SPMS 2016

Stochastic and Physical Monitoring Systems

Book of abstracts of the 7^{th} international conference SPMS2016

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Organized by the Group of Applied Mathematics and Stochastics (GAMS),
Department of Mathematics, Faculty of Nuclear Sciences and Physical Engineering,
Czech Technical University in Prague

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Foreword

Dear Colleagues,
it is our pleasure to welcome you to the 7^{th} STOCHASTIC & PHYSICAL MONITORING SYSTEMS.

The SPMS 2016 conference is held for the seventh time with the aim to bring together students and researchers with areas of interest related to the following topics: Analysis of microscopical structure of vehicular traffic streams and traffic modeling, Monitoring and classification of acoustic signals in material defectoscopy, New statistical distances and informational divergences with applications in acoustic emission, Small area estimation of geographical characteristics gained from data sets, and Data processing in high energy particle physics, which are all together briefly called Stochastic and Physical Monitoring Systems (SPMS). The conference links both the informal character of lively student meeting and the unique platform for the research presentations and discussions of the conference participants.

The meeting is organized by the Group of Applied Mathematics and Stochastics, Department of Mathematics, Czech Technical University in Prague and this year's venue is Sokol Dobřichovice is just a stone's throw from Prague, close to one of the most famous Czech castle, Karlštejn and has many sports facilities.

Local Organizing Committee:

Jiří Franc, Pavel Hrabák, Marek Bukáček, Václav Kůs (Chair)

Scientific and Program Committee:

Václav Kůs, Tomáš Hobza, Milan Krbálek.

Invited Speakers:

Jarosław Wąs	- AGH University of Science and Technology, Kraków, Poland,
Domingo Morales	- Universidad Miguel Hernández de Elche, Spain,
Milan Chlada	- IT, Czech Academy of Sciences, Prague, Czech Republic,
Zdeněk Převorovský	- IT, Czech Academy of Sciences, Prague, Czech Republic.
Jiří Grim	- UTIA, Czech Academy of Science, Prague, Czech Republic,
Vladislav Šimák	- FNSPE, Czech Technical University, Prague, Czech Republic
Petr Veverka	- UTIA, Czech Academy of Science, Prague, Czech Republic.

We gratefully acknowledge the institutional support provided by the funds of specific research, namely by the SGS grant SVK 29/15/F4.

The Organizers

Contents

Supervised divergence decision tree with adaptive kernel density estimation in high energy physics

Petr Bouř

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Abstract

Binary decision trees are a widely used tool for supervised classification of high-dimensional data, for example among particle physicists. We present our proposal of the supervised binary divergence decision tree with nested separation method based on kernel density estimation. A key insight we provide is the clustering driven only by a few selected physical variables. The proper selection consists of the variables achieving the maximal divergence measure between two different subclasses of data. Further we apply our method to Monte Carlo data set from the particle accelerator Tevatron at the DO experiment in Fermilab. We also introduce the modification of statistical tests applicable to weighted data sets in order to test homogeneity of the Monte Carlo simulation and real data.

Key words: binary decision trees, equiprobable histogram, kernel density estimation, machine learning, multivariate data analysis, ϕ-divergence, statistical hypothesis testing, supervised classification, top quark.

Multiple Bottleneck Systems: Experiment, Model and Hand Calculations

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Abstract

The pedestrian behavior in front of a single bottleneck have been studied on microscopic level using both, experimental and model approach. The passing time of selected person through a rectangular room may be predicted by linear model with respect to the length of free path, the width of the exit and the size of the crowd in front it. The most important message rezoning in all previous studies highlights the heterogeneity in pedestrian's reaction to the actual conditions in the room. The sensitivity coefficients referred as aggressiveness or path selection strategy of each participant enable to model the

individual travel time respecting the variance in the data.
In case of more complex geometries, where more pedestrian streams join each other, there are even more phenomena to observe and explain. Preliminary results of a lecture hall evacuation indicates the effects of synchronization âĂŞ the degree of pedestrian group organization increased after passing each bottleneck, measured by the variance of time headway. Once the stochastic model is calibrated and verified on two independent experimental data sets, even more complex scenarios may be evaluated. In this case, results are compared to cellular automata model simulations.

