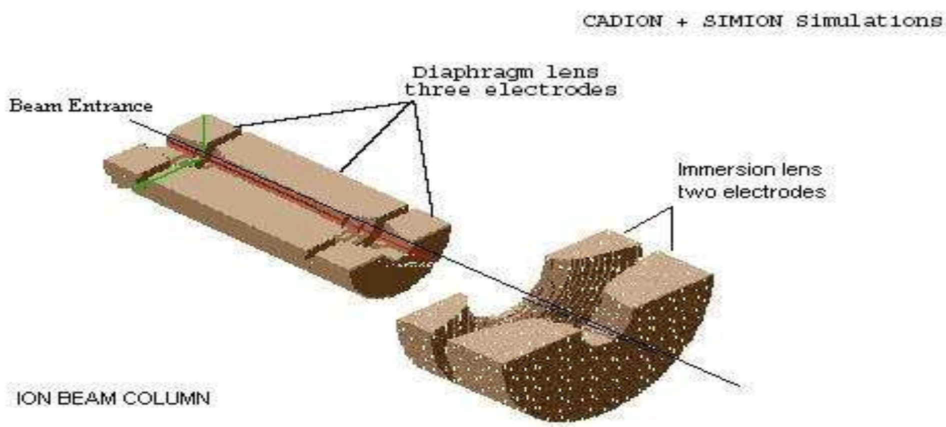
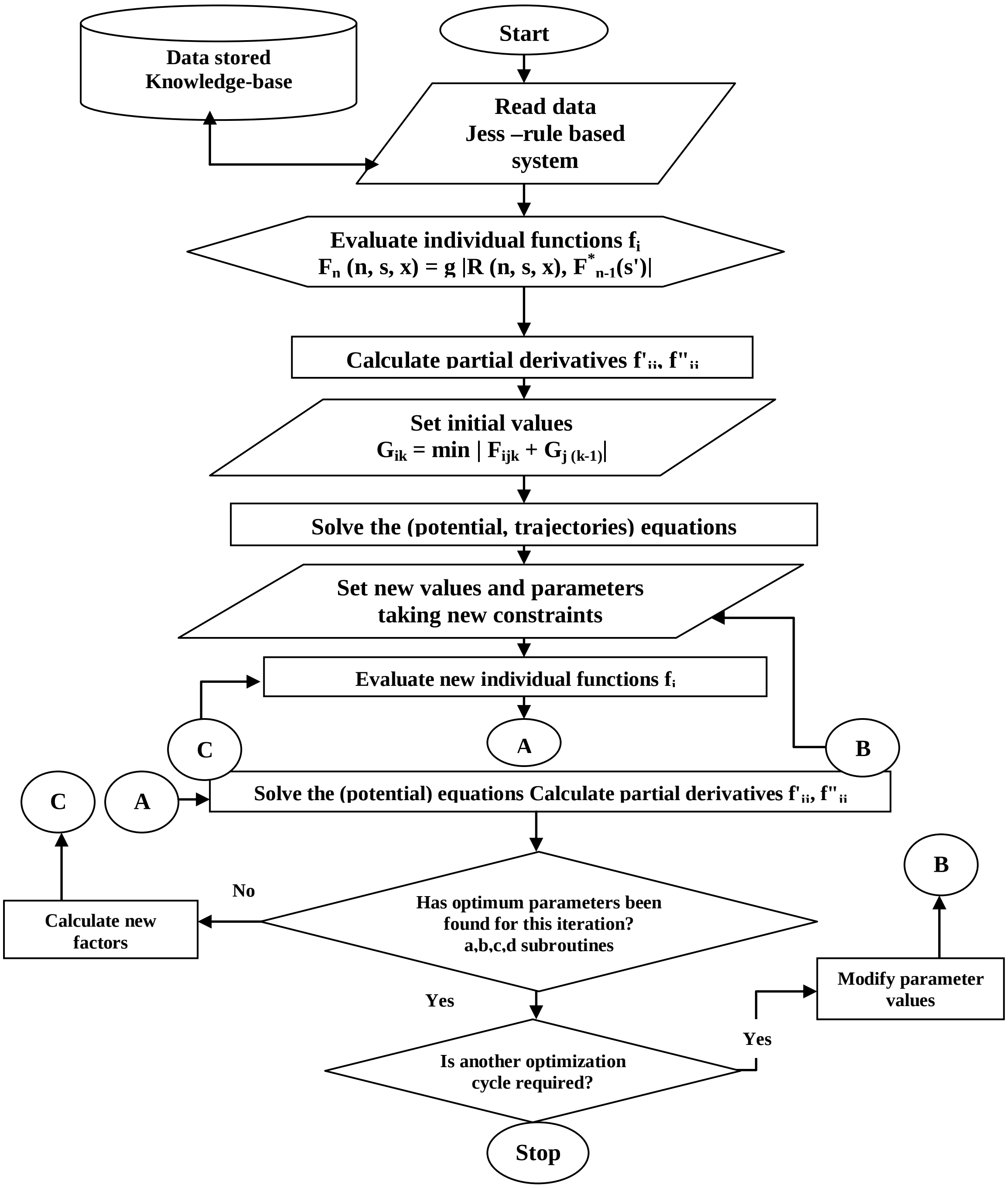


Figure 11. The electrodes configuration for a two-lens system (2) with collimated beam between focusing elements

4. The present work flowchart of the expert system “CADION analyzer”

The program CADION Analyzer is the main significant optimizer" the present expert system"; the steps are configured as included in the following flowchart:



5. Conclusion

The present investigation has clearly adopted a combined optimization procedures by adding the dynamic programming procedure and the artificial intelligence technique, which were mixed together for finding a smart simulator, packed in one program (i.e. expert system). This computational work was made to get CADION package. The present rule based expert system is the CADION ANALYZER (i.e. program"b"), which it comprise the facts of our calculations, and our results have been obtained according to this rule based system.

6. Acknowledgement

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7. References

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