REACTION-DIFFUSION COMPUTERS

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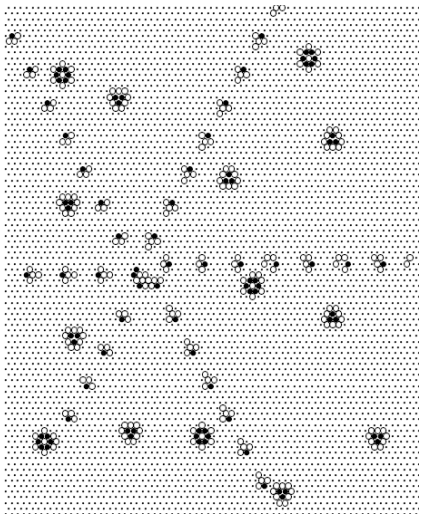
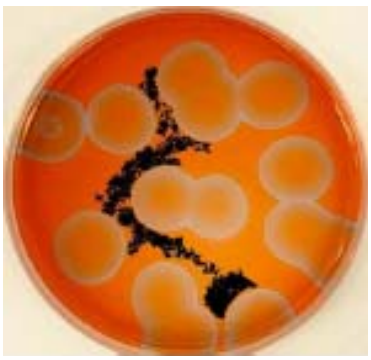
Lecturers:
Andrew Adamatzky, Benjamin De Lacy Costello, Tetsuya Asai

The tutorial introduces a hot topic of novel and emerging computing paradigms and architectures --- computation with travelling waves in reaction-diffusion non-linear media. A reaction-diffusion computer is a massively parallel computing device, where micro-volumes of the chemical medium act as elementary few-bit processors; and chemical species diffuse and react in parallel. In the reaction-diffusion computer both the data and the results of the computation are encoded as concentration profiles of the reagents, or local disturbances of concentrations, whilst the computation per se is performed via the spreading and interaction of waves caused by the local disturbances. The tutorial brings out results of decade-long studies in designing experimental and simulated prototypes of reaction-diffusion computing devices for image processing, path planning, robot navigation, computational geometry, logics and artificial intelligence.

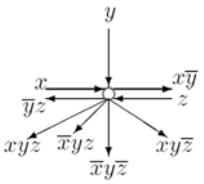


The tutorial is unique because it gives a comprehensive presentation of theoretical and experimental foundations, and cutting-edge computation techniques, chemical laboratory experimental setups and hardware implementation technology employed in development of the novel nature-inspired computing devices.

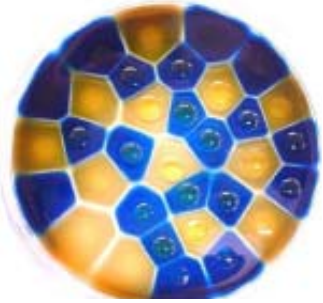


This timely session presents a nearly exhaustive overview and original analysis of information processing in spatially extended amorphous non-linear media, and applies the theoretical findings in fabrication of working prototypes of wetware. The tutorial is self-contained and requires a minimal knowledge in computer science, chemistry and physics, and electronic engineering to understand all parts of the lectures. All concepts and findings are extensively illustrated, so attendees from all walks of life will enjoy the tutorial.

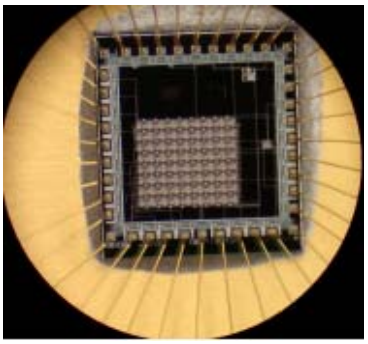
Tutorial schedule



Part 1. Theoretical background of reaction-diffusion computing (1 hour 20 min) [A. Adamatzky]: What is a reaction-diffusion computer? Problems with natural parallelism. Cellular-automaton models of chemical media. Computational models of reaction-diffusion computing. Solving computational geometry problems: Voronoi diagram and skeleton. Solving optimisation problems: shortest path. Control of robot navigation with reaction-diffusion processors. Universality of reaction-diffusion media (artchitecture-based and collision-based logical circuits). Programmability of chemical computers.



Part 2. Chemical laboratory prototypes of reaction-diffusion computers (1 hour 20 min) [B. De Lacy Costello]: Chemical reactions for non-classical computation. Order versus disorder. Self-organisation in simple chemical systems. Controllability. Overview of chemical processors. Precipitating reactions. Active chemical media. Excitable chemical media. Sub-excitable chemical media. Oscillating reactions. Bistable and multi-stable reactions. Approximation of Voronoi diagram and skeleton in chemical processors. Logic gates in chemical processors. Chemical waves in channels. Light controlled logic. Solving shortest path problem. Demonstrations of real chemical processors in action will punctuate this tutorial.