Key words: pedestrian behavior, stochastic analysis, evacuation experiments, cellular models.

Evaluation of continuous acoustic emission data

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Abstract

The continuous acoustic emission (AE) diagnostic method can be a part of mechanical component health monitoring systems. Latest AE measuring devices provide continuous recording of high-frequency signals registered during longtime monitoring of machinery such as rotating gearboxes, bearings etc. The attention is paid to disclose the early damage phases (cracks) or certain imperfections as rolling contact fatigue on surface of a bearing race resulted in formation of pitting or spalling. Evaluation of continuous AE signals enables to detect much smaller defects than commonly used vibrodiagnostics, capable to intercept mostly the onset of the final damage of the specimen. Recorded AE data represent extremely large amount of information to analyze, hence, the new signal processing and analysis approaches as normalized spectrogram and multilevel countogram are suitable and shown for cases of helicopter gearbox or a rolling-element bearing.

Key words: Continuous acoustic emission, wavelet analysis, countogram, rolling contact fatigue, helicopter gearbox diagnostics.

Automatic proofs of termination of term rewriting systems

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Abstract

Proofs of termination of term rewriting systems play an important role in software verification. Automated proofs provided by termination tools are often based on the dependency pair theory and the usage of techniques called dependency pair processors, that simplify the original termination problem ideally to a trivial one. The application of these techniques usually requires finding suitable orderings on terms.The construction of such orderings leads to finding a solution of a system of nonlinear inequalities. The usage of primal and penalty methods for solving the resulting systems by reducing them to nonlinear programming will be studied and compared. Computational experiments with selected term rewriting systems from the Termination problems data base will be presented.

Key words: Term rewriting systems, Dependency pairs.

Robust Hypotheses Testing

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Abstract

We introduce Renyi pseudodistance estimator and discuss its robustness. Based on this estimator, a Wald-type hypotheses test is constructed. We present simulation results and real data apllications of the test.

Key words: robustness, hypotheses testing.

Statistical methods used in measurement of the inclusive ttbar production cross section in ppbar collisions at $\sqrt{s} = 1.96$TeV

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Abstract

Many different statistical techniques have to be applied to determine any physical properties in HEP. All statistical methods, that has been used in measurement of the inclusive cross section of top quark-antiquark pairs produced in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV in lepton+jets and dilepton decay channels, will be introduced and explained in this talk. The corresponding data sample corresponds to 9.7 fb^{-1} of integrated luminosity recorded with the D0 detector during Run II of the Fermilab Tevatron Collider.

Key words: Top quark, inclusive cross section, Pole mass, Tevatron, D0, ppbar collision.

Numerical solution of geodesic equations and optimalization on models of real bodies

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Abstract

This bachelor project deals with numerical solution of geodesic equations on models of real bodies. For this purpose, finite difference method, Newton-Raphson method and functional iteration method are implemented. Moreover optimalization methods to faster calculation are tested and developed. In case, that a body contains a hole, way of computation is invented.

Key words: Acustic emission, geodesics, optimalization.

Feasibility Study of an Interactive Medical Diagnostic Wikipedia

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Abstract

In the last years we have proposed three basic statistically justified tools based on product distribution mixtures which can be combined as a platform to accumulate small pieces of decision-making know-how. First, in a series of papers we have studied different aspects of the structural mixture model to estimate probability distributions in multidimensional spaces from incomplete and possibly weighted data vectors. Second, we have shown that a discrete multivariate mixture of product components can be used as a knowledge base of a probabilistic expert system (PES) to infer conclusions from uncertain input information in a fully symmetrical way. Finally, as the most important aspect, we have shown that, by applying the exact Shannon formula of conditional informativity to product mixtures, we can choose the most relevant questions with respect to any goal or diagnostic variable. By combining the above formal tools we can design a statistical open-access system to enable interactive diagnostics with automatic accumulation of decision making knowledge. The most natural application area of such a system is the medical decision making.

