# Computers and Creativity

Jon McCormack • Mark d'Inverno
Editors

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Springer

*Editors*
Jon McCormack
Faculty of Information Technology
Monash University
Caulfield East, Victoria
Australia

Mark d'Inverno
Computing Department
Goldsmiths, University of London
New Cross, London
UK

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# Foreword

If I had to pick just one point out of this richly intriguing book, it would be something that the editors stress in their introduction: that these examples of computer art involve creative *computing* as well as creative *art.*

It's a happy—or perhaps an unhappy—coincidence that the book is going to press only a couple of weeks after the opening of David Hockney's one-man exhibition, "A Bigger Picture", at the Royal Academy of Arts in London.

A happy coincidence, in that such a famous traditional artist has chosen to link his most recent work with computers so publicly, and—according to the many favourable reviews—so successfully. This effectively puts paid to the all-too-common view that creative art cannot depend in any way on computers. For the "bigger pictures" that inspired the exhibition's title weren't produced with Hockney's oils, paintbrush, and easel, but with the help of computer software designed for colour graphics—specifically, Adobe's *Photoshop* and the iPad's app *Brushes.* Hockney used *Brushes,* for example, to move and blend colours, and—using his fingers on the tiny screen—to draw lines of varying thickness on the developing image.

An unhappy coincidence, however, in that Hockney's fame, alongside the critical success of this particular exhibition, will very likely lead people to think that his latest work is an iconic example of computer art. "And what's wrong with that?"—Well, Hockney's software is due to Adobe and Apple, not to Hockney himself. Even more to the point, the novelty, skill, and creativity—and the aesthetic judgements—evident in the huge images hanging on the Academy's walls aren't due to, or even reflected in, the software as such.

*Photoshop* can be—and has been—used to produce images of indefinitely many different styles. Years ago, to be sure, Adobe's professional programmers created (sic) the then-novel code that would eventually enable anyone to buy it off the shelf and use it in their own art-making. But that code wasn't intrinsically connected with the specific nature of any of the artworks that would be produced with its help. That is, it involved no aesthetic judgements on its creators' part.

The computer art that's described in this book is very different. It's not merely computer-assisted (as Hockney's is), but computer-generated. In other words, the program—originally written by, or under the direction of, the human artist—is left to run with minimal or zero interference from the human being.

Sometimes, as in Harold Cohen's work, the program runs entirely by itself. The artworks that result are literally untouched by human hand—and, occasionally, untouched even by *post hoc* human choice, or selection. At other times, although the code "runs by itself" in the sense that it's not altered by human beings during the running process, *what it actually produces* depends partly on various sorts of interaction between the program and the human artist and/or observer. These interactions can range from bodily movements, through noises or temperature-changes caused by human beings, to conscious choices made by the observer in selecting certain images (or musical compositions) to be preferred over others. And of course, for *this* or *that* interaction to be possible, with *this* or *that* result, the code had to be created in the appropriate way in the first place. The program had to be aesthetically motivated, not just technically effective. Off-the-shelf software simply doesn't fit the bill.

As various chapters make clear, this raises many difficult questions about the locus of creativity in the overall human-computer system. And it makes the aesthetic appreciation of computer art more problematic than it is in the familiar halls of the Academy's current exhibition. In general, the more someone understands the processes involved in the production of an artwork (wielding a paintbrush, perhaps, or turning a potter's wheel), the better they are able to appreciate the artist's achievement. But the code, in computer art, is even less evident than the chemicals and brush-strokes of traditional fine art. Worse: even if the code were to be made evident, many people would find it hard, or impossible, to understand.

These points, and many others, are explored in this book. For its aim is not only to describe a wide range of computer art, but also to indicate the many philosophical and aesthetic problems raised by this new genre. The answers are hotly contested, so don't expect a calm consensus in the following pages.

One thing, however, is agreed: the computer, here, is being used by the human artist not as a mere tool, but as a partner (or perhaps a quasi-partner) in the creative endeavour.

Brighton, England
2012

Margaret A. Boden

# Preface

## Why Does Computing Matter to Creativity?

This book, *Computers and Creativity*, examines how computers are changing our understanding of creativity in humans and machines. It contains chapters from twenty-five leading researchers in this field, on topics ranging from machine-assisted art creation, music composition and performance to formal theories of creativity and the emergence of novelty in natural and artificial systems. Before introducing these contributions we thought it useful to reflect on why we feel this book is both timely and important.

In just a single generation, computers and information technologies have brought about seismic changes in the way we communicate, interact, learn and think. Yet while these technologies are now well integrated into the fabric of modern society, their operation, design, and potential is understood by relatively few people. This limited appreciation of computing might explain why there remains a general reluctance to see its practice as something creative, and computers as machines that present a radical new potential for extending our own creativity.

