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Quasi-self-similarity for laser-plasma interactions modelled with fuzzy scaling and genetic algorithms

Danilo Rastovic
Control Systems Group
Nehajska 62, 10110 Zagreb, Croatia

1. Introduction

We use the methods of fuzzy fractals description and genetic algorithms for laser-plasma interactions. We work with reduced fractals. The optimization of laser beams and target modelling could be obtained by the methods of artificial intelligence as in a tokamak physics. Normally, the expression for Vlasov equation is different than it is in the case of tokamak. The differences are also true for appropriate Maxwell equations because the design is different. The applications of Vlasov-Maxwell equations in the case of inertial confinement fusion are already done by many authors. We shall find with fractal theory the main directions of particles movements and on such a way we will be able to calculate appropriate stochastic differential equations.

An energy source based on inertial fusion has several inherent advantages:

- the underlying target physics can be established on a single shot basis using existing or soon to be completed facilities.

- most, if not all, of the fusion nuclear science and technology can be developed and demonstrated on one repetitively pulsed facility. This includes the target physics, the driver/final optics, the target fabrication and injection, materials and components, and the chamber architecture (Dean, 2008).

By 2010-2012, we should be poised to take full advantage of National Ignition Facility (NIF) ignition with proposals for credible designs of such advanced targets that could be fielded on later phases of NIF.

NIF could also pre-qualify beam injection, tracking, beam slewing requirements for such targets. It might also entertain the fielding and igniting of targets in „burst-mode“, e.g., several targets injected on the fly at a few Hz. This would complement the target injection efforts planned by the high average power laser program on smaller high-rep laser systems.

The objective of the work is to give possibility of applications of the methods of artificial intelligence (fuzzy sets and logic, genetic algorithms) and fractals theory to get better understanding of inertial confinement fusion.

In the theory, the self-similarity of fractals is always an infinite process. But, in practice, as we shall see, this process must be stopped after finite time of steps. Then such a process we call quasi-self-similarity. The second novelty is that in nature, the self-similarity is generally non-symmetric, and it can be described inside the fuzzy sets and systems theory. On such a case each individual object, process etc. has the properties of originality. New is also the applications of fuzzy scaling on partial differential equations that describe the complexity of plasma behaviour .

2. Laser-plasma interactions

NIF's first four beams were fired into various-sided gold-plated cylinders known as hohlraums, only a few millimeters long. This was a very clear demonstration that NIF is indeed on the path toward ignition. It has been shown analytically that plasma filling by hohlraum wall ablation imposes an upper bound to hohlraum X-ray production. Current simulations indicate that hohlraums used in inertial confinement fusion (ICF) are optimized to drive a fusion capsule to ignition before reaching the x-ray production limits (Dewald et al., 2005).

In the future NIF ignition experiments, the deuterium-tritium fuel capsule will be placed inside a larger hohlraum. All 192 NIF laser beams will heat the interior of the hohlraum, creating x-rays that ablate (burn off) and implode the capsule to ignition. Although the beams of high-power ultraviolet laser light only lasted a maximum of nine nanoseconds, that's considered long to ignition researches.

The Laser MegaJoule and the NIF are mainly designed for indirect drive thermonuclear fusion. Their beam configuration are optimized for x-ray drive. New studies were proposed to employ the x-ray drive configuration for direct-drive fusion. All have focused on irradiation uniformity which is a key parameter for direct-drive and its optimization has been proposed by repointing the beams and by using different pulse shapes. A new solution for high-gains direct-drive fusion with the indirect drive beam irradiation of Laser MegaJoule is presented in the paper (Canaud et al.,2007). Sources of asymmetry are due to facility imperfections such as power imbalance or pointing errors.

