2009 AAAI Spring Symposium

Benchmarking of Qualitative Spatial and Temporal Reasoning Systems

Stanford University
March 23-25, 2009

Organizing Committee

Bernhard Nebel (University of Freiburg, DE)
Anthony G. Cohn (University of Leeds, UK)
Jean-François Condotta (University of Artois, FR)
Max J. Egenhofer (University of Maine, USA)
Ulrich Furbach (University of Koblenz-Landau, DE)
Jochen Renz (Australian National University, AUS)
Peter van Beek (University of Waterloo, CA)
Stefan Wölfl (University of Freiburg, DE)
Diedrich Wolter (University of Bremen, DE)

Funding Institutions

Transregional Collaborative Research Center SFB/TR 8 (University of Bremen and University of Freiburg, DE)

MONDAY, MAR 23

Welcome (9:00am – 10:30am)

Welcome
Introduction
Statements of Interest

∗ ∗ ∗ Coffee Break

Benchmarking in Theorem Proving (11:00am – 12:30pm)
Chair: Bernhard Nebel

Keynote Lecture:
Geoff Sutcliffe: *Evaluating Automated Theorem Proving Systems*.

Matthias Westphal and Stefan Wölfl: *Confirming the QSR Promise*.

∗ ∗ ∗ Lunch Break

Applications of Qualitative Reasoning (2:00pm – 3:30pm)
Chair: Reinhard Moratz

Carl Schultz, Robert Amor, and Hans Guesgen: *Towards A Theory of Application for QSTR Systems*.

Jason Jingshi Li and Jochen Renz: *Blocks World for the Real World — A Proposal*.

Torsten Hahmann and Michael Gruninger: *Detecting Physical Defects: A Practical 2D-Study of Cracks and Holes*.

∗ ∗ ∗ Coffee Break

Short Presentations (4:00pm – 5:30pm)
Chair: Jochen Renz

Debasis Mitra: *Explanation Generation over Temporal Interval Algebra*.

Sanjiang Li: *Combining RCC-8 with Qualitative Direction Calculi: Algorithms and Complexity*.

Joe Steinhauer: *A Representation Scheme for Description and Reconstruction of Object Configurations Based on Qualitative Relations*.

Shyamanta M. Hazarika: *Qualitative Spatial Change in Mereotopology: Mining Spatio-temporal Patterns*.

Anthony Cohn

James Pustejovsky: *The Qualitative Spatial Dynamics of Motion as Expressed in Language*.

Reception (6:00pm – 7:00pm)

TUESDAY, MAR 24

Finite and Qualitative CSP (9:00am – 10:30am)
Chair: Bernhard Nebel

Keynote Lecture:
Toby Walsh: *SAT and CSP Competitions and Benchmark Libraries*.

Jean-François Condotta, Gérard Ligozat, and Mahmoud Saade: *Qualitative Constraints for Job Shop Scheduling*.

$* * *$ Coffee Break

Qualitative Reasoning and Navigation (11:00am – 12:30pm)
Chair: Diedrich Wolter

Marco Ragni and Gregory Kuhnmünch: *A Cognitive Perspective on QSR: Navigation as an Example*.

Reinhard Moratz: *Ambiguous Landmark Problems in Cognitive Robotics: A Benchmark for Qualitative Position Calculi*.

Jan Oliver Wallgrün: *Multi-Hypothesis Topological Mapping Using Qualitative Spatial Reasoning*.

∗ ∗ ∗ Lunch Break

Qualitative Reasoning and Knowledge Bases (2:00pm – 3:30pm)
Chair: Stefan Wölfl

Keynote Lecture:
Michael Witbrock: *There's a Time and Place for Everything*.

Matteo Cristani and Nicoletta Gabrielli: *Practical Issues of Description Logics for Spatial Reasoning*.

∗ ∗ ∗ Coffee Break

Tool Demo Session (4:00pm – 5:30pm)
Chair: TBA

Cui Jian, Hui Shi, and Bernd Krieg-Brückner: *SimSpace: A Tool to Interpret Route Instructions with Qualitative Spatial Knowledge*.