Whilst general society may not think of computing as being a creative enterprise, we find ourselves in a world where we are now dependent on computers in almost every aspect of contemporary culture. Computers have become an extension of ourselves and how we communicate and think, even changing the way we think. They form a complex network of dependencies around us, and are constantly and rapidly developing, ever expanding in their role as a dynamic cultural and creative partner.

However the majority of traditional computing education and training has struggled to keep abreast of these changes. In September 2011, Google chairman Eric Schmidt criticised UK education, claiming: "Your IT curriculum focuses on teaching how to use software, but gives no insight into how it's made. That is just throwing away your great computing heritage." Art and Science need to be brought back together if we are to better tackle the challenges this rich entanglement with technology brings. And that doesn't just go for art either, to be a successful sociologist, journalist or social entrepreneur, for example, a deeper understand of computing as a creative discipline is becoming increasingly indispensable.

Creativity is critical for our ability to function and change as a society. Yet until recently, the practice of computing has not formally situated itself around the exploration of creative artistic ideas. Rather it has been taught in the main from a scientific and engineering perspective, using data structures (how to represent data) and algorithms (how to process or manipulate data) to directly solve problems. One of the great challenges for computing is to achieve a fuller understanding of process and representations which are beyond those that are easily computable or even fully comprehensible by humans. Necessarily, human design of software requires reducing difficult and complex concepts to far simpler abstractions that can be practically implemented, in some cases even ignoring those aspects of a phenomena that are too complex to express directly in a program. One way to overcome this limitation is to design programs that are capable of initiating their own creativity—to increase their complexity and discover ways of interacting independently of human design. Yet people don't naturally think of creative expression in terms of formal algorithms, leading to a perceived gap between natural creative human expression and computation.

Despite these difficulties, a field known as "creative coding" has emerged as an artistic practice of rising popularity. Here, software is considered a medium for creative expression, and the field has been enthusiastically embraced by many artists, designers and musicians. Software undergoes development at a pace and complexity that far exceeds all prior tools humans have developed, so these practitioners see the computer as something more than a benign tool such as a chisel or paintbrush. However, many artists find their artistic expression limited by a lack of knowledge in how to program *creatively*. While social and information networks allow easy access to a vast repository of resources and examples, what is often missing is a cogent technical, historical and philosophical foundation that allows practitioners to understand the "how and why" of developing creativity with computers. We hope this book makes important contributions by engaging with these foundational issues.

It is our belief that we now need to embrace and support the new forms of creativity made possible by technology across all forms of human endeavour. This creativity is important because it provides opportunities that have not been previously available, and are necessary if we are to address the complex challenges we face in our increasingly technology-dependent world.

Many excellent titles that look at creativity in general already exist.[1] Similarly, many works on the technical or didactic aspects of creative coding can be found, and are becoming standard in many university computing and design departments. However, due to a growing interest in appreciating computing as a creative discipline, and as a means of exploring creativity in new ways, the time is right for an edited collection that explores the varied relationships between computers and creativity. This book differentiates itself from general books on creativity or artistic coding because it focuses on the role of computers and computation in defining,

[1] Here we would suggest titles such as the *Handbook of Creativity* (edited by Robert J. Sternberg, Cambridge UP, 1999) and Margaret Boden's *The Creative Mind: Myths & Mechanisms* (2nd edition, Routledge, London, 2004).

augmenting and developing creativity within the context of artistic practice. Furthermore, it examines the impact of computation on the creative process and presents theories on the origins and frameworks of all creative processes—in human, nature, and machine.

Many of the book's authors come from an interdisciplinary background. Indeed, the origins of this book arose from a 2009 seminar on interdisciplinary creativity organised by the editors (McCormack and d'Inverno) and Professor Margaret Boden (University of Sussex), held at Schloss Dagstuhl–Leibniz-Zentrum für Informatik in Germany (http://www.dagstuhl.de/09291). Participants included artists, designers, architects, musicians, computer scientists, philosophers, cognitive scientists and engineers. With such diversity you might wonder what, if anything, was able to be understood and discussed beyond the traditional interdisciplinary boundaries and misinterpretations. It turned out that everyone passionately supported the view that computers have a substantial role to play in developing new forms of creativity, and the value of better understanding creativity from computational models in all its varied guises.

This book will appeal to anyone who is interested in understanding why computers matter to creativity and creative artistic practice. It is a proudly interdisciplinary collection that is suited to both those with a technical or scientific background along with anyone from the arts interested in ways technology can extend their creative practice. Each chapter arose in response to group discussions at the Dagstuhl seminar, and has undergone extensive review and development over a sustained period since, leading to what we hope will be a seminal volume on this topic that will remain relevant for many years to come.