By focusing an enormous 1.8 megajoules of energy on a pellet of deuterium-tritium fuel a couple of millimetres in diameter, in a pulse lasting only three nanoseconds, the NIF should make the pellet implode, causing centre to „ignite“ in a brief, selfsustaining fusion reaction. Fusion in the pellet could be induced either directly, by placing it in a cylindrical target, or hohlraum, about one centimetre long, and using laser pulse to induce x-rays from the hohlraum which would compress the pellet. Even short of ignition, laser experiments such as the NIF cause some fusion in their targets.

3. The role of fractals theory and fuzzy scaling for ICF design

Quite broadly in ICF design and theory, a salient role has been played by the class of solutions characterized by self-similarity. The similarity property has the highly convenient effect of reducing systems of partial differential equations depending on both space and time variables into ordinary differential equations depending on only a single self-similar variable. In ICF there exist self-similar implosions which transform uniform density solid spheres into uniform density solid spheres of arbitrarily high density.

Any practical ICF implosion begins from an initial shock. There is the inevitably non self-similar character of the flow during the transition period between the (non-self-similar) initial conditions and the (self-similar) asymptotic state. High aspect ratio implosions are the most prone to deviating from self-similarity and stagnating in a non-isochoric configuration. A balance must evidently be struck between competing objectives. The degree of target robustness to deviations in pulse shaping is typical of self-similar implosions (Clark & Tabak, 2007). In this situation are formed different kinds and shapes of fractals.

With over 50 times more energy than present facilities and the ability to produce ignition, NIF will explore new physics regimes. Ignition will allow even larger-parameter space to be accessed as well as new experimental capabilities like high flux neutron experiments. The facility contains a 192-beam Nd-glass laser system that will produce 1.8 MJ, 500 TW of 351-nm light for target experiments (Moses et al., 2008). Some experiments study the effects of microstructure in beryllium and high-density carbon on shock propagation in capsule ablaters. Target design efforts continue to study diagnostic signatures in simulated experiments. One result of these studies is understanding the importance of Advanced Radiographic Capability to take high-energy x-ray radiographs of the imploding core for ignition experiments. There are a series of images of an imploding capsule with an imposed asymmetry on the x-ray drive flux. Ignition experiments have stringent requirements for laser energy, power, stability and beam conditioning.

To obtain ignition at ICF laser facilities requires an energetically efficient compression of deuterium and tritium fuel. Ideally this compression should be spherical. However, the cylindrical hohlraum and temporal profiles of the required laser shocks, due to thermodynamic and hydrodynamic constraints, cause the fuel configuration at peak compression to vary. Studies have shown this variation can depend on laser drive conditions and deviate significantly from a sphere. Neutron imaging can be useful diagnostics for determining the nature of the drive conditions (Grim et al., 2008).

Since commercially available metrology equipment is not ideally suited for certifying meso-scale capsules, several unique characterization tools have been developed. This include a very sensitive x-ray transmission radiography system for monitoring the uniformity of these coatings, and quantitative analysis methods for analysing radiographs which allow verification of the distribution (Rastovic, 2005).

One can view the Boltzmann and Vlasov-Poisson-Fokker-Planck(VFPF) equations as providing complementary physics since they both succeed and fail in complementary regimes. The Boltzmann equation gets the short distance physics correct, while the (VFPF) equation captures the long-distance physics (Rastovic, 2008).

In addition to refraction by density gradients, a variety of parametric instabilities exist that convert laser energy into internal plasma waves and scattered electromagnetic waves. Since the irradiation of the fuel pellet requires symmetry for proper implosion and since stray laser light can damage optical systems, understanding the laser-plasma interaction is of critical importance in ICF experiments. For full simulation of ignition-scale geometries and times, it is impractical to use traditional Particle-In-Cell methods (Hittinger & Dorr, 2006).

The change in grid resolution the collar grid requires a nonuniform differencing stencil in the composite grid cells adjacent to the interface.

Within the hohlraum target of indirect drive ICF experiments, the plasma does not have a uniform composition. The fractal picture of the plasma can be obtained if we consider a plasma with N distinct material regions, i.e. as multifluid model.