Key words: Multivariate statistics, mixtures of product components, sequential classification, EM algorithm.

Median based robust estimators for logistic regression

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Abstract

This contribution deals with robust estimation of parameters of logistic regression models. It introduces a modified median estimator of the underlying parameters of these models based on statistically smoothed binary responses. Sensitivity to contaminations and leverage points is studied by simulations and compared in this manner with the sensitivity of some robust estimators previously introduced to the logistic regression. The new estimator appears to be more robust for larger sample sizes and higher levels of contamination.

Key words: Logistic regression, Median estimator, Robustness.

Time-headway distribution for genTASEP

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Abstract

The Totally Asymmetric Simple Exclusion Process with generalized update (genTASEP) is studied analytically in stationary state. The formula for time-headway distribution and fundamental diagram is derived. A way of using these formulas to fit the model parameters to traffic flow data is introduced.

Key words: Time-headway distribution, genTASEP, large L approximation.

Cluster function for DUE random matrices

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Abstract

The one way to describe any stochastic ensemble is to study the cluster function. The cluster function is used for comparison of the particle ensemble with composed potential with chosen class of random matrices. The particle ensemble with composed potential is a thermodynamic system of particles on a circle with the particle interaction through the linear combination of logarithmic and hyperbolic potential. The researched class of random matrices is the class DUE (damped unitary ensembles). Those matrices have stochastic diagonal elements and deterministic off-diagonal elements. In the first chapter the mathematical model is composed. The derivation of the probability density function of particle spacing between nearest neighbor particles follows. The numerical results and mathematical predictions are compared at the end of this paper. The numerical model is made in MATLAB by using the Metropolis algorithm. The main goals are graphical comparisons of the probability densities and the cluster function.

Key words: Cluster Function, Damped Unitary Ensembles, DUE, Composite Potential,, Headway-Distribution, Particle Ensembles, Random Matrix, Thermodynamic Systems.

JUST COUNT IT!

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Abstract

The main topic of the presentation is the counting proces theory focusing on renewal process and level process. After the definition of a general counting process and providing some of the fundamental results about it, the major part of the presentation is devoted to the renewal process. A numerous useful properties are shown for this process within the second chapter. A very important role is played by the moments of the process which will be discussed as well. Their significance is due to appropriate way they describe the counting process. The moment analysis is included also for the level process. The crucial quantities here are the so called rigidity and corigidity. Thanks to their quite simple expressions and information capability, they are appreciated and appropriate to apply in some real problem.

Key words: Counting process, Renewal, Level, Moment, Asymptotic expansion.

Skin elasticity evaluation through PM space density identification

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Abstract

The ultrasonic device developed for Non Destructive Testing (NDT) enables us to measure a damage or aging of complex structural materials such as human skin tissues. It can be also utilized for medical or cosmetics applications. An acousto-mechanical experiment using the mixing of mechanical loading and ultrasonic TR-NEWS probing system has been carried out in order to extract the non-classical nonlinearity of porcine skin tissue, which is closely resembled to the human skin. The corresponding hysteretic behaviour coming from the complex loading of the porcine skin tissue was assessed by means of Preisach-Mayergoyz (PM) space statistical model, which can be expressed in the form of weight combination of various hysterons. To identify the probability density of hysterons in PM space, the iterative simulated annealing optimization algorithm was used under the classical L_2 metric distance

convergence criterion. Moreover, the specific statistical distances called phi-divergences, originated from information theory, were used as the alternative convergence criterion, mainly the Hellinger divergence H. The principle advantage of our approach is employment of distribution mixtures which might well comply with the structure of real material. It was found that the final PM space (containing 1000 hysterons) is distributed along the mixture of two Guyer distributions and phenomenological hysteretic parameters extracted from the PM space model are presented. Detailed analysis of data coming from 6 different porcine skin hysteretic behaviour shows that the PM space identification can be considered as a new tool for extracting multiscale parameters containing rather exact information about the structure of the skin under testing.