## Summary of Contributions

The book is divided into four sections: Art, Music, Theory and an Epilogue. However, as we have tried to make each chapter self-contained, the reader may read chapters in any order if they wish.

Part I, *Art*, addresses the long-standing question of machine creativity: can we build a machine that is capable of making art? And not just art, but good or even great art. Art that is exhibited in major art museums, prized and respected for its creative brilliance. Since the earliest days of computing, the idea of a machine being independently creative has been challenged. As Ada Lovelace famously claimed, a computer cannot be an artist because a computer cannot *originate* anything. All the machine does is what it is told to do, so how can a machine be independently creative?

Of course these arguments are closely tied to the history of Artificial Intelligence (AI), a research effort now more than sixty years old. The most famous and celebrated example of a "creative painting machine" is the *AARON* system of Harold Cohen. Cohen's initial investigations followed the "GOFAI" (Good Old-Fashioned Artificial Intelligence) approach to automated painting, but over its forty year history has developed considerably, producing an impressive oeuvre of paintings in collaboration with its creator. Cohen remains reluctant to ascribe independent creativity to AARON and sees the software as an extension of his artistic process rather than an independent, autonomous creative entity (he also acts as a curator and filter, carefully selecting specific images from AARON's prolific output).

Simon Colton's *Painting Fool* (Chap. 1) is the 21st-century continuation of research pioneered with AARON. Colton's bold and ambitious goal is to build a computer painter recognised in its own right as an independent artist. He deftly uses a diverse array of methods from contemporary AI, and anticipates the use of many more if he is to achieve his goal. Like Cohen, this ambitious agenda may require a lifetime's work, and also similarly, Colton is not deterred by this prospect. His chapter also addresses a number of criticisms and philosophical issues raised in both the idea of creating a computer artist, and the exhibition and appreciation of paintings made by a machine.

The chapter by Jon McCormack takes a very different approach to the problem of machine creativity. He sees the processes of biological evolution as a creative algorithm that is eminently capable of being adapted by artists to allow a machine to originate new things. Importantly, these "new things" (behaviours, artefacts) were not explicitly stated by the programmer in authoring the program. Using ideas drawn from biological ecosystems, he illustrates the creative potential of biological processes to enable new kinds of machine creativity. Here the computer is able to discover new artistic behaviours that were not explicitly programmed in by the creator, illustrating one way in which Lady Lovelace's enduring criticism can be challenged.

Pioneering artist Frieder Nake has been working with computational art since the 1960s. Nake frames creativity as a "US American invention" and through a series of vignettes examines the processes of developing creative works from the earliest days of digital computer art. As one of the first artists to create work with computers, Nake is uniquely placed to appreciate and reflect on over 40 years of endeavour in this field. His evaluation of the work of Georg Nees, A. Michael Noll, Vera Molnar, Charles Csuri, Manfred Mohr, Harold Cohen and even himself is fascinating.

Both Nake and Cohen are highly sceptical about machines ever being autonomously creative, and this is explored in the final chapter of this section: a discussion on machine creativity and evaluation between Nake, Cohen and a number of other Dagstuhl participants. These informal, and sometimes frank discussions reveal the complexities and diversity of opinion on the possibility of developing machines capable of independent artistic creativity that resonates with human artists. This chapter has been included for both its insights and its historical significance in documenting a rare discussion between several of computer art's most experienced and significant practitioners.

Part II, *Music*, deals with issues related to computers, music and creativity. A major challenge for machine creativity is in musical improvisation: real time, live interaction between human and non-human performers. This not only sets challenges for efficiency and on-the-fly decision making, but also in articulating what encompasses musically meaningful interactions between players. The chapter by François Pachet draws on the concept of "virtuosity" as an alternative way of understanding the challenge of improvisation. Pachet aims to create a computational musician who, in its improvisational skill, would be as good as the best bebop jazz musicians. He describes in detail the construction of a system that is capable of competently improvising with, and challenging, professional jazz musicians. Many think of AI's most public successes as game playing (such as Deep Blue's defeat of world chess champion Garry Kasparov in 1997) or mathematical problem solving, but as demonstrated by a number of authors in this book, intelligent musical interaction with computers is now a real possibility.

The goal of musically meaningful interaction between human and machine performers is the basis of what has become known as "Live Algorithms". The chapter by Tim Blackwell, Oliver Bown and Michael Young summarises a series of frameworks for human-machine interaction and improvisation inspired by the Live Algorithms model. The authors detail the kinds of interactions necessary for musically meaningful exchanges to occur and document some recent projects and research in this area.

