Representing Space in Cognition

Interrelations of Behaviour, Language, and Formal Models

Edited by
Thora Tenbrink, Jan Wiener,
and Christophe Claramunt

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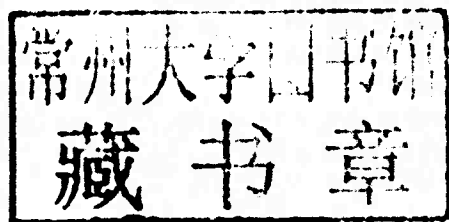
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Representing Space in Cognition

EXPLORATIONS IN LANGUAGE AND SPACE

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Preface

This book emerged from a collaborative interdisciplinary specialized workshop in 2010, located at the HWK Hanse Institute for Advanced Studies in Delmenhorst (Germany), <http://www.wayfinding.uni-bremen.de/workshop/>. The workshop concluded the Tandem project on 'Wayfinding strategies in behavior and language', funded by the Volkswagen Foundation, and furthermore followed up on excited debates at the Conference of Spatial Information Theory (COSIT) 2009. Based on the invitation of renowned experts in the various related fields, the workshop led to energetic discussion and a broad variety of inspirations for future interdisciplinary research in the field of spatial cognition. Our aim in compiling this book was to capture this spirit and enhance progress in this direction. Following the workshop we circulated a call among experienced researchers in the fields of cognitive science, psychology, linguistics, and computer science, inviting submissions and triggering a range of excited responses. We firmly believe that interdisciplinary research in this area carries considerable promise for enhancing state-of-the-art spatial assistance technology, based on solid empirical insights and specialized formal modelling techniques.

We would like to thank the Volkswagen Foundation, the COSIT committee, and the Hanse Institute for Advanced Studies for jointly financing the workshop, and the Volkswagen Foundation for funding the foregoing Tandem project. Further research funding by the DFG for the SFB/TR 8 Spatial Cognition Research Centre is acknowledged. We are grateful to our reviewers for substantially contributing to the quality of this book, and to the OUP editorial team—most particularly Julia Steer and Kate Gilks—for making the final editing steps a smooth and pleasant experience.

Thora Tenbrink
Jan Wiener
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Marios Avraamides is an Associate Professor of Cognitive Psychology at the University of Cyprus (Nicosia, Cyprus). Previously he has worked as a research scientist at the Max-Planck-Institute for Biological Cybernetics (Tübingen, Germany) and at the University of California, Santa Barbara (USA). His research interests lie within the field of spatial cognition and include among others the organization of spatial memories from different inputs and the spatial updating of information during movement.

Michael Barclay is currently developing natural language system software and doing associated consulting work for Life Inside Ltd. He graduated in engineering science from Trinity College Cambridge and spent twenty years designing and modelling radio systems. Needing a change he went back to University and obtained a PhD in computer science from Exeter. His principal focus is on machine learning of human language and in particular spatial language.

Mehul Bhatt is a researcher in the Cognitive Systems (CoSy) group within the Faculty of Mathematics and Informatics at the University of Bremen, Germany. He also serves as project leader within the Spatial Cognition Research Center (SFB/ TR 8) at the Universities of Bremen and Freiburg. Mehul studied economics (bachelors, India), Information Technology (masters, Australia), and computer science (PhD, Australia). Mehul publishes on spatial cognition, spatial representation and reasoning, commonsense and non-monotonicity, and applied ontology. He addresses applications in computational design analysis, behaviour interpretation, cognitive robotics, and dynamic GIS. Mehul has edited for the journals *Spatial Cognition and Computation, Human-Centred Computing and Information Sciences, Ambient Intelligence and Smart Environments*, and *Automation in Construction*.