Piecewise linear reconstruction on these predicted cell-centered values produces approximate predicted values at the cell interfaces. A fluid plasma model consists of a system of mass, momentum, and energy equations for each electron and ion species, coupled through a Lorentz force term to Maxwell's equations. Nevertheless, due to the wide range of spatial and temporal scales, computational laser-plasma interactions is still in need of major algorithmic improvements, in order to simulate routinely at NIF-relevant scales.

4. Computational models of inertial confinement

We observe the development of the Rayleigh-Taylor (RT) instability whenever two fluids of different densities are accelerated against the density gradient. The unsteady anisotropic and inhomogeneous turbulent process is a fundamental problem in fluid dynamics.

The model of collisionless plasmas especially in the applied contexts of controlled fusion, and of laser fusion, is a highly idealized one. A way to incorporate collisional effects of a plasma with the background material (e.g. a plasma system in a thermal bath or reservoir) is to consider the motion of an individual particle as Brownian motion caused by collisions with the background medium.

A multi-level approach on the construction of effective partitioning of unstructured graphs used in parallel computations is described. The quality of partitioning is estimated by its using in parallel iterative solution of large sparse linear systems arising in discretization of partial differential equations on unstructured grid. Various algorithms of balancing under certain constraints are considered.

Since the nineteenth century, when Boltzmann formalized the concepts of kinetic equations, their range of application has been considerably extended. They are now used also in plasma physics. They all are characterized by a density function that satisfies a partial differential equation in the phase space. Possible singularities of the solution (shock waves for instance) make the chain rule no longer available. Regularity of the solution can be proved using tools as averaging lemmas.

When considering so-called microscopic quantities one discovers that the problem undergoes really complex dynamics. The most noticeable general result is the regularization by averaging on velocities which states that for $f(0)$ element of Lebesgue p integrable functions with bounded support in v , macroscopic quantities belong to Sobolev or Besov spaces with positive numbers of derivatives.

The precise gain in regularity, and not only compactness, can be useful for regularity questions. This appears for instance in the topic of nondegenerate hyperbolic scalar balance law, where the kinetic formulation provides a method for proving regularizing effects. Historical progress in the mathematical theory of the Boltzmann equation has been the theory of Di Perna and Lions which proves global existence of weak solutions (so-called

renormalized solutions) in the physical space, i.e. using only a priori estimates. If there is a strong solution, then the normalized solution is unique.

State sensitivities are partial derivatives describing how the state of a system changes when a design parameter is perturbed. In the context of fluid flows, these states are velocity, pressure, turbulence variables, etc. which are known approximately by a numerical solution of partial differential equations. The continuity sensitivity equation (CSE) is a natural approach to take when using adaptive methods and is useful for developing general purpose software. Both the flow and sensitivity solutions are taken into account for mesh adaptation. If an adaptive mesh generation routine is used for the flow, then the CSE only needs to be computed on the finest mesh. This allows a better control of the sensitivity solution accuracy (Turgeon et al., 2001) .

5. Description of IFC with differential equations

A reduced 1D Vlasov-Maxwell system introduced recently in the physical literature for studying laser-plasma interaction is analyzed (Carrillo & Labrunie, 2006). The electrons move under the effect of an electric field E and magnetic field B . Then, their distribution function $f(t,x,v)$, where x denotes the position variable, is a solution to the Vlasov equation. To achieve a high gain in laser thermonuclear targets, deuterium-tritium fuel should be compressed 10000-100000 times with respect to its initial density. In practice, a 100% uniformity of irradiation is impossible due to nonuniform overlapping of the beams, nonuniform amplification in the laser path, and defects in laser amplification channels.

The fields E and B are the sum of three parts:

- a.) the self-consistent fields created by the electrons
- b.) the electromagnetic field of a laser wave which is sent into the medium(called the pump wave)
- c.) The electrostatic field $E(x)$ generated by a background of ions which are considered immobile during the time scale of the wave, and/or by an external, static confinement potential

The model of Vlasov equation and the two remaining Maxwell equations features a strongly nonlinear coupling between the kinetic and electromagnetic variables.