The idea of a computer as "creative partner" is a major topic of this book. In combination, how can humans and computers expand our creative consciousness? The chapter by Daniel Jones, Andrew Brown and Mark d'Inverno details how computational tools extend and modify creative practice: challenging old assumptions and opening up new ways to simply "be creative".

Rather than looking for a general theory of human creativity through the work of others, researcher and musician Palle Dahlstedt introspected deeply about his own creative processes. This has lead to his theory of how materials, tools and ideas all interact and affect the creative process in complex, layered networks of possibility. While the theory comes from a musical understanding, it is broadly applicable to any creative discipline based around computers and software.

Many artists working with computers do so at the level of writing their own code. Coding is a unique form of artistic endeavour, which is often poorly understood as it lacks the extensive mainstream critical analysis and heritage found in more traditional art practices. Alex McLean and Geraint Wiggins—both coders and composers—examine the special relationship between a computational artist and their programming environment. Borrowing the art idea of the bricolage, they examine how perceptions affect the creative process when working with code. It is interesting to compare the use of feedback processes discussed by McLean & Wiggins, Dahlstedt, Jones, Brown & d'Inverno in relation to the current design of creative software, which often does little to facilitate or enhance the types of feedback emphasised as crucial by these authors.

Personal- and practice-based understandings of creativity are contextualised next in Part III, *Theory*. As discussed in Part I, for any machine to be creative it is argued that it must have some way of evaluating what it is doing. Philip Galanter undertakes an extensive survey of methods used in computational aesthetic evaluation: considered a first step in designing machines that are able to produce aesthetically interesting output. Although the chapter focuses primarily on visual aesthetics, the techniques can be applied more broadly, and Galanter's chapter provides a distinctive and comprehensive survey for researchers entering this challenging field. Similarly, Juan Romero and colleagues look at perceptual issues in aesthetic judgement and discuss how a machine might take advantage of things like psychological models of creativity. Both these chapters provide a much-needed overview of the field that has previously been lacking.

While the computer has brought new creative possibilities for artists, designers and performers, computer science has challenged traditional definitions of creativity itself. Over the last two decades, Jürgen Schmidhuber has developed a formal theory of creative behaviour, one that he claims explains a wide variety of creative phenomena including science, art, music and humour. Schmidhuber sees creativity as the ability of an agent to create data that through learning becomes subjectively more compressible. What humans term "interesting" is a pattern (image, sculpture, poem, joke, etc.) that challenges our compression algorithm to discover new regularities from it. Similarly, the chapter by Alan Dorin and Kevin B. Korb challenges the long-held definition of creativity that relies on a concept of appropriateness or value. Dorin and Korb define a creative system as one that can consistently produce novel patterns, irrespective of their value. These definitions appear to accommodate a number of criticisms levelled at previous definitions of creativity. For example, that some discovery may lie dormant for decades or centuries before its "value" is recognised, or that aesthetic appreciation is a truly subjective thing. It is interesting to read these theories in light of the dialogue of Chap. 4.

A different approach is taken by Oliver Bown, who distinguishes two fundamentally different kinds of creativity: generative and adaptive. The main distinction is the teleology of each – generative creativity is not goal-directed, adaptive creativity is. Bown also looks at the role of social processes in determining creativity often (mistakenly) ascribed exclusively to individuals.

Finally Peter Cariani presents his theory of emergent creativity, which like Schmidhuber, he has been working on for over two decades. Cariani shows how new informational primitives arise in natural systems and presents a detailed and ambitious framework for developing creatively emergent artificial systems.

Throughout this book you will find many different definitions of creativity and opinions of what (if any) level of autonomy and creativity might be possible in a machine. For example, Nake and, to an extent, Pachet downplay the importance of creativity in individuals. In Pachet's case, he demonstrates a system that can competently improvise with professional jazz musicians to illustrate how virtuosity, rather than creativity, is the predominate factor in musical improvisation. In a sense Pachet (a jazz musician himself) has been able to begin "reverse engineering" the complex motifs employed by famous jazz musicians such as Charlie Parker and Dizzy Gillespie. His challenge is to compute the "99 % explainable stuff" of jazz music and make serious inroads into the "1 % magic" that we might intuitively call human creativity. Computer scientists such as Schmidhuber see the way forward in terms of formal, computable definitions, since in theory they can be implemented and verified practically on a computer. Of course, any formal model of creativity requires abstractions away from the complexity of real human creative practice, so any such model could never fully represent it. Conceivably, neuroscience will eventually provide a full understanding of the mechanisms of human creativity, potentially overcoming current difficulties in validating computer models of human creative processes.

