Artificial Intelligence and The Environment

AI Blueprints for 16 Environmental Projects Pioneering Sustainability

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The Pioneers

BECAUSE OF THE EVENTS of the world today, every person who participated in the first International AI and Environment symposium listed below deserves a medal and recognition. If we left you out, please get in touch and we can add you in, no problem. We thank all of you for your sweat and devotion to being caring technologists. I hope that life has been good to you in all ways. *Best wishes, Cindy.*

Paolo Avesani, Italy
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Brian Williams, USA
Steve Young, USA
Byoung-Tak Zhang, Germany

Carl Linnaeus, famous for naming all things in nature, shines a light on goddess Mother Earth removing the shroud of darkness (ignorance). Both AI and the human mind rely heavily on names of things. Image adapted from Fragment of Frontispiece by Jan Wandelaar (1690–1759) of Linnaeus, C. (1738), Hortus Cliffortianus.

About This Book

"This is not your usual collection of science papers, and these are not usual times."
– Tim Foresman, former chief environmental scientist for the United Nations

WE NEED TO BUILD a more sustainable human experience on our planet and AI can help. The book contains AI blue prints for 16 different important environmental projects. Created by more than 50 scientists, engineers and AI researchers around the globe, the chapters include AI systems for firefighting resource planning, toxic algae bloom prediction, waste water treatment, sustainable forestry, weather prediction, flood prediction, and systems for cooperation and sharing.

If you chose this book because you are hoping to use AI technology to help with the environment crisis, you have come to the right place. Scientists, educators and administrators from all different disciplines and all areas of the world are learning how to use AI technologies for the public good. Each chapter comes from a collection of papers from the first international AI and Environment workshop where pioneers used every AI trick in the book to produce blueprints to problems that plague us now. The AI methods used here are the brick and mortar of today's AI and includes software agents, neural nets, learning, search, genetic algorithms, integrated and hybrid AI and so on. The AI architectures in these chapters depict compositions of computing components that are as interconnected and interdependent as GAIA herself.

If you chose this book because you are an educator, or a student, I hope you will find the section "Classroom Connections" and the sets of questions at the end of each chapter useful and inspiring. Composed by world class AI and environmental scientists, each chapter has been reviewed and screened through a peer review process at IJCAI, the world's foremost international AI conference. All the chapters are from projects conducted at institutions with a long history of important contributions. Historically, the projects in these chapters were the first AI systems in the world to work on environmental problems. And as Tierney Thys, the National Geographic Explorer said, we have a lot of *caring* technologists.

During the book-making process The Extinction Rebellion began – students in more than 270 cities across the world went on strike to demand action on environmental issues. On 21 February 2019, the President of the European Commission, Jean-Claude Juncker, stated his intent to spend hundreds of billions of euros on climate-change mitigation, a fourth of the EU budget. Weather maps now have 2 additional colors for heat and new records for heat set with each passing day. The Intergovernmental Panel on Climate Change (IPCC) made an announcement that the early figures were wrong, and things are worse than we thought. Also during this time, the U.S. pulled out of the Paris Accord. News programs now have regular segments on pollution.

The good news is that we have a lot of technology and it can help deal with what is happening in the world. But we also need cooperation. In the US, beliefs about environmental problems are often highly political. Each of us has overcome obstacles to create these chapters. Despite the obstacles each scientist faced at the time, cooperation, friendship and love enabled us to overcome these obstacles. With the publication of this volume we share pioneering AI blueprints (software agents, system structures, and algorithms) for 16 environmental problems. As you skim, read, or study the Environmental AI systems described here, it is my hope that you have a spark or connect the dots to something or someone you already know, and this can give rise to something that helps us now – in our cities, in our classrooms, in our world.

Foreword

BY TIERNY THYS

National Geographic Explorer, marine biologist, educator, and founder of oceansunfish.org

DECADES AGO, the researchers whose work appears in this volume saw into the future and knew how crucial it would be for humanity to create extensive and innovative tools for long-term monitoring of our fast-changing environment. Nowhere is this more evident than in studies of our dynamic world ocean – that vast realm which hosts a mere 99% of Earth's habitable space. Our consumption and combustion of fossil fuels, as you know, is not only warming the ocean but shifting its pH to be more acidic, from 8.2 to 8.1 While this change may seem small, past natural shifts have taken between 5,000 and 10,000 years. We have made this shift happen at relatively lightning speed – 50-80 years.