David Thau, Shawn Bowers, and Bertram Ludäscher: *CLEANTAX: A Framework for Reasoning about Taxonomies*.

Matthias Westphal and Stefan Wölfl: *GQR: A Fast Solver for Binary Qualitative Constraint Networks* .

Diedrich Wolter: *SparQ — A Spatial Reasoning Toolbox*.

Spring Symposia Plenary Session (6:00pm – 7:30pm)

WEDNESDAY, MAR 25

Working Groups (9:00am – 10:30am)

Working groups

∗ ∗ ∗ Coffee Break

Plenary Discussion (11:00am – 12:30pm)
Chairs: Bernhard Nebel, Stefan Wölfl

Reports from the working groups

Plenary discussion

ABSTRACTS

Keynote Talks

Geoff Sutcliffe (University of Miami, USA):
Evaluating Automated Theorem Proving Systems.

Abstract. A key concern of Automated Theorem Proving (ATP) research is the development of more powerful systems, capable of solving more difficult problems within the same resource limits. In order to build more powerful systems, it is important to understand which systems, and hence which techniques, work well for what types of problems. This talk deals with the empirical evaluation of general purpose ATP systems, in the context of the TPTP project. This includes the underlying principles and processes of the offline evaluation that is performed, and the organization and outcomes of the annual CADE ATP System Competition (CASC). The offline evaluation provides a measure of the difficulty of each problem in the TPTP, and a rating for each ATP system for each class of problems. The CASC evaluation is similar in structure to the offline evaluation, and in addition to being a public evaluation of ATP systems, aims to provide stimulus and insight for the development of more powerful ATP systems.

Toby Walsh (NICTA and University of New South Wales, Sydney, AUS):
SAT and CSP Competitions and Benchmark Libraries.

Abstract. Based on my experiences with CSPLib.org, SATLib.org and observation of the CSP and SAT competitions, I suggest some "Do's" and "Don'ts" for setting up competitions and benchmark libraries. When designed well, they can push forwards a field. However, there are elephant traps awaiting the unwary.

Michael Witbrock (Cycorp, Austin, Texas, USA):
There's a Time and Place for Everything.

Abstract. In building a very large, broad coverage knowledge base like Cyc, handling context is vital; it's usually simply not possible to act as if assertions in logic are acontextually true. Cyc content is therefore organised into thousands of contexts, arranged in an inheritance network.The talk will give an brief overview of the Cyc project, and discuss the structure and application of its context system. Two of the most important kinds of context in Cyc are time and space; we'll discuss how these are represented, how inference is done regarding them, and how they are applied in applications, for reasoning about medical records and intelligence analysis. Finally, the talk will touch on some applications, of, and problems with, automated knowledge acquisition in a contextual KR system.

Full Papers

Jean-François Condotta[†], **Gérard Ligozat**[‡], and **Mahmoud Saade**[†] ([†]CRIL-CNRS, University of Artois, FR; [‡]LIMSI-CNRS, University of Paris-Sud, FR):
Qualitative Constraints for Job Shop Scheduling.

Abstract. This paper introduces a translation of the job shop scheduling problem into a qualitative constraint satisfaction problem using INDU and Allen relations. We show that the translation is sound and complete. We also use the notion of frozen constraints and show that it allows the user to consider only partial solutions when searching for solutions. Our work constitutes a new approach to the problem of constructing content-motivated benchworks for qualitative calculi.

Matteo Cristani and **Nicoletta Gabrielli** (University of Verona, IT):
Practical Issues of Description Logics for Spatial Reasoning.

Abstract. Spatial reasoning with description logic has become an important research topic in the recent past. Several authors dealt with the problem of finding logical frameworks in which concept definitions can be made by using also spatial operators, particularly those of the Region Connection Calculus. Lutz and Milicic investigated the formal properties required to the concrete domain of the logical structure ALC(C) to accommodate decidable reasoning. This properties, named the patchwork property and the compactness property, along with the decidability of the constraint system C guarantee the condition of ω-admissibility which, in turn, guarantees decidability of ALC(C). Lutz and Milicic also proved that ALC(RCC-$8_{\mathbb{R}^2}$) is decidable. The expressiveness of this system is enough to define interesting concepts, but other frameworks result useful too. We investigate the combination of ALC(C) with the Cardinal Direction Calculus, and with a combined constraint system formed by the Region Connection Calculus and the Cardinal Direction Calculus recently studied by Li. We prove that the mentioned reasoning systems are useful by comparing their expressiveness in translating natural language sentences describing concepts of common usage. This analysis is a concrete benchmark of the obtained formalisms in order to measure the relative cognitive adequacy of Lutz's framework when comprises constraint algebras that have already shown to be adequate by themselves. We then exhibit some computational properties of the framework.