To conclude the book, Part IV, *Epilogue*, contains a short chapter that poses questions that were raised while editing this volume. As is often the case with new and emerging research fields, we are left with many more questions than answers and here what we consider the twenty-one most interesting and critical questions that this book has inspired are summarised. Competently answering these questions will take decades of research and investigation, the results easily filling many more volumes like this.

Whatever your views on creativity are, and whether you think a machine is capable of it or not, this book presents many new and inspiring ideas—wonderfully written and passionately argued—about how computers are changing what we can imagine and create, and how we might shape things in the future. We hope you enjoy reading *Computers and Creativity* as much as we have enjoyed producing and editing it.

Melbourne, Australia and London, England Jon McCormack and Mark d'Inverno
2012

# Acknowledgements

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We would also like to acknowledge Schloss Dagstuhl–Leibniz-Zentrum für Informatik in Germany and all the participants at the seminar we organised in 2009, where the genesis of this book was formed. Even though not all were able to contribute a chapter, we're sure that their influence and ideas from the seminar will have found their way into many of the contributions to this volume.

We also thank our universities, Goldsmiths, University of London and Monash University, for supporting the editing and production of this volume. Indeed Goldsmiths has been a wonderfully inspiring place to develop many of the ideas around creativity and computing which is home to Mark and where Jon is a visiting research fellow. Much of the research and teaching at Goldsmiths is aligned with the spirit of this book in understanding the relationship between technology and creativity. We acknowledge the support of The Centre for Research in Intelligent Systems, and the Centre for Electronic Media Art (CEMA), Monash University, who provided funds and assistance for the original seminar. Fiammetta Ghedini did an excellent job designing the cover image. We would also like to thank our publisher, Springer, and in particular Ronan Nugent for his invaluable support and assistance in seeing this book through into print. We really enjoyed working with Margaret Boden in co-organising the Dagstuhl seminar and would like to thank her especially for writing the Foreword to this book—her influence is abundantly clear in so much of the work presented in the chapters that follow.

Finally, we dedicate this book to our families: Julie, Imogen, Sophie, Melly, Felix, Olive and Iris.

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# Contributors

**Tim Blackwell** Department of Computing, Goldsmiths, University of London, London, UK

Tim Blackwell is a senior lecturer in Computing at Goldsmiths, University of London. He has degrees in physics, theoretical physics and computer science and has researched a wide range of subjects including quantum field theory, condensed matter theory, computer music, digital art and swarm intelligence. He is well known for the application of swarms to improvised music, and his Swarm Music system has been the subject of numerous articles, radio programmes and a Discovery Channel documentary. His work in computational swarm intelligence has focused on dynamic optimisation problems, bare bones and discrete recombinant swarms and theoretical analysis of particle swarm optimisation. More recent work includes modelling animal social learning in spatial environments. He was Principal Investigator for the EPSRC funded Live Algorithms for Music research network, and was joint Principal Investigator for the EPSRC Extended Particle Swarms project.

**Oliver Bown** Design Lab, Faculty of Architecture, Design and Planning, University of Sydney, Sydney, NSW, Australia

Oliver Bown is an electronic musician, programmer and researcher in computing, evolutionary and adaptive systems, and music. He completed his PhD from Goldsmiths, University of London, in 2008 studying the evolution of human musical behaviour using multi-agent simulations, under the supervision of Geraint Wiggins and Tim Blackwell. From 2008 to 2010 he worked at the Centre for Electronic Media Art with Jon McCormack on the Australian Research Council funded project, *Computational Creativity, an Ecosystemic Approach*. His electronic music projects include the duo *Icarus*, the improvisation collective *Not Applicable* and the Live Algorithms for Music research group.

**Andrew R. Brown** Queensland Conservatorium of Music, Griffith University, Brisbane, Australia

Andrew R. Brown is Professor of Digital Arts at the Queensland Conservatorium of Music, Griffith University in Brisbane, Australia. His research interests include live algorithmic music, the aesthetic possibilities of computational processes, and the design and use of creativity support tools. He is an active computer musician, computational artist, and educator.

**David C. Brown** AI Research Group, Computer Science Department, Worcester Polytechnic Institute, Worcester, MA, USA

David C. Brown is Professor of Computer Science and Professor of Mechanical Engineering at Worcester Polytechnic Institute. From 2001-2011 he was the Editor in Chief of the Cambridge UP journal *AIEDAM: AI in Engineering, Design, Analysis and Manufacturing*. His research interests include computational models of engineering design, and the applications of AI to Engineering and Manufacturing. In addition he has interest in Intelligent Interfaces and in Computational Creativity.