The ocean is our bright blue planet's dominant feature – and to this day – remains our biggest unknown. If we are to make any meaningful progress in understanding our home and preparing for our future, we really need to dive inside the ocean and maintain a 24/7 presence. Alas, being air breathing, land-lubbing hominids, our undersea residency options are somewhat limited. That's where the combination of AI, underwater robotics and remote sensing from satellites come in as our most economical and time-efficient tools for exploring and documenting large expanses of the ocean. The workshop Cindy Mason organized, where the work in this volume of papers was first presented, helped catalyze interest, action and progress in this realm as well as many others.

The workshop was truly an important gathering, both nationally and internationally, and expansive in its coverage of the planet and its range of topics. It included the first underwater robot in Antarctica, a software agent that monitored for nuclear testing, software agents for storm warnings, water level monitoring, pollution monitoring, and so many things we now find essential to our future. From this workshop, it appears more scientists took up the mantle in Europe and continued the work, although it's odd in the U.S. there was a large time span with no further research in this area. It's helpful these papers are now to be finally published.

Today with such tools at the Oculus Rift virtual reality headset, Google Ocean and Caitlin Seaview's Underwater Streetview, Synthetic Aperture Radar and Sonar (SAR and SAS) imagery as well as Planetlabs, Skybox and our growing ability to image the ocean – coupled with aerial drones – wave gliders, Argo floats, slocum gliders, DIY ROVs and more – we are sailing ahead at full tilt, assisted by smart machines at our sides.

As Cindy has pointed out in some of her other papers, the machine/man partnership is absolutely crucial to increase our mechanistic understanding of ocean dynamics and, perhaps even more importantly, to reinvigorate our increasingly urbanized indoor masses to care deeply about the wonders and workings of the wild.

This volume of papers represents a group of people who are definitely forward-thinking and caring technologists and scientists. We need more people like this if we are to sustain ourselves into the bright future.

With gratitude, Tierney

Introduction

BY CINDY MASON

AI researcher, computer scientist, educator, and founder of 21stcenturymed.org

PIONEERING A SUSTAINABLE FUTURE means engineering environmental systems as dynamic and complex as nature itself. The data for an environmental problem is not just big, its big and hairy and lumpy. Environmental problems are often ill defined with incomplete, uncertain and sometimes totally absent information. There is not just an enormous amount of data, but complex combinations of time-series, satellite, weather station, flood and water instrumentation, human logs, etc. that can also vary in time and scale from a small collection of regions to the entire planet. There is also a need to integrate information and *the meaning of that information* across different kinds of media from hydro, spatial, topo and Landsat maps to images of species and handwritten notes. These varied kinds of data, formats and their meanings are also integrated across differing governments and organizations, each with their own rules and policies for use. AI technology is particularly well suited to help with big hairy data and complexity – they are AI's *raison d'être*. Each chapter in the book presents a pioneering AI system that takes on the challenges of an environmental problem. In Part I, 'Boots on the Ground', AI takes on projects like sewage treatment, water supply control, algae bloom prediction and fire fighting. In Part II, 'Data, Data Everywhere', the chapters lay out AI blueprints for biodiversity cataloging, product life cycle design and cross governmental, cross agency digital resource sharing. The authors pioneered AI systems using every trick in the AI hand book and then some – from fuzzy sets to automated planning to machine learning.

To address these complex scenarios of environmental projects, many of the pioneers here used what is called *hybrid AI*. Hybrid AI means using more than just one kind of AI, or using AI in combination with other kinds of computing like databases or high performance digital signal processing. Hybrid AI is used to solve a problem when just one AI method is not enough. So just machine learning, just fuzzy inferencing or language understanding or qualitative modeling… alone, these are not enough to work on most environmental problems. It is only through combining AI methods in novel ways that hairy environmental problems get solved. Environmental AI researchers knew this a long time ago, before AI was popular, and before the Paris accord existed and certainly before there was an inter governmental panel on climate change (IPCC). Perhaps it is because GAIA's ecosystems are so interconnected and interdependent that these hybrid AI solutions seem naturally suited for these problems.