Part 3. Silicon prototypes of reaction-diffusion computers (1.5 hr) [T. Asai]:

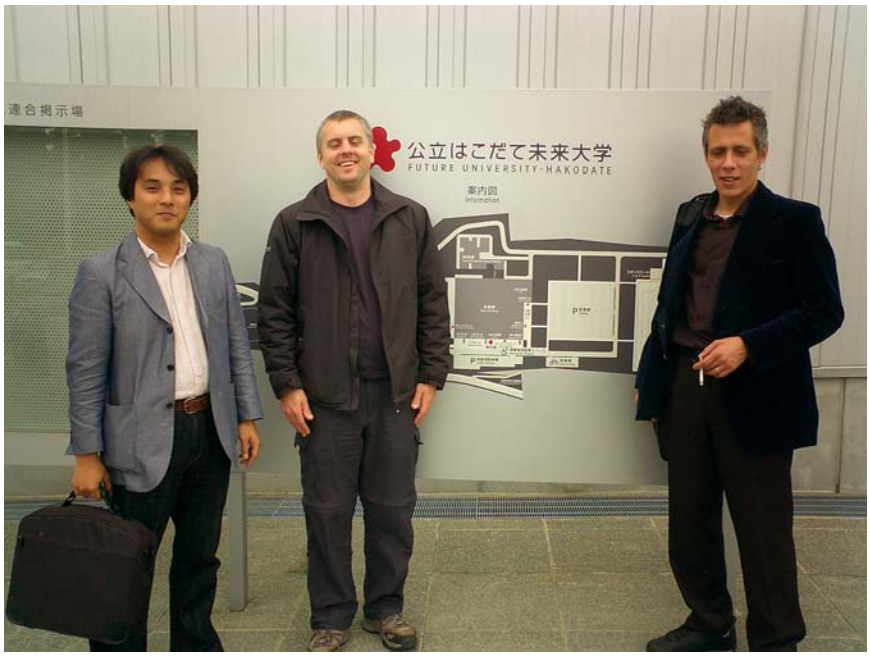
In this part, we learn how nonlinear differential equations for reaction-diffusion (RD) models is solved by analog VLSI circuit. Conventional CMOS devices have limited nonlinearity in their input-output functions; e.g. exponential, square functions etc. Direct implementations of arbitrary functions in RD equations are thus very difficult, but some of the reaction-diffusion models have successfully been implemented. As an example, analog implementation of the Oregonator, which is one of the famous model of the Belousov- Zhabotinsky reaction, will be introduced as well as implementation of typical nonlinear oscillators. Required knowledge for participants in this part is then only basics of mathematics and electronic circuits

About Tutors

Dr. Andrew Adamatzky is a Professor of Unconventional Computing, Faculty of Computing, Engineering and Mathematical Sciences, University of the West of England, Bristol, UK. He does research in cellular automata, reaction-diffusion computing, distributed artificial intelligence, and robotics. He authored “Identification of Cellular Automata” (Taylor & Francis, 1995), “Computing in Nonlinear Media and Automata Collectives” (IoP Publishing, 2001), “Dynamics of Crowd-Minds” (World Scientific Publishing, 2005), and “Reaction-Diffusion Computers” (Elsevier, 2005).

Dr. Benjamin De Lacy Costello is a Senior Research Fellow, Department of Physics and Chemistry, Faculty of Applied Sciences, UWE, Bristol, UK Dr. B. de Lacy Costello has an interdisciplinary research background and has worked on a number of industrial and research council funded projects. His research interests are primarily in the synthesis and characterisation of novel conducting polymer and inorganic semiconductor materials to be used as chemical sensors. A major part of his research is focussed on the integration and design of prototype sensing systems for real world applications. More recently his research interests have been focussed in the area of non-linear chemical reactions particularly the Belousov-Zhabotinsky reaction, other oscillating reactions and a class of inorganic pattern forming reactions of the Liesegang type. He authored “Reation-Diffusion Computers” (Elsevier, 2005).

Dr. Tetsuya Asai is an Associate Professor in the Department of Electrical Engineering, Hokkaido University, Sapporo, Japan. He received the B.E. and M.E. degrees in electrical engineering from Tokai University, Kanagawa, Japan in 1993 and 1996, respectively, and the Dr. Eng. degree in electrical and electronic Engineering from Toyohashi University of Technology, Aichi, Japan in 1999. His current research interests include nonlinear analog processing in neural networks and reaction-diffusion systems as well as design and applications of neuromorphic VLSIs. He authored “Reaction-Diffusion Computers” (Elsevier, 2005).



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