**Paul Brown** Informatics, University of Sussex, Brighton, UK

Paul Brown is an artist and writer who has specialised in art, science and technology since the late 1960s and in computational and generative art since the mid-1970s. His early work included creating large-scale lighting works for musicians and performance groups like Meredith Monk, Music Electronica Viva and Pink Floyd. He has an international exhibition record that includes the creation of both permanent and temporary public artworks and has participated in shows at major venues, including the Tate, Victoria & Albert Museum and ICA in the UK, the Adelaide Festival, ARCO in Spain, the Substation in Singapore and the Venice Biennale. He is an honorary visiting professor and artist-in-residence at the Centre for Computational Neuroscience and Robotics, University of Sussex, UK and also Australia Council Synapse Artist-in-Residence at the Centre for Intelligent System Research, Deakin University, Australia.

**Adrian Carballal** Faculty of Computer Science, University of A Coruña, Campus de Elviña, A Coruña, Spain

Adrian Carballal holds a BSc and a PhD in Computer Science from the University of A Coruña (Spain) were he works as post-doctoral research associate at the Department of Information Technologies and Communications. His main research interests include Image Processing and Computer Graphics.

**Peter Cariani** Department of Otology & Laryngology, Harvard Medical School, Boston, MA, USA

Peter Cariani's training and work has involved theoretical biology, biological cybernetics, and neuroscience (BS 1978, MIT, biology; MS 1982, PhD 1989, Binghamton University, systems science). His doctoral work developed a semiotics and taxonomy of self-constructing adaptive systems, and explored epistemic implications of evolutionary robotics. For the last two decades Dr. Cariani has investigated temporal coding of pitch, timbre, and consonance in the auditory system and proposed neural timing nets for temporal processing. He is currently engaged in auditory scene analysis research. He has served as external scientific consultant for the John Templeton Foundation on emergence and consciousness. He is a Clinical Instructor in Otology and Laryngology at Harvard Medical School and teaches courses on music perception and cognition at MIT and Tufts. www.cariani.com.

**Harold Cohen** University of California, San Diego, CA, USA

Harold Cohen was born in London in 1928 and moved to the USA in 1968. He is a practising artist, having represented the UK at the Venice Biennale, 1966, and represented the US at the Tsukuba World Fair, 1985. He has exhibited at the Tate Gallery, London, Museum of Modern Art, San Francisco, Stedelijk Museum, Amsterdam, Brooklyn Museum, New York, Computer Museum, Boston, and the Ontario Science Center, Toronto. His artworks are held in many private and public collections worldwide. He is currently a distinguished Emeritus Professor, UCSD, and the Founding Director, Center for Research in Computing and the Arts, UCSD. Cohen is widely known as the creator of *AARON*, a semi-autonomous art-making program that has been under continuous development for nearly forty years.

**Simon Colton** Computational Creativity Group, Department of Computing, Imperial College, London, UK

Simon Colton is a Reader in Computational Creativity in the Department of Computing at Imperial College London, and an EPSRC Leadership Fellow. He leads the Computational Creativity Group (ccg.doc.ic.ac.uk) where researchers study fundamental notions of creativity in software via applications to graphic design, mathematical discovery, video game design and the visual arts. Dr. Colton has written more than 130 papers, and his research has won national and international awards. He is a co-organiser of the AI and Games Industry/Academic Research Network (www.aigamesnetwork.org) and is best known for his HR mathematical theory formation software and *The Painting Fool* automated artist (www.thepaintingfool.com).

**João Correia** Department of Informatics Engineering, University of Coimbra, Coimbra, Portugal

João Correia received an MSc degree in Computer Science from the University of Coimbra (Portugal) in 2011. He is currently a PhD candidate at this university. He is also a researcher for the Cognitive Media Systems group at the CISUC—Centre of Informatics and Systems of the University of Coimbra. His main research interests include Computer Vision, Evolutionary Computation, Neuroscience and Machine Learning.

**Palle Dahlstedt** Dept. of Applied Information Technology, University of Gothenburg, Göteborg, Sweden

Palle Dahlstedt is a composer, improviser and researcher from Sweden. He is Associate Professor in computer-aided creativity at the Department of Applied IT, and lecturer in composition at the Academy of Music and Drama, at the University of Gothenburg. He holds MFA and MA degrees in composition from there, and a degree in composition from the Malmö School of Music, Lund University. He holds a PhD in design and media from Chalmers University of Technology. As a composer, he received the Gaudeamus Prize in 2001, and he performs regularly as an improviser on piano or electronics, alone and in various constellations.