Torsten Hahmann and **Michael Gruninger** (University of Toronto, CA):
Detecting Physical Defects: A Practical 2D-Study of Cracks and Holes.

Abstract. Theoretical work on Qualitative Spatial Reasoning (QSR) is abundant, but the actual requirements of practical applications have been widely ignored. This paper discusses how ontologies allow to compare different QSR formalism with respect to definability of spatial concepts, which are taken from a real-world problem. We introduce the problem of detecting physically defective parts (such as in manufacturing) and review

which qualities are necessary for modeling these as QSR problem. We show that—besides standard mereotopological concepts—a set of artifacts, especially cracks and holes, are of foremost importance in the domain of interest. However, most currently available region-based QSR approaches fail to distinguish these. In the future, the proposed set of problem can be used to evaluate different QSR formalism for their adequacy with respect to defining and distinguishing cracks and holes.

Jason Jingshi Li and **Jochen Renz** (Australian National University, Canberra, AUS):
Blocks World for the Real World — A Proposal.

Abstract. Qualitative spatial representation and reasoning is an active research area where many different aspects of space are modeled and analyzed. Despite the obvious importance of the area for intelligent systems and different other applications such as geographical information systems, there are surprisingly few existing applications that use the techniques developed in this area. A possible reason may lay in the lack of a standard scenario, a widely used abstract model that has most of the important spatial features of the real world. Such a scenario would allow researchers to test the expressiveness of their spatial representations and reasoning mechanisms. It allows us to identify possible shortcomings and to analyze what additional expressiveness is required for obtaining an adequate model. In this paper we propose such a scenario, we call it Real-World Blocks World, in analogy to the Blocks World model commonly used in planning. We propose criteria for representing such worlds without abstracting away vital spatial components, intuitive models of which these representations could be based on, and possible associated reasoning tasks. We hope that this proposal can act as a test bed for the design of different spatial representations and reasoning mechanisms, and identify possible inadequacies in current approaches.

Reinhard Moratz (University of Maine, Orono (ME), USA):
Ambiguous Landmark Problems in Cognitive Robotics: A Benchmark for Qualitative Position Calculi.

Abstract. In this paper we introduce a task which can serve as a benchmark for qualitative relative position calculi. In this task ambiguous local landmark observations have to be integrated into survey knowledge. We show that the most prominent relative position calculus, Freksa's Double Cross Calculus can solve a specific instance of this task. The observations can be represented in a constraint network and standard constraint propagation solves the ambiguity problem. However, more general instances of the ambiguous landmark problem cannot be solved using the Double Cross Calculus. Therefore we present an extension to relative position ternary point configuration calculi which uses an adaptable level of granularity. This family of calculi is capable to solve general instances of the proposed benchmark. Thereby robot applications including reasoning about ambiguous perceptions will be made possible.

Marco Ragni and **Gregory Kuhnmünch** (University of Freiburg, DE):
A Cognitive Perspective on QSR: Navigation as an Example.

Abstract. One of the main intentions and central motivations for the development of qualitative reasoning was the investigation of a "naïve physics", with the aim to describe the physical world with human "everyday" concepts. This implies the idea that a formal description alone is not sufficient – it should be combined with cognitive features. In this article we (i) present main findings from Cognitive Science about QSR and cognitive modelling, (ii) to relate them to current research about QSR, (iii) suggest methodological adjustments that allow both for a more comprehensive evaluation of formalisms and for more realistic and varied test-beds. Finally, we argue that the field of navigation is a drosophila for a more cognitive QSR.