Key words: PM space, elasticity, porcine skin tissue,numerical methods, simulated annealing.

On a link between novel ensembles of random matrices and systems of self-driven particles

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Abstract

Stochastic analysis of individual quantities measured in various systems of self-driven particles (agents: walkers, drivers, birds) reveals many common features. Indeed, statistical distributions of headways among succeeding agents as well as the statistical rigidity in those systems show significant mathematical similarities. Such a striking resemblance is not accidental, although each of those systems is ruled by a different level of mutual agent repulsions/attractions or a different level of stochasticity. Thus, to what extent are these distributions affected by the interaction rules? We will present (by means of novel classes of random matrices) a general scheme of agent dynamics producing the same statistical micro-distributions as those revealed in empirical data. Non-triviality of that correspondence will be confirmed by testing of associated statistical rigidities.

Key words: Random matrix theory, vehicular traffic.

Predictive current limiter for control of permanent magnet synchronous machine drives

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Abstract

Using linear quadratic control (LQ) is a popular technique in control theory. Main advantage of this technique is the possibility to optimize a quadratic cost function on a long horizon. On the other hand, it is not possible to use LQ techniques for optimization problem with hard constraints on the system state variable. We propose to use the limited lookahead approach of dynamic programming to introduce the constraint on the system state variable and interpret the LQ controller as an approximate solution of the constrained problem on a long horizon. Stable and sufficiently fast algorithms for control of a permanent magnet synchronous machine (PMSM) in real time are introduced. Performance of the algorithms was tested on a laboratory prototype PMSM drive.

Key words: Dynamic programming, Interior Point method, linear quadratic control, permanent magnet synchronous machine.

Poverty mapping in small areas under a two-fold nested error regression model

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Abstract

Specific software for small area estimation of general non-linear parameters (e.g. poverty indicators) include only estimators based on models with random effects at one of the levels (cluster or domains) but not both, see ebBHF function from R package sae. One might be willing to use this software or to consider a one-fold model just for simplicity. In that situation, at which level should one include the random effects? Is a model with cluster effects alone good enough for estimation at the domains, or should we always include random effects for the domains of interest? Is a model with only random effects for the domains good enough, or should we also include the cluster effects? To answer these questions, we will compare, in terms of bias and efficiency, EB estimators obtained under the two-fold

model with those obtained under a one-fold nested error regression model with random effects either at the clusters or at the domains of interest. We will also compare with the traditional ELL method, based on a one-fold nested error model with random effects for the sampling clusters but not for the domains of interest. A parametric bootstrap procedure will be used for MSE estimation and the problem of underestimation of the MSE when the random effects are misspecified will be studied for estimation of domain means. Finally, an application to estimation of income and poverty indicators in small domains from the Spanish region of Valencia will be described.

Key words: Small areas estimation, two-fold nested error regression model, EB estimator, ELL method, random effects model, estimation of income and poverty indicators.

Network traffic classification

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Abstract

In the network security industry new threats appear every day and their detection represents a challenge as the amount and variability of threats increases. Current signature or pattern matching systems still have a limited capability to detect new and previously unseen malicious behaviors. Moreover, indicators of compromise identified by the state of the art approaches are prone to false alerts and when presented individually (and not in a combination), they often represents a weak proof of malicious activity, or some activity may remain hidden on the infected device.
The proposed method models behaviours of individual users in the real network traffic to find malware infections. The method creates time distributions of anomalous web activities of each user calculated from the proxy log records. The distributions of different users are compared using dynamic time warping, which guarantees the similarity of two time series even when affected by shifting of the activities. This gives the algorithm more flexibility and increases the generalization of the classifier built on the top of it. The proposed approach was evaluated on the real network traffic and compared with the existing methods.

Key words: Classification, K-means, KNN.

