Proceedings of the First Interdisciplinary CHESS Interactions Conference

Chary Rangacharyulu • Emmanuel Haven
editors

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Saskatoon, Saskatchewan, Canada 17 – 20 August 2009

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FOREWORD

As the pursuits of the sciences, arts, literature or engineering or any conceivable discipline, are all anthropocentric endeavors which are solely depending on human logic, creativity and intuition, it is unlikely that the methodologies of them all are totally disconnected. Even amongst two disciplines, which are seemingly quite farther apart and completely orthogonal, there may be some common threads in modes of thought, lines of discourse, methods of analysis and interpretation of data.

Thus, a conference exploring the methodologies of diverse disciplines which brings together active inter-disciplinarians from various fields of study may serve the purpose of finding commonalities, identifying distinct features and initiating discussions which can, with some concerted efforts, foster inter-disciplinary dialog among practicing researchers and young minds. At such conference, ideally, people will emphasize how they do things, how they reason, how they interpret (but less so on what they do). It is expected that these dialogs would, while sharing this information, lead to cross-fertilization and even to some collaborative research ventures. This was the aim of the first international interdisciplinary conference on Computer science, Humanities, Engineering/ Education/Economics and ScienceS (natural and social sciences) interactions, also known as the First Interdisciplinary CHESS Interactions Conference.

The seeds for this conference were sown in the Summer of 2006, as we got together for the Third Feynman Festival conference at the University of Maryland, USA. We picked Saskatoon in August 2009 as the venue for the first gathering. From the very early planning stages of the conference, we were well aware, that a conference of this type can easily get out of hand, get diluted and become a forgotten episode. In order to avoid such cataclysm, we assigned ourselves a few tasks. We set ourselves as a first task to invite serious researchers whose work influenced more than just their main discipline. Secondly, we reminded our speakers, regardless of their international status, that the two main goals of this conference were i) to share their methodologies with people from diverse areas of research and ii) to draw parallels between their field of study and other disciplines as much as possible. Our third task consisted in imploring them to submit papers for inclusion in the proceedings.

We believe that this proceedings volume shows that we were quite successful in attracting serious scholars of international renown from a diversity of disciplines.

Given that this is a first attempt at organizing such a unique conference, we were not disappointed to observe that some contributors decided not to leave their comfort zones. As we have indicated above, we actively asked contributors to explore the common and distinct features of their field(s) of study with those of other disciplines. We also reminded them to carefully assess constraints and be aware of misconceptions which may be generated when one borrows concepts and techniques from other fields.

Almost all contributions in this proceedings volume fall into either one or more categories of generation, practice and communication of knowledge across disciplines. Many authors spoke about applications of a set of techniques to more than one area of study.

Not all presentations and discussions of the conference are included in this proceedings volume. The reader will find an extensive discussion of statistical physics approaches as they apply to cognitive psychology, economics and market analysis and phase transitions as they pertain to religion and languages (Tsallis, Stanley, Jackson, Switzer and Ausloos). Knowledge acquisition and epistemology are the subjects of more than one contribution (Juurlink, Gupta, Pollack and Roychoudhury). Methods of quantum mechanics and its applications were the subject of the papers by Goyal, Busemeyer and Khrennikov. Some of them ventured into pointing out the pitfalls and mishaps that might befall if one imports metaphors of one discipline to another one oblivious to the subtle distinctions amongst them (Jackson, Porter, Rangacharyulu and Haven). Csapó elucidated symmetry and asymmetry as underlying currents in music composition, while Augsburg focused on integrating different modes of inquiry for school teachers.

We have many people and organizations to thank for the success of this conference. The Honorable Rob Norris, Minister of Advanced Education, Government of Saskatchewan (Canada) was a supporter and provided funds. We have also received financial support from the Universities of Saskatchewan and Leicester (UK). Janusz Kozinski, Dean of Engineering at the University of Saskatchewan, not only sponsored this conference, but he also lent his staff to actively help us in organizing the event. Brij Verma of the Division of Science gave a helping hand in organizing the local events. As always, Marj Granrude and Angelika Ortlepp of the Physics and Engineering Physics department provided unstinting help. M.P.M. Nair donated his time, energy and technical prowess in videotaping the full conference. Karen Tanino and Anne-Marie Cey were indispensable in pulling the conference together and getting the word out. We also thank Peter Jackson (Dean of Social Science at the University of Leicester) and Alan Bryman (Head of Department of the School of Management at the University of Leicester) for their ongoing support.