The chapters are authored by individuals belonging to an international community of AI researchers known as IJCAI. So the chapters originate from New Zealand, Italy, Germany, Canada, the US and many other countries. Newcomers to AI will benefit by knowing that AI methods vary according to which part of the world you're in. For a long time Japan, China and Russia embraced fuzzy methods for all areas of AI, while in the US, fuzzy methods were very slow to be adapted, and scientists in the US were skeptical. So you will find many more fuzzy AI techniques used outside the US. Also there are periods of time when symbolic approaches to knowledge have been important and other times when mathematically centered representation of knowledge was king. Regardless of what is popular in your country or organization at the moment, it's about finding what works for the problem you have.

To find and use AI technology today you no longer need to be part of an elite AI club like IJCAI or AAAI. You'll find much of today's AI know-how, software and data is publicly shared through online courses, videos and websites. For instance, take a look at the website for project "Argo Float." With over 3800 ocean-going robots sampling our seas, the project has posted a data collection on the net that anyone can access, including an active map of the locations of each robot that has transmitted in the past 30 days. Another inspiring project, although not specific to AI, is the Rasperry Pi project. As I write this introduction, Carnegie Melon University has made all their AI software available free online, and the Pi community just announced a toolkit to build AI software agents. The new Pi 4 is out – its a quad processor and costs about 55 dollars, including power supply. The Raspberry Pi is a small unix based computer that fits in the palm of your hand, yet it has USB slots, two display ports and Bluetooth/Wi-Fi. They can be stacked, mounted on a wall, or fit in a pocket. They can also be used to build hybrid AI systems where conventional and AI systems work together.

Machine learning and neural nets help us recognize patterns from our sensor data and networks. Common sense AI methods help explain and share the meaning of data and decisions in a way that is accessible to people. Many AI technologies also help people to consider decisions in the face of uncertainty and incomplete information. AI automation, unlike us humans, can run 24/7 and robots can take us where we cannot go. Finding patterns in data, making tough decisions when dealing with imperfect and missing information, explaining and sharing the meaning of what we see… and doing this day after day, week after week, year after years.. These are all key features of most environmental problems. When the Fukushima nuclear disaster happened, robots went where we could not go and showed us what happened. AI is already part of pioneering sustainability.

Each group or individual whose project was represented at the first IJCAI AI and Environment workshop in Montreal has a chapter here.[1] Many of the projects included here have grown, expanded or inspired global environmental systems we use today. We can also learn that if a hybrid AI architecture can't help us, what should we do different. Students and innovative entrepreneurs may look at these systems as case examples of hybrid-AI architectures – adapting and innovating from the designs and architectures… reimagining some of these blueprints with drones, IOT and Raspberry PI's running software agents. These chapters show that AI has already been creatively applied across a number of environmental problems.

At the end of each chapter is the Classroom Connections. If you are a teacher or wish to use this book to instruct or build discussion in a classroom, the questions help stir thinking, deepen understanding and create new ideas. It's also where you can test your understanding. Answers are at the back of the book. There's also a Nutshell, if you're in a rush and just need to get the gist of what's in the book. There are a few entries with just one or a few pages. To me these are equally important to include, *e.g.* the entry on using AI to detect environmental crime. For readers with backgrounds outside of AI, it is helpful to explain how the word "domain" is used throughout the book. Because AI is generally about creating computationally intelligent behaviors, e.g. planning and scheduling, image analysis, learning, natural language understanding, etc., the word domain refers to the application of an AI method to a particular problem or domain. So for instance, firefighting and flood prediction would be considered a domain for applying AI. In attempting to solve a problem, new AI methods are often created. The AI method can then be used on other problems or domains. This is why we can look at the chapters as containing blueprints. I hope they inspire your own ideas for sustainability.

Good luck to us all,
Cindy Mason

1 The meeting was sponsored by NASA Ames, The U.S. National Research Council, the Canadian Meteorological Organization, the Canadian Society for Computational Studies of Intelligence, the International AI establishment called IJCAI and Cindy Mason.