Research of the influence of mechanical loading on a quality of time reversal signal reconstruction

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Abstract

Ultrasonic time reversal experiments are realized on many field of application. Ultrasonic time reversal experiments were realized on metallic sample subjected to mechanical loading. Ultrasonic waves are excited on uploaded sample surface. Forward and back propagated time reversal signals are transmitted from waveform generator and received using high speed digitizer. Quality of the source signal reconstruction after time reversal procedure on loaded sample is evaluated in Matlab. The goal is to assess possibilities of time reversal processing for acoustic emission sources reconstruction during fatigue loading of materials.

Key words: Ultrasonic testing, mechanical loading, steel material.

Recently discovered new particles and problems with their interpretation

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Abstract

The history of the discovery of penta-quarks and tetra-quarks will be reviewed and existence of followers of Higgs boson will be discussed. How can we interpret these new particles in terms of Quantum Field Theory? What are new trends in High Energy Physics and what happens at the LHC?

Key words: Pentaquarks, Tetraquarks, New partciles, Experimental Physics, LHC.

Correlation analysis and study of probability distributions in ensembles of empirical vehicular data

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Abstract

Double-loop detectors positioned under the expressway R1 (Prague Ring) provided us sufficient amount of data to carry out correlation analysis. To avoid an inhomogeneity of traffic flow the data set was separated into two main categories: free flow and congested traffic. Analyzed were 2 methods and only edge detection algorithm was used for further statistical studies. This approach turned out to be well-founded in multiclearance distribution analysis, where considerably different results were obtained for whole data set and for data extracted from separated phases. Our interest was essentialy aimed at studies of correlations coeficients. Specific variants include velocity correlation coeficient, correlation coeficient between velocity and clearance and correlation coeficient between clearances of two successive vehicles. Parallel study was carried out for non-neigbour vehicles and pairs of different types of vehicles. In all correlation studies has been carreafully distinguished between two approaches: classical (Pearson's) and brownian, which gave us space to compare both and finaly to present certain benefits of brownian approach.

Key words: Brownian correlation coeficient, Pearson's correlation coeficient, separation of traffic phases, three-phase traffic theory, time clearance distribution, velocity distribution.

Stochastic properties of the auditory nerve excitation

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Abstract

The transfer of information in the auditory nerve is an important step in the mechanism of hearing. The process is not entirely understood especially due to the difficulty of acquiring direct experimental data. This contribution presents a physiologically well-justified mathematical model of the process based on stochastic differential equations. Analysis of stochastic properties of the model is a crucial step in assessing its correctness and performance.

Key words: Random process, stochastic differential equations, auditory nerve, mathematical modeling.

Application of statistical hypothesis testing to datasets from HEP experiments

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Abstract

In High energy physics, it is necessary to verify if measured data correspond with Standard model of particle physics. Measured data are compared with Monte Carlo generated values which are weighted. For this purpose, generalized forms of homogeneity tests are used. ROOT, a C++ object oriented framework, is used to work with data in High energy physics. We implemented generalizations of some homogeneity tests into ROOT and used them to test whether measured data from ATLAS detector have same distribution as Monte Carlo generated values.

Key words: HEP, ROOT, homogeneity tests, MC and data comparison.

Bayesian estimation of linear regression model parameters with unknown prior and noise covariance matrix

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Abstract

The problem of determination of a source of atmospheric release of pollutant can be formalized as a linear regression problem, $y = Mx + e$, with two specific features. First, the matrix M is usually poorly conditioned, which prevents usual statistical estimation methods from being effective on the problem of estimation of the source parameter x. Second, the covariance matrix of the measurement noise is typically unknown. Both of these problems are solved using Bayesian inference scheme that proposes the structure of hierarchical priors over unknown model parameters. This structure aims to improve both the estimates of source term x and covariance matrix of measurement noise. Specifically, covariance matrix designs are made to take into account possible temporal and spacial correlations of measurements, and the prior model for x is designed to promote sparse solutions.