Thanks also to Stephen Garrett (from the Mathematics Department at the University of Leicester) for suggesting Paul Towers (also in the Mathematics Department) as ‘the’ gentleman who would take care of all our formatting problems. Stephen was indeed correct!

We must also thank Philippe Haven for having supplied one of his drawings to grace the cover of this proceedings volume.

Preparations for a sequel to this conference, which will be held at the University of Leicester in the Summer of 2011, are underway. We look forward to a continuation of engaging intellectual discourses of diverse disciplines enriching each other.

Chary Rangacharyulu (Dept. of Physics and Engineering Physics; University of Saskatchewan (Canada))

Emmanuel Haven (School of Management; University of Leicester (UK))

Congress Participants

Conference Programme

Monday August 17 - 2009

1:00 – 4:00 Tutorial/Workshop by Dr. M. Gupta
Room 103 Physics Building
Fuzzy Neural Computing Systems: Theory and Applications
4:00 – 5:00 Tour of Canadian Light Source
Meet outside Room 103 Physics Building
5:00 – 7:00 Wine & Cheese Reception
Registration – *Geology Atrium*

Tuesday August 18 – 2009

8:00 – 8:30 Opening Ceremony
8:30 – 9:30 Prof. E. Stanley
Boston University, USA
Liquid Water, the "Most Complex" Fluid
9:30 – 10:15 Prof. L. Switzer
Concordia University, Canada
Market Efficiency and the Risks and Returns of Dynamic Trading Strategies with Commodity Futures
10:15 – 10:30 COFFEE BREAK
10:30 – 11:15 Prof. M. Gupta
University of Saskatchewan, Canada
On the Morphology of Uncertainty in Human Perception and Cognition
11:20 Transportation to Dinner
Bus departs from U of S for the Radisson Hotel
11:45 – 1:15 LUNCH – *Radisson Hotel*
Guest Speaker: Dr. G. Küchler
Lufthansa Systems, Germany
One Day in the Airline Industry or What it Takes to Run a Highly Chaotic System at the Highest Standard of Safety and Security
2:15 – 3:00 Prof. B. De Baets
University of Gent, Belgium
Rock-Paper-Scissors Revisited
3:00 – 3:45 Prof. C. Rangacharyulu
University of Saskatchewan, Canada
Structures and Symmetries in Physics
3:45 – 4:00 COFFEE BREAK
4:00 – 4:45 Prof. C. Roychoudhuri
University of Connecticut, USA
Consilience: Unity of Knowledge by Synthesizing an Evolving Epistemology
4:45 – 5:30 Prof. T. Augsburg
San Francisco State University and Stanford University, USA
Integrating Different Modes of Inquiry for Pre-service Teachers

Wednesday August 19 – 2009

8:30 – 9:30 Prof. C. Tsallis
CBPF, Brazil & Santa Fe Inst, USA
Entropy, a Unifying Concept
9:30 - 10:15 Dr. T. Porter
University of Saskatchewan, Canada
Impossibility of a Theory of Everything
10:15 – 10:30 COFFEE BREAK
10:30 – 11:30 Prof. G. Pollack
University of Washington, USA
Water, Energy, and Life: Fresh Views from the Water's Edge
11:30 – 12:00 Prof. J. Vassileva
University of Saskatchewan, Canada
Social Computing – A New Interdisciplinary Study
12:00 – 1:00 LUNCH – *Marquis Hall*
1:00 – 1:45 Prof. B. Juurlink
Alfaisal University, Saudi Arabia
Fumbling Towards Ecstasy
1:45 – 2:30 Dr. P. Goyal
Perimeter Institute, Canada
What is Quantum Theory Telling Us About How Nature Works?
2:30 – 3:00 Prof. K. Tanino
University of Saskatchewan, Canada
CHESS Interactions – Common Research Themes from a Plant Agriculturist's Perspective
3:00 – 4:30 Group Photo of Conference Participants
Graduate Student Poster Session and Coffee (*Foyer, Arts 241*)
5:30 Transportation to Banquet
Bus departs from U of S for ***Dakota Dunes***. There will be a half hour stop at the ***Radisson Hotel*** before the banquet.
7:00 – 9:30 BANQUET – *Dakota Dunes*
Guest Speaker/Performer: Prof. Gyula Csapó
University of Saskatchewan, Canada