Two reduced models have been defined by physicist: a.) The nonrelativistic model (NR) approximates the relativistic dynamic by the Newtonian one. It is physically justified when the temperature is low enough. b.) the quasi-relativistic model (QR) is acceptable when the proportion of ultra-relativistic electrons is negligible and the pump intensity is moderate. An iterative procedure to solve the 1D Vlasov-Maxwell system for the NR and QR cases is presented.

In the paper (DiPerna & Lions, 1989) the Vlasov-Maxwell system in its classical and relativistic form is studied. The stability of solutions in weak topologies is proven and from this stability result the global existence of a weak solution with large initial data is deduced. The main tools consists of a new regularity result for velocity averages of solutions of some general linear transport equation.

We obtain compactness in $L(1)$ under some extra hypothesis on the initial data. We first recall a regularity result about the Vlasov-Poisson-Fokker-Planck (VPFP) system involving in additional control of entropy. From a probabilistic point of view, the Fokker-Planck equation characterizes the evolution of the probability mass density of particles in phase

space, if we consider the position $x(t)$ and the velocity of the particle $v(t)$ as random variables which satisfies the stochastic differential equation. The VPFP system appears when we consider a great deluge of mutually interacting particles which move in a Brownian way. We know that for initial data small enough and satisfying some suitable integrability conditions, global solutions exist. The plasma region is bordered by a shock. Therefore, to analyze the beam region we return to the Vlasov - Poisson problem and introduce different scalling assumptions (Degond et al., 2003).

We present a collision potential for the Vlasov-Poisson-Boltzmann (VPB) system near vacuum in plasma physics case. This potential measures the future possible collisions between charged particles with different velocities and satisfied a time-decay estimate. The purpose of the paper (Chae et al., 2006) is to study the large-time behaviour of the VPB system via the robust Lyapunov functional $D(f)$ measuring possible future collisions between particles. A generalized collision potential is constructed and the time-asymptotic equivalence between VPB system and linear Vlasov system is established.

In the paper (Carrillo & Toscani, 1998) is intended to study the rate of convergence of homogeneous solutions of the Vlasov-Fokker-Planck(VFP) equation. VFP equation describes a plasma in which the particle change only slightly their momentum during collision events. Assuming that the collision between heavy particles are negligible, the collisions with light particles by means of Brownian motion are approximated. The aim of this work is to study the rate of convergence of solutions. This result can be a first step to reach some results for the VFP system or the non-homogeneous case. It was done for VPFP system in the paper (Carpio, 1998). The VFP equation has been studied in the presence of a external confinant potential in [Bouchut & Dolbeault,1995] proving that the distribution of particles tend to the stationary distribution where in the expression the confinant external potential is also included. To achieve exponential decay, the smoothing effect of the Fokker-Planck term can be used.

The multiscale representation of a function can be compressed with a controlled approximation loss by setting to zero the details with an absolute values less than some given threshold depending on the level. We construct an adaptive mesh. When electromagnetic waves propagate through a plasma layer, they become parametrically unstable. Vlasov simulations provide an excellent description of the small scales of the phase-space mixing are saturated by the numerical dissipation of the numerical scheme. This category of models is motivated by the important problems of the nonlinear interaction of high intensity ultrashort laser pulses with plasmas, with specific application to particle acceleration or inertial confinement fusion purpose. Given the value of the function f at the mesh points at any given time step, we obtain the new value at mesh point. It is semi-Lagrangian Vlasov method.

The change in the fuzzy rule base is done using a variable-structure direct adaptive control algorithm to achieve the pre-defined control objectives. It has a good performance in the training phase as it makes use of initial rule base defined for the fuzzy logic stabilizer. It has a robust estimator since it depends on a variable structure technique. The adaptive nature of the new controller significantly reduces the rule base size and improves its performance.