Tad Brunyé is a Senior Cognitive Scientist with the US Army and a Research Assistant Professor at Tufts University (Medford, MA, USA). His primary interests

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Antony Galton is a Reader in Knowledge Representation at the University of Exeter, and has worked in the Computer Science department there since 1987. His research interests are focused on the analysis and representation of spatial and temporal knowledge, with particular reference to philosophical and ontological issues. He is the author of *The Logic of Aspect* (Oxford University Press, 1984) and *Qualitative Spatial Change* (Oxford University Press, 2000), as well as numerous papers in journals and edited collections.

Nathan Greenauer is an Assistant Professor of Applied Psychology at Pennsylvania State University, Berks (USA). Previously he was a postdoctoral research fellow in the Experimental Psychology Laboratory at the University of Cyprus (Nicosia, Cyprus). His research interests lie in the area of spatial cognition and include, among others, the study of the organization and structure of long-term spatial memory and spatial category formation. In particular, his research examines the role of egocentric and allocentric cues in the integration of spatial knowledge across experiences.

Joana Hois is a PhD student at the University of Bremen, Germany. She is a developer of the spatial module for the 'Generalized Upper Model', a linguistic ontology, and works on combining formal models of space with spatial language. Her current research activities are focused on modular ontologies of space in different domains and applications as well as on combining ontologies with different kinds of uncertainties.

Parisa Kordjamshidi is a PhD student at Katholieke Universiteit Leuven. She did her bachelor and masters degrees in computer science at the University of Isfahan and Tarbiat Modares University in Iran. Afterwards she was a university lecturer for computer science in Iran. In December 2008 she started her PhD on spatial language understanding from an artificial intelligence and machine learning point of view. Her ongoing PhD research is on structured machine learning for mapping natural language to formal spatial representations. She has formulated the first semantic evaluation task and benchmark of 'Spatial role labelling' to consider spatial semantics in SemEval2012.

Catherine Mello is an independent research consultant and translator. Prior to this, she was a postdoctoral fellow in the Experimental Psychology Laboratory at the University of Cyprus (Nicosia, Cyprus). As a consultant and instructor, she has provided workshops and training on the use of virtual reality in psychological research. Her research interests reside in multimodal spatial perception, navigation, and spatial updating. She also examines the roles and influence of technology on human spatial reasoning and performance.

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Nhung Nguyen was a PhD student and research assistant in the Artificial Intelligence Group at Bielefeld University. In her PhD thesis, conducted in the Collaborative Research Center 673—Alignment in Communication in the project C1—Interaction Space, she investigated how artificial, embodied (virtual) agents' different bodily sensor modalities form a representation of the agent's body and the space immediately surrounding it. Her research interests include cooperative and social behaviour in artificial agents, as well as perception and sensation for virtual humans, and spatial perspective taking.

Martijn van Otterlo lectures on Artificial Intelligence at the Radboud University Nijmegen (Netherlands). His PhD thesis at the University of Twente (Netherlands) was on the combination of reinforcement learning and logic (partially as a Marie Curie Fellow at the University of Freiburg, Germany). Recently he undertook a postdoctoral project (K.U. Leuven, Belgium) on computational logic for language, vision, and robotics. He has published the books *The Logic of Adaptive Behavior*

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Carl Schultz is a postdoctoral researcher working in the Cognitive Systems Group (CoSy) at the University of Bremen as a member of the DesignSpace project. His current research focus within DesignSpace is on modelling and reasoning about high-level spatial knowledge for architectural design. His primary research area focuses on methodologies for facilitating the development of qualitative spatial reasoning software applications; on this topic he completed his PhD in July 2010 at the University of Auckland, New Zealand.

Inessa Seifert is a postdoctoral research scientist at the German Research Centre for Artificial Intelligence (DFKI GmbH), where she works in the Intelligent Interfaces department. She holds a doctoral degree in Informatics from the University of Bremen with a thesis in artificial intelligence and spatial cognition on 'Spatial Planning Assistance: a Cooperative Approach'. While at Bremen, Inessa worked within the Cognitive Systems Research Group and the Transregional Collaborative Research Centre SFB/TR 8 Spatial Cognition. She holds a masters degree from the Technical University Berlin. Inessa is interested in spatial cognition, interactive maps, schematization, and information visualization approaches.