Thursday August 20 – 2009

8:30 – 9:30 Prof. J. Busemeyer
Indiana University, USA
Comparison of Quantum and Bayesian Inference Models
9:30 – 10:15 Prof. G. Rodgers
Brunel University, United Kingdom
Statistical Physics and Healthcare Systems
10:15 – 10:30 COFFEE BREAK
10:30 – 11:15 Prof. E. Haven
University of Leicester, United Kingdom
Title of Talk TBA
11:15 – 12:00 Prof. M Ausloos
University of Liege, Belgium
On Religion and Language Evolutions Seen Through Agent Based Models

12:00 – 12:30 Conclusion
12:30 – 1:30 LUNCH – *Marquis Hall*
Guest Speaker: Prof. Richard Florizone
University of Saskatchewan, Canada
Title of Talk TBA
2:00 – 6:00 Optional Tours of Batoche or the Western Development Museum
Advanced sign-up at the registration table

CONTENTS

SWITCHING PHENOMENA

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One challenge of biology, medicine, and economics is that the systems treated by these serious scientific disciplines can suddenly "switch" from one behavior to another, even though they possess no perfect metronome in time. As if by magic, out of nothing but *randomness* one finds remarkably fine-tuned processes in time. The past century has, philosophically, been concerned with placing aside the human tendency to see the universe as a fine-tuned machine. Here we will address the challenge of uncovering how, through randomness (albeit, as we shall see, strongly correlated randomness), one can arrive at some of the many temporal patterns in physics, economics, and medicine and even begin to characterize the switching phenomena that enable a system to pass from one state to another. We discuss some applications of correlated randomness to understanding switching phenomena in various fields. Specifically, we present evidence from experiments and from computer simulations supporting the hypothesis that water's anomalies are related to a switching point (which is not unlike the "tipping point" immortalized by Malcolm Gladwell), and that the bubbles in economic phenomena that occur on all scales are not "outliers" (another Gladwell immortalization).

1. Switching Phenomena: Introduction

The title I have given to this talk I owe in part to interactions with biological and medical researchers. Many of them believe that *randomness* means *uncorrelated randomness.* They learn that statistical physics deals with random phenomena, so they assume that our field cannot possibly yield any insights into the real world as they correctly know that no system in which they are interested corresponds to simple *uncorrelated randomness.* Hence, we found using the adjective "correlated" helped persuade our collaborators that what we do may possibly be applicable to systems in which they are interested.

Indeed, 100 years ago most of our understanding of systems was based on the assumption that the constituents were basically uncorrelated, and so we understood well ideal gases, and ideal paramagnets. When correlations were introduced, gases developed a completely new phenomenon, the liquid state. And paramagnets developed a completely new magnetic phenomenon, the ferromagnetic state.

In this talk, I will discuss recent applications of correlated randomness to three areas of science for which statistical physics is becoming useful: liquid water, economics, and physiology/medicine.

2. Switching Phenomena in Water

It is widely acknowledged that if we do not understand water we cannot understand biology. Scientifically, water is the prototype complex fluid. It is not a simple, "bag-of-marbles" liquid, but a "bag of tetrahedra"–charged tetrahedra interacting with long-range Coulomb forces.

Our approach is based on the fact that water has a tetrahedral local geometry. In this sense water shares features with other liquids such as silicon, silica, and carbon. Because water is both tetrahedral and charged it means that a simple Lennard-Jones potential is not sufficient to describe its complexity. One way to modify the Lennard-Jones potential to provide at least a simplified description is to bifurcate the single minimum into two minima. The first minimum, at a closer distance, corresponds to two pentamers (a water molecule and its four neighbors) of water interacting with each other in a rotated configuration. The second minimum, at a greater distance, occurs in the unrotated position (Fig. 1). This second position is a deeper minimum because although the pentamers are farther apart there is the potential for hydrogen bonding between the molecules and we can see the beginnings of an ice-like hexagonal structure.[1–3]