In the paper (Besse et al., 2008) is presented a new method for the numerical solution of the relativistic Vlasov-Maxwell system on a phase-grid using an adaptive semi-Lagrangian

method. The multiscale expansion of the distribution function allows to get a sparse representation of the data. Interaction of relativistically strong laser pulses with overdense plasma slabs is investigated. Vlasov codes are powerful tools to study wave-particle interaction with interesting results for trapping and action transfer from particles and waves. Since non-linear kinetic effects are important in laser-plasma interaction, we choose a kinetic description for the plasma.

The algorithm is based on the conservation of the flux of particles, and the distribution function is reconstructed using various techniques that allow control of spurious oscillations or preservation of the positivity. Nonetheless they might be a first step toward more efficient adaptive solvers based on different ideas for the grid refinement or on more efficient implementation.

The main way to improve the efficiency of the adaptive method is to increase the local character in phase-space of the numerical scheme by considering multiscale reconstruction with more compact support and by replacing the semi-Lagrangian method with more local-in space-numerical scheme as compact finite difference schemes, discontinuous-Galerkin method or finite element residual schemes which are well suited for parallel domain decomposition techniques. To overcome the problem of global dependency, we decompose the domain into patches, each patch being devoted to a processor. One patch computes its own local cubic spline coefficients by solving reduced linear systems.

Thanks to a restrictive condition on the time step, the inter-processor communications are only done between adjacent processors, which enables us to obtain competitive results from a scalability point of view up to 64 processors. Parallelism is one of the underlying principles of the artificial neural networks. It is known that the neural networks training can be efficiently implemented on parallel computers.

6. Methods of artificial intelligence

Artificial neural networks (ANNs) are computational models implemented in software or specialized hardware devices that attempt to capture the behavioral and adaptive features of biological nervous systems. In order to solve computational or engineering problems with neural networks, learning algorithms are used to find suitable network parameters. At dissipative scales, where the fluid flow is differentiable, the phase-space density of particles is supported on a dynamically evolved fractal set. This attractor is characterized by a non-trivial multiscaling properties. Evolutionary algorithms provide an interesting alternative, or complement, to the commonly used learning algorithms, such as back-propagation. Instead of using a conventional learning algorithm, the characteristics of neural networks can be encoded in artificial genomes and evolved according to a performance criterion.

The evolutionary synthesis of a neural network leads to several design choices. Recent benchmark experiments with evolution strategies, which use a floating-point representation of the synaptic weights, have reported excellent performance with direct encoding of a small, fixed architecture. The topology of a neural network can significantly effect its ability to solve a problem. Direct encoding is typically applied to fixed network topologies, however, it can also be used to evolve the architecture of an ANN (Floreano et al., 2008). Hybrid approaches have attracted considerable attention in the Computational Intelligence community. One of the most popular approaches is the hybridization between fuzzy logic

and genetic algorithms (Herrera, 2008). It is all connected with the phenomena of adaptive behaviour.

Although much effort has been devoted to the fuzzy scaling factors in the past decades, there is still no effective solution. Most of the research works on fuzzy logic controllers have either neglected this issue by directly applying a set of scaling factors (Chopra et al., 2008). We shall apply it to the nonlinear Vlasov-Fokker-Planck equation. The advantage of using the description with IF-AND-THEN rules for VPFP equations is obtaining the possibility for description of anisotropic turbulence. Genetic algorithms can additionally help when there are problems with delays. Theoretical description of non-equilibrium transport is a challenging problem due to singular aspects of governing equations.