**Mark d'Inverno** Department of Computing, Goldsmiths, University of London, London, UK

Mark d'Inverno holds an MA in Mathematics and an MSc in Computation from Oxford University and a PhD from University College London in Artificial Intelligence. He is Professor of Computer Science at Goldsmiths, University of London and for four years between 2007 and 2011 was head of the Department of Computing which has championed interdisciplinary research and teaching around computers and creativity for nearly a decade. He has published over 100 articles including books, journal and conference articles and has led recent research projects in a diverse range of fields relating to computer science including multi-agent systems, systems biology, art, design and music. He is currently the principal investigator or co-investigator on a range of EU and UK projects including designing novel systems for sharing online cultural experiences, connecting communities through new techniques in video orchestration, building online communities of music practice and investigating new ways of integrating London universities with London's creative and cultural sectors. During the final editing of this book he was enjoying a research sabbatical shared between the Artificial Intelligence Research Institute in Barcelona and Sony Computer Science Laboratory in Paris. He is a critically acclaimed jazz pianist and composer and over the last 25 years has led a variety of successful bands in a range of different musical genres.

**Alan Dorin** Centre for Electronic Media Art, Monash University, Clayton, Victoria, Australia

Alan Dorin is a researcher in electronic media art and artificial life at the Centre for Electronic Media Art, Monash University, Australia. His interests include animation and interactive media, biology (artificial and natural), computer science, history, music, philosophy, self-assembly, visual art and the links which bind these fields together. Alan received his PhD in Computer Science in 1999 from Monash University and degrees in Applied Mathematics (Monash 1991) and Animation and Interactive Media (RMIT 1995).

**Philip Galanter** Department of Visualization, Texas A&M University, College Station, Texas, USA

Philip Galanter is an artist, theorist, curator, and an Assistant Professor at Texas A&M University conducting graduate studios in generative art and physical computing. His research includes the artistic exploration of complex systems, and the development of art theory bridging the cultures of science and the humanities. Philip creates generative hardware systems, video and sound art installations, digital fine art prints, and light-box transparencies. His work has been shown in the United States, Canada, the Netherlands, and Peru. Philip has written for both art and science publications, and was a collaborating curator for Artbots 2002 and 2003, and COMPLEXITY.

**Daniel Jones** Goldsmiths, University of London, London, UK

Daniel Jones is a doctoral researcher at Goldsmiths, University of London. His research focuses on the relationships between complexity, evolution and social dynamics, and the wider affordances of complex systems towards creative activity. With an MA in Sonic Arts and an honours degree in Philosophy with Computer Science, he has a committed belief in cross-fertilisation across domains. He lectures on process music, mathematics, and digital sociology, and has worked with the National Institute for Medical Research and Dresden's Institute for Medical Informatics.

**Kevin B. Korb** Clayton School of IT, Monash University, Clayton, Victoria, Australia

Kevin Korb is a Reader in the Clayton School of Information Technology, Monash University. He received his PhD in philosophy of science from Indiana University in 1992. His research interests include Bayesian philosophy of science, causal discovery algorithms, Bayesian networks, artificial life simulation, and evolutionary simulation. He is the author of 'Bayesian Artificial Intelligence' (CRC, 2010) and 'Evolving Ethics' (Imprint Academic, 2010) and co-founder of the journal *Psyche*, the Association for the Scientific Study of Consciousness and the Australasian Bayesian Network Modelling Society. He was an invited speaker at the Singularity Summit (Melbourne, 2010).

**Jon McCormack** Centre for Electronic Media Art, Monash University, Caulfield East, Victoria, Australia

Jon McCormack is an Australian artist and researcher in Artificial Life, Creativity and Evolutionary Music and Art. He holds an Honours degree in Applied Mathematics and Computer Science from Monash University, a Graduate Diploma of Art from Swinburne University and a PhD in Computer Science from Monash University. He has held visiting research positions at the University of Sussex (UK), Goldsmiths, University of London and the Ars Electronica Future Lab in Linz, Austria. He is currently Associate Professor in Computer Science and co-director of the Centre for Electronic Media Art (CEMA) at Monash University in Melbourne, Australia. CEMA is an interdisciplinary research centre established to explore new collaborative relationships between computing and the arts.

**Alex McLean** Interdisciplinary Centre for Scientific Research in Music (ICSRiM), University of Leeds, Leeds, UK

Alex McLean is a PhD candidate on the Arts and Computational Technology programme at the Department of Computing in Goldsmiths, University of London. His research applies an embodied approach to representation in improvised computer music, informed by his practice as a live coding musician. He is a member of slub, a live coding band making people dance to their algorithms at festivals across Europe. He is active across the electronic arts, co-founding the long running *dorkbotlondon* meetings, and the award-winning *runme.org* software art repository.