Holly A. Taylor is a Professor of Psychology at Tufts University (Medford, MA, USA). Her main research interest is to examine the mental representation of information, sometimes referred to as mental models or situation models, and how information sources influence the representation. She is particularly interested in the domains of spatial cognition and comprehension. She is the author of numerous empirical publications, as well as integrative book chapters. She was named a Fellow of the Association for Psychological Science (APS) in 2012.

Thora Tenbrink is a Senior Lecturer in Cognitive Linguistics at Bangor University (Wales, UK). She worked for ten years as a research scientist at the Faculty of Linguistics at Bremen University (Germany), and is a principal investigator in two projects in the Collaborative Research Centre SFB/TR 8 Spatial Cognition (Bremen/ Freiburg). Her main interest concerns the relationship between cognitive processes and linguistic representations. She is the author of *Space, Time, and the Use of Language* (Mouton de Gruyter, 2007), and editor (with Kenny Coventry and John Bateman) of *Spatial Language and Dialogue* (Oxford University Press, 2009).

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List of abbreviations

AAL	Ambient Assisted Living
AI	Artificial Intelligence
CAAD	Computer-Aided Architecture Design
CMP	Cognitive Model of Planning
CRF	conditional random field
DC	disconnected (RCC-8 relation)
DD	direction down
DR	direction right
EC	externally connected (RCC-8 relation)
EQ	equal (RCC-8 relation)
EST	Event Segmentation Theory
FOR	frame of reference
GIS	Geographic Information System
GPS	Global Positioning System
HP-TSP	human performance on the Travelling Salesman Problem
HPI	Haptic Pointer Interface
ICM-9	Internal Cardinal Direction Model
NN	nearest neighbour
NTPP	non-tangential proper part (RCC-8 relation)
NTPPI	non-tangential proper-part inverse (RCC-8 relation)
PO	partial overlap (RCC-8 relation)
PP	prepositional phrase
PrP	peripersonal
QSR	qualitative spatial representation
RCC	Region-Connection Calculus
RFID	Radio Frequency Identification
RIAS	Remote Infrared Audible Signage
SAS	spatial assistance system
SpQL	spatial qualitative labelling
SpRL	spatial role labelling

SSE	Structured Spatial Environment
SVM	support vector machine
TPP	tangential proper-part (RCC-8 relation)
TPPI	tangential proper-part inverse (RCC-8 relation)
TSP	Travelling Salesman Problem

Contents

Part 3: Human-centred assistance

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Representing space in cognitive science: from empirical insights via computational models to human-centred assistance

THORA TENBRINK, JAN WIENER,
AND CHRISTOPHE CLARAMUNT

Research in the areas of spatial language, spatial cognition, and spatial information theory has rapidly developed over the last few decades. This is reflected by the steadily growing number of researchers addressing spatial topics, national and international conferences and meetings, and major interdisciplinary research projects spanning a wide variety of issues from spatial behaviour, interaction, and knowledge representation to formal and computational models. Recent developments have now highlighted a widespread interest in establishing a reliable basis for combining insights and representation models from various sources and applications. The combination of perceptual and language-based representations, for example, has led to a better understanding and knowledge of how humans process space in various strands of research. Examples are findings as diverse as functional components associated with spatial prepositions (Coventry and Garrod, 2004; Carlson and van der Zee, 2005), the representation of direction (Klippel and Montello, 2007) and distance relations (Montello, 2009), a rich diversity of spatial planning processes reflected in language (Tenbrink and Wiener, 2009; Hölscher, Tenbrink, and Wiener, 2011), and the integration of functional (affordance-related, cf. Gibson, 1977) factors (Gorniak and Roy, 2007; Moratz and Tenbrink, 2008). Findings such as these highlight the potential of systematically combining the existing manifold approaches to interpreting spatial representations in language with behavioural navigation and action data, associated cognitive processes and strategies, and formal representation systems capturing cognitively relevant structures, categories, and features of space.