Consider the following IF-THEN rules:

$$\begin{aligned} &\text{IF } m(1) \text{ is } M(i1) \text{ and... IF } m(p) \text{ is } M(ip) \\ &\text{THEN } (df/dt) = (A(i) + E(i))f(t) + A(di)f(t-h) + B(i)u(t) + G(i)w(t), \\ &i=1,2,\dots,k \end{aligned} \quad (1)$$

where $M(i,j)$ are fuzzy sets and $m(1), \dots, m(p)$ are given premise variables, $E(i)$ are the uncertain matrices and $Gw(t)$ is stochastic control. The fuzzy system is hence given by sum of equations

$$(df/dt) = a(i) ((A(i) + E(i))f(t) + A(di)f(t-h) + B(i)u(t) + G(i)w(t)), \quad i=1,2,\dots,k \quad (2)$$

where $a(i)$ are the fuzzy basis functions. The fractional integration is changed by integration on fractals. On these equations if possible apply the standard methods of stochastic control, for example the Monte Carlo method, the method of Riccati equations etc. The delay-dependent condition show the robust stabilizability for some parameters. On such a way are obtained the control systems with fuzzy scaling. With delay expressions is given the influence of genetic algorithms. Under some conditions the system is robustly stable by the Lyapunov theorem (Rastovic, 2009). In the case of instabilities the natural assumption is that the process must be recurrent. Recent technical progress allows to investigate, both experimentally and numerically, the correlation properties of fully developed turbulence in terms of particle trajectories. Non-equilibrium turbulent processes are anisotropic, non-local, multi-scale and multi-phase, and often are driven by shocks or acceleration. Their scaling, spectral and invariant properties differ substantially from those of classical Kolmogorov turbulence.

In the paper (Zielinski, 2005) are investigated the problems of computing the interval of possible values of the latest starting times and floats of activities in networks with uncertain durations modeled by fuzzy or interval numbers. There has been provided a possibilistic representation of the problem of determining the fuzzy latest starting times of activities and their floats, a difficulty connected to it has been pointed out. The complexity results for floats are presented (the computation of floats is probably intractable) and some polynomially solvable cases are described. It could be useful in the applications of Kolmogorov-Arnold-Moser theorem for describing the quasi-periodic orbits (Rastovic, 2007). The Kolmogorov-Arnold-Moser theorem uses mainly the fractals that are called Cantori as it is in the case of tokamak theory.

According to Bohr the external conditions of an experiment have to be described in the language of classical physics. The macroscopic arrangement of the measuring part can interact with individual samples of the physical system in such a way that a direct objectively traceable (macroscopic alternative) effect occurs or does not occur. Being thus based operationally on the same kind of objective facts and effects which are already familiar from classical physics, this interpretation avoids the introduction of any subjective element (like knowledge of observers, or human consciousness) into the theory (Cattaneo et al., 2004). A good approximation is a semi-transparent mirror in a path of a photon beam. No doubt this is a certain macroscopic arrangement producing a macroscopic alternative effect (either the photon reaches the plasma „yes“ or it does not). In laser plasma interactions the description with fuzzy logic methods can be also be useful.

The finite element method (FEM) is one of the most used techniques for solving partial differential problems. The idea of FEM is to divide the domain of definition of the problem into small regions called elements of the mesh, where an approximation of the solution is searched.

The current numerical approach to the problem of finding the best grid is the mesh adaptation strategy. In the paper (Manevitz & Givoli, 2003), an alternative solution to this problem is obtained using soft computing methods. Fuzzy logic is used for the mesh generation process because it allows reproducing the qualitative reasoning typical of humans, by translating numerical inputs into linguistic values (such as „good“, „near“, „high“) and by evaluating some if-then rules in parallel. Solving the Poisson problem for example, with the FEM in an „intelligent“ way requires having an idea of the general behaviour of the solution over the domain. Where it will be smooth, large elements will be required, while elements will be smaller where the solution exhibits great changes. FEM experts state that elements must be very small where there is a singularity in the boundary conditions.

The Navier-Stokes equation is supercritical. The nonlinearities become stronger at small distance scales, making it impossible to know (using present techniques) whether solutions remain smooth for all time. Thus it is crucial to understand the scale dependence of nonlinearities in fluid mechanics. Renormalization theory, which is the systematic study of short distance limits, is one of the deepest ideas ever to appear in physics. Experience from quantum field theory suggest that we must first replace the Navier-Stokes equations with a „regularized“ version, in which there is a short distance cutoff.