The important point is that there are two minima with the outer one corresponding to a larger specific volume—because the distance is larger—and a lower entropy. The possibility is that liquid water could at low temperatures condense not into a single phase—as we anticipate when a gas with a simple interaction like a Lennard-Jones potential condenses into a fluid—but into two different phases. This possibility was first raised by Takahashi 60 years ago and various elaborations of this model have been made by a number of people.[4–6] Hence at low temperatures there will be enhanced entropy and volume fluctuations, and enhanced anticorrelations between entropy and volume (since the deeper outer well corresponds to lower entropy but higher specific volume). The consequences of this fact qualitatively explain the phenomenon we were describing at the beginning—volume fluctuations are increased, entropy fluctuations are increased, and cross-fluctuations of volume and entropy are decreased. This singularity-free picture has been actively studied for the past 31 years.[7–11] Additional scenarios are discussed in[12] (see Fig. 2).

It has been speculated that at low temperatures there will be a genuine phase transition in which the single component liquid actually separates into two different phases. The implications of this when applied to real water molecules produce a phase diagram of liquid water (Fig. 3). This liquid-liquid phase transition hypothesis was first proposed on the basis of computer simulations.[13] A first test of this hypothesis is that at very low temperature we find a glassy phase, not unlike that of any other liquid except that at high pressure this glassy phase suddenly switches from a low-density form to a high-density form. These two forms correspond to the two different local arrangements characteristic of water tetrahedra. The order parameter jump between these two phases is not a trivial amount, but on the order of 30 percent.[14]

Between the liquid and glassy phases of water we have a region in which water does not exist as a liquid—a "No Man's Land." The hypothesis that follows from the reasoning we have just described is that this first order phase transition line known to separate the two amorphous forms of solid water extends into this No Man's Land and ultimately terminates at a critical point. Just as the glassy water first-order transition line separates a low-density amorphous phase from a high-density amorphous phase of water, so also this extension of the line into the liquid region separates a low-density liquid from a high-density liquid. The power-law behavior uncovered over the years by Angell, Anisimov and collaborators corresponds to the fact that the extension of this first-order line beyond the critical point—the

"Widom line," defined to be the locus of maximum correlation length.[15–18] Experiments on a path approaching the Widom line display phenomena that initially look as though there will be a divergence, as the correlations increase. However since the correlation length itself is not infinite, there will ultimately be rounding.

The degree of ordering and disordering of local tetrahedrality of water upon changing thermodynamic variables, such as pressure or temperature, offers a simple measure of order and disorder in the case of liquid water. Kumar and his collaborators derive a relation for the subset of the structural entropy which is associated with the degree of local tetrahedral ordering.[16] They find that the most relevant part of the total entropy fluctuations (or the specific heat) of water comes from the tetrahedral fluctuations – suggesting that the fluctuations of local tetrahedrality of water contributes the most to the total specific heat.[16] Moreover, the specific heat associated with the tetrahedral ordering C_P^Q behaves identically, within error bars, to the total specific heat C_P^{total} (Fig. 4), consistent with the qualitative idea that the principal contributor to temperature dependence of the entropy are the angular variables, not the translational variables. In particular, both functions display clear maxima at the Widom line, which is equivalent to saying that at the Widom line the entropy fluctuations are a maximum (and the dependence of entropy on temperature is a maximum).

This phase diagram is hypothesized, but it has not been proved. What has been proved is that computer simulations using tried and tested models of liquid water confirm the broad features of this phase diagram (see, e.g.,[19–22] and refs. therein). But computer models of water (like computer models of anything) are subject to the charge "garbage-in, garbage-out"—you get out what you put in. All computer models of complex systems such as liquid water are of necessity simplifications.

Here we are guided by exact solutions of simplified models. Simplified models are designed less for the purpose of matching experimental detail, but rather to capture the essential physical features of a real system to explore the effect of these features. A family of models introduced first by Jagla seems to reveal the fact that in order for a system to display a liquid-liquid phase transition, the essential feature of an interaction potential must be that it has not one but rather two characteristic length scales (see Ref.[23] and references therein).

Current experiments on this problem are of two sorts. The first is a set of experiments inspired by Mishima that involves probing the No Man's Land by studying the metastable extensions of the melting lines of the various