Since the inference of unknowns from available measurement is not feasible, approximate inference methods are derived for each of them. For this approximation, two deterministic methods, Variational Bayes and Expectation propagation, and one stochastic method, Gibbs sampler, are used. Different variants of models and approximation techniques are compared using standard model selection techniques on real data from the European tracer experiment.

Key words: Approximate Bayesian inference, linear regression, ETEX.

Statistical rigidity in systems with socio-physical interactions

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Abstract

Firstly, we mathematically formalize theory of statistical rigidity, we define basic terms such as particle count and unfolded headways and we derive basic relations between them. Furthermore, we also introduce the concept of a cluster function and distinguish statistical rigidity from number variance. Afterwards, we use the new formalization of statistical rigidity to derive Laplace image of a general formula for statistical rigidity. Secondly, we normalize and scale probability density of the generalized inverse Gaussian distribution (GIG), at the same time we bring analytical approximation of scaling constant which guarantees its accordance with exact value even for small values of distribution parameter. In the end, Laplace image of a general formula for statistical rigidity enables us to predict the behavior of the linear tail for statistical rigidity in systems of particles whose distances follow the GIG distribution. Finally, we reduce the GIG distribution to more concrete one for which we perform visualization and comparison of our purely analytical calculations with numerical data and previously used phenomenologically-corrected formulas.

Key words: Statistical rigidity, cluster function, GIG distribution, corrective function, scaling equation.

Systems Nonlinearity Comparison

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Abstract

It is known that in order to be controlled, nonlinear systems are linearized in an operating point or small area. As common sense suggests, more difficult systems, e.g. those described by more complex equations, are more likely to be thrown off balance. In other words the linearization works on smaller interval than with simpler systems. It would be beneficial to have a way of describing how much is the system nonlinear. We will demonstrate Vinnicombe's metric dealing with this problem.

Key words: Control Systems, Linearization.

High-frequency market making: perspectives and challenges.

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Abstract

The problem of market making on high-frequency electronical markets is an extremely complex task due to an enormous nuber of agents in the market, dependence of the variables of interest on the past, time scale of milliseconds and also due to some technical and hardware limitations. In the talk, we will recall some recent results in optimal control of market maker's cash and inventory process and we indicate some possible new directions. The talk is based on work in progress with C. Orrieri, E. Bandini and M. Šmíd.

Key words: Market making, stochastic processes, optimal control.

Atlas distributed computing

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Abstract

ATLAS is one of the high energy physics experiment at CERN that use LHC (Large Hadron collider) proto-proton accelerator to study physics of the elementary particles. ATLAS detector process hundreds of millions particle collisions per second and use millions of electronic detector readout channels to record data for further physics analysis. The amount of data is enormous (dozens of petabytes each year) and

their analysis requires significant computing power. Distributed computation model was natural choice that took advantage of scalable computing infrastructure provided by universities and research institutions participating on ATLAS physics program. We'll provide brief description of the most important building blocks in ATLAS computing architecture that gives researches a tool to efficiently run hundreds of thousands parallel jobs and ensure optimal data distribution between all national and regional computing centers.

Key words: LHC, ATLAS, Distributed computating, ATLAS computing architecture.

Adaptation of Social Force Model for simulation of downhill skiing

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Abstract

Our main purpose is research into skiers' physics and behavior modeled with the use of a modified social force approach. The proposed model includes the following social forces: way-point forces âĂŞ directing a skier towards consecutive way-points on the slope, skiers' repulsion forces âĂŞ keeping distance between skiers using a concept of skier's social ellipses, obstacle repulsion forces âĂŞ keeping skiers away from obstacles, and slope edge repulsion âĂŞ keeping a skier along the slope route using repulsion force inspired by BiotâĂŞSavart law. The proposed model also includes additional behaviors: slowing down when exceeding the skier's safe speed and braking before the end of the slope as well as a possibility of using accelerating force from ski poles. The study takes into account the whole system including ski routes and ski lifts.

Key words: Skiers' physics and behavior models, downhill skiing, modified social force model.

Notes