A „fuzzy“ version of fluid mechanics would describe even larger scale motion, which averages over a fluid elements. Such a „mesoscopic“ theory may be what we need to understand many physical phenomena, such as the stability of large vortices. A method that imposes a smallest possible length, and a largest possible wavenumber, without breaking symmetries could help us in mathematical, physical and engineering approaches to fluid mechanics.

7. Conclusion

For numerical simulations of laser-plasma interactions we can use the methods of fuzzy scaling and genetic algorithms for obtaining the possibility of description of inertial

controlled fusion phenomena. The same consequences of fractal plasma behaviour can be found as in tokamak physics (Rastovic, 2009). Only, in the case of tokamak we must use the fractals of the type of fuzzy Cantori, but in the case of inertial controlled fusion we must use, for example, the fractals of the type of circle fuzzy Koch curves, i.e. first draw polygon and then on each side of the polygon draw the first step of the Koch curve. At some time the process of self-similarity must be finished. We have got the reduced fractals for fuzzy scaling description. On such a way we obtain the main directions of the particles movements and the possibility for numerical calculations. In different directions of intersections of the sphere should be taken the appropriate polygons.

8. References

1. Dean, S. O. (2008). The rationale for expanded inertial fusion energy program, *J. Fusion Energy*, 27, 3, 149-153, ISSN 0164-0313
2. Dewald, E. L. ; Suter, L. J. ; Landen, O. L. et al. (2005). Radiation-driven hydrodynamics of high-Z hohlraum on the National Ignition Facility, *Phys. Rev. Letters*, 95, 21, 215004-215007, ISSN 0031-9007
3. Canaud, B. ; Garaude, F. ; Clique C. et al. (2007). High-gain direct-drive laser fusion with indirect drive beam layout of Laser Megajoule, *Nucl. Fusion*, 47, 12, 1652-1655, ISSN 0029-5515
4. Clark, D. S. ; Tabak, M. (2007). A self-similar isochoric implosion for fast ignition, *Nucl. Fusion*, 47, 9, 1147-1156, ISSN 0029-5515
5. Moses, E. I. (2008). Ignition on the National Ignition Facility, *Journal of Physics: Conf. Series*, 112, 3, 012003-012008, ISSN 1742-6596
6. Grim, G. P. ; Bradley, P. A. ; Day, R. D. et al. (2008). Neutron imaging development for MegaJoule scale Inertial Confinement Fusion experiments, *Journal of Physics: Conf. Series*, 112, 3, 032078-032081, ISSN 1742-6596
7. Rastovic, D. (2005). Transport theory and systems theory, *Nucl. Technology & Radiation Protection*, 20, 1, 50-58, ISSN 0164-0313
8. Rastovic, D. (2008). Fractional Fokker-Planck equations and artificial neural networks for stochastic control of tokamak, *J. Fusion Energy*, 27, 3, 182-187, ISSN 0164-0313
9. Hittinger, J. A. F. ; Dorr, M. R. (2006). Improving the capabilities of a continuum laser plasma interaction code, *Journal of Physics: Conf. Series* 46, 1, 422-432, ISSN 1742-6596
10. Turgeon, E. ; Pelletier, D. ; Borggaard, J. (2001). Sensitivity and uncertainty analysis for variable property flows, 39th AIAA Aerospace Sci. Meeting and Exhibit, Reno, NV, Jan. , AIAA Paper 2001-0139
11. Carrillo, J. A. ; Labrunie, S. (2006). Global solutions for the one-dimensional Vlasov-Maxwell system for laser-plasma interaction, *Math. Models Meth. Appl. Sci.* , 16, 1, 19-57, ISSN 0170-4214
12. DiPerna, R. J. ; Lions P. L. (1989). Global weak solutions of Vlasov-Maxwell systems, *Comm. Pure Appl. Math.* , 42, 6, 729-757, ISSN 0010-3640
13. Degond, P. ; Parzani, C. ; Vignal, M. H. (2003) Plasma expansion in vacuum: modeling the breakdown of quasi neutrality, *Multiscale Model. Simul.* , 2, 1, 158-178, ISSN 1540-3459