**Penousal Machado** Department of Informatics Engineering, University of Coimbra, Coimbra, Portugal

Penousal Machado, PhD, teaches Artificial Intelligence and Computational Art at the University of Coimbra, Portugal. He is the author of more than 50 refereed journal and conference papers in these areas and co-edited the book “The Art of Artificial Evolution”. His research interests include computational art, artificial intelligence and nature-inspired computation. He is the recipient of several scientific awards, including the prestigious award for Excellence and Merit in Artificial Intelligence (PremeIA) granted by the Portuguese Association for Artificial Intelligence. His work was featured in Wired magazine and exhibited at the Museum of Modern Art (MoMA), USA.

**Frieder Nake** University of Bremen, Bremen, Germany

Frieder Nake is a professor of interactive computer graphics at the computer science department of the University of Bremen. He also teaches digital media at the University of the Arts, Bremen. He holds a Diplom and a Dr.rer.nat. degree in mathematics from the University of Stuttgart. He is recognised as a pioneer of computer art, with his first exhibition held in 1965. Nake has contributed to the aesthetics and the theory of digital art for more than 40 years. He has recently focussed his work on the *compArt* database of digital art and the aesthetic laboratory at the University of Bremen.

**François Pachet** Sony CSL-Paris, Paris, France

Francois Pachet received his PhD degree and Habilitation from University of Paris 6, Paris, France. He is a Civil Engineer (Ecole des Ponts and Chaussées) and was an Assistant Professor in Artificial Intelligence and Computer Science, Paris 6 University, until 1997. He then set up the music research team at SONY Computer Science Laboratory, Paris, which conducts research in interactive music listening and performance. He developed several innovative technologies and award winning systems (*MusicSpace*, constraint-based spatialisation, *PathBuilder*, intelligent music scheduling using metadata, *The Continuator* for Interactive Music Improvisation). He is the author of over 80 scientific publications in the fields of musical metadata and interactive instruments.

**Juan Romero** Faculty of Computer Science, University of A Coruña, Campus de Elviña, A Coruña, Spain

Juan Romero, PhD, is an associate professor at the University of A Coruña, Spain. He is founder of the “Working Group in Music and Art” of EvoNet—the European Network of Excellence in Evolutionary Computing—and of the European Workshop on Evolutionary Art and Music (evoMUSART). He is the author of more than 30 refereed journal and conference papers in the areas of evolutionary computation and artificial intelligence, and editor of a special issue of the MIT Press journal “Leonardo” and of the book “The Art of Artificial Evolution”, published by Springer in its Natural Computing Series.

**Jürgen Schmidhuber** IDSIA, University of Lugano & SUPSI, Manno-Lugano, Switzerland

Jürgen Schmidhuber is director of the Swiss Artificial Intelligence Lab IDSIA (since 1995), Professor of Artificial Intelligence at the University of Lugano, Switzerland (since 2009), Head of the CogBotLab at TU Munich, Germany (since 2004, as Professor Extraordinarius until 2009), and Professor SUPSI, Switzerland (since 2003). He obtained his doctoral degree in computer science from TUM in 1991 and his Habilitation degree in 1993, after a postdoctoral stay at the University of Colorado at Boulder. In 2008 he was elected a member of the European Academy of Sciences and Arts. He has published more than 250 peer-reviewed scientific papers on topics such as machine learning, mathematically optimal universal AI, artificial curiosity and creativity, artificial recurrent neural networks, adaptive robotics, algorithmic information and complexity theory, digital physics, the theory of beauty, and the fine arts.

**Geraint Wiggins** School of Electronic Engineering and Computer Science, Queen Mary, University of London, London, UK

Geraint A. Wiggins was educated in Mathematics and Computer Science at Corpus Christi College, Cambridge, and then to PhD in Computational Linguistics at the University of Edinburgh. He took a second PhD in Musical Composition at Edinburgh, in 2005. Since 1987, Geraint has been conducting research on computational systems for music, with a strong emphasis on cognitively motivated approaches. He was Professor of Computational Creativity in the Department of Computing in Goldsmiths, before taking a new position at Queen Mary College, University of London in 2011.

**Michael Young** Department of Music, Goldsmiths, University of London, London, UK

Michael Young is a composer with interests in improvisation, generative media and artificial intelligence. He is a Senior Lecturer and Head of the Department of Music, Goldsmiths, University of London. His work explores real-time interaction and learning systems for performance, including the "_prosthesis" series for soloist and computer (oboe, flute, piano, cello). In "Argrophylax" (2006) and "ebbs-" (2008) players negotiate a musical score in dialogue with interpretation-sensitive electronics. He has collaborated in a number of joint science/visual arts projects: "Exposure" (2010), is a real-time generative installation and exhibition exploring sonification, human habitation and environmental change www.ground-breaking.net. Personal website: www.michaelyoung.info.