14. Chae, M. ; Ha, S. Y. ; Hwang, H. J. (2006) Time-asymptotic behavior of the Vlasov-Poisson-Boltzmann system near vacuum, *J. Diff. Equations*, 230, 1, 71-85, ISSN 0022-0396
15. Carrillo, J. A. ; Toscani G. (1998). Exponential convergence toward equilibrium for homogeneous Fokker-Planck-type equations, *Math. Meth. Appl. Sci.* , 21, 12, 1269-1286, ISSN 0170-4214
16. Carpio, A. (1998). Long-time behaviour for solutions of the Vlasov-Poisson-Fokker-Planck equation, *Math. Meth. Appl. Sci.* , 21, 11, 985-1014, ISSN 0179-4214
17. Bouchut, F. ; Dolbeault, J. (1995). On long asymptotic of the Vlasov-Fokker-Planck equation and of the Vlasov-Poisson-Fokker-Planck system with coulombic and newtonian potentials, *Diff. Integ. Eq.* , 8, 3, 487-514, ISSN 0893-4983
18. Besse, N. ; Latu, G. ; Ghizzo, A. et al. (2008). A wavelet-MRA-based adaptive semi-Lagrangian method for the relativistic Vlasov-Maxwell system, *Jour. Comp. Phys.* , 227, 16, 7889-7916, ISSN 0021-9991
19. Floreano, D. ; Durr, P. ; Mattiussi, C. (2008). Neuroevolution: from architectures to learning, *Evol. Intel.* , 1, 1, 47-62, ISSN 1864-5909
20. Herrera, F. (2008). Genetic fuzzy systems: taxonomy, current research trends and prospects, *Evol. Intel.* , 1, 1, 27-46, ISSN 1864-5909
21. Chopra, S. ; Mitra, R. ; Kumar, V. (2008). Auto tuning of fuzzy PI type controller using fuzzy logic, *Int. Jour. Computational Cognition*, 6, 1, 12-18, ISSN 1542-8060
22. Rastovic, D. (2009). Fuzzy scaling and stability of tokamaks, *J. Fusion Energy*, 28, 1, 101-106, ISSN 0164-0313
23. Zielinski, P. (2005). On computing the latest starting times and floats of activities in a network with imprecise duration, *Fuzzy Sets and Systems*, 150, 1, 53-76, ISSN 0165-0114
24. Rastovic, D. (2007). On optimal control of tokamak and stellarator plasma behaviour, *Chaos, Solitons & Fractals*, 32, 2, 676-681, ISSN 0960-0779
25. Cattaneo, G. ; Dalla Chiara, M. L. ; Giuntini, R. et al. (2004). An unsharp logic from quantum computation, *Int. J. Theor. Phys.* , 43, 7-8, 1803-1817, ISSN 0020-7748
26. Manevitz, L. ; Givoli, D. (2003). Automating the finite element method: a test-bed for soft computing, *Appl. Soft Computing Jour.* , 3, 1, 37-51, ISSN 1568-4946
27. Rastovic, D. (2009). Fractional variational problems and particle in cell gyrokinetic simulations with fuzzy logic approach for tokamaks, *Nuclear Technology & Radiation Protection*, 24, 2, 138-144, ISSN 1452-8185

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Uncertainty presents significant challenges in the reasoning about and controlling of complex dynamical systems. To address this challenge, numerous researchers are developing improved methods for stochastic analysis. This book presents a diverse collection of some of the latest research in this important area. In particular, this book gives an overview of some of the theoretical methods and tools for stochastic analysis, and it presents the applications of these methods to problems in systems theory, science, and economics.

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University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China

Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

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