Carl Schultz[†], **Robert Amor**[†], and **Hans Guesgen**[‡] ([†]University of Auckland, NZ; [‡]Massey University, NZ):
Towards A Theory of Application for QSTR Systems.

Abstract. A wide variety of qualitative spatial and temporal reasoning systems have now been developed that formalise various commonsense aspects of space and time. Despite this, relatively few applications have made use of the reasoning tasks provided by these systems. We address this in a novel way by adopting the perspective of application designers. We present an outline of QSTR application theory, and use this to develop methodologies that support designers in creating suitable qualitative models, implementing metrics for analysing QSTR applications, and conducting application-level QSTR logic validation.

Jan Oliver Wallgrün (University of Bremen, DE):
Multi-Hypothesis Topological Mapping Using Qualitative Spatial Reasoning.

Abstract. We describe a multi-hypothesis mapping system for mobile robots that learns graph-based topological representations. Our approach exploits direction information and the assumption of planarity to prune the space of possible map hypotheses. Qualitative spatial reasoning is used to check satisfiability of individual hypotheses. We evaluate the effects of absolute and relative direction information and incorporate the approach into a mapping system based on Voronoi graphs.

Matthias Westphal and **Stefan Wölfl** (University of Freiburg, DE):
Confirming the QSR Promise.

Abstract. Within the qualitative spatial reasoning community it has been a widely accepted commonplace that reasoning in qualitative constraint calculi outperforms reasoning in other more general and expressive formalisms. To check the correctness of this assumption we conducted some empirical case studies in which we compared the performance of a qualitative constraint solver with different automated reasoning systems, namely first-order and description logic reasoners. We also report on some first results from comparing the

performance of qualitative and finite constraint solvers. Our empirical tests are based on randomly generated instances of qualitative constraint satisfaction problems, which have been encoded as reasoning problems for first-order reasoners, description logic reasoners, and finite CSP solvers, respectively. Given our currently used encodings, these studies show that first-order and description logic reasoners are far from being feasible for problem sizes that can easily be solved by a qualitative reasoner. In contrast, finite CSP solvers are competitive, but still outperformed by a qualitative reasoner on the problem instances considered here.

Tool Description Papers

Cui Jian, **Hui Shi**, and **Bernd Krieg-Brückner** (University of Bremen, DE):
SimSpace: A Tool to Interpret Route Instructions with Qualitative Spatial Knowledge.

Abstract. This paper describes our work on using qualitative spatial interpretation and reasoning to achieve a natural and efficient interaction between a human and an intelligent robot on navigation tasks. The Conceptual Route Graph, which combines conventional route graphs and qualitative spatial orientation calculi, serves as an internal model of human spatial knowledge on top of the robot's quantitative representation, such that humans' qualitative route instructions can be interpreted according to the model. The tool SimSpace then visualizes and proves the interpretation using qualitative spatial reasoning. Furthermore, SimSpace will generate appropriate natural feedback if a route instruction cannot be interpreted properly.

David Thau, **Shawn Bowers**, and **Bertram Ludäscher** (University of California, Davis (CA), USA):
CLEANTAX: A Framework for Reasoning about Taxonomies.

Abstract. The CLEANTAX framework relates (aligns) taxonomies (inclusion hierarchies) to one another using relations drawn from the RCC-5 algebra. The taxonomies, represented as partial orders with additional constraints, can frequently (but not always) be represented with RCC-5 relations as well. Given two aligned taxonomies, CLEANTAX can infer new relations (articulations) between their concepts, detect inconsistent alignments, and merge taxonomies. Inference and inconsistency detection can be performed by a variety of reasoners, and in cases where all relations can be described by the RCC-5 algebra, qualitative spatial reasoners may be applied. When inferring new articulations between taxonomies, CLEANTAX often poses many highly related queries of the nature "given what we know about the relations between two taxonomies, T_1 and T_2 , what do we know about the relationship between concept A in T_1 and concept B in T_2?" This context of posing many

(millions) of simple, but highly related queries motivates the need for qualitative reasoning systems that can perform batch jobs and leverage reasoning performed in the past to optimize answering queries about similar situations. This paper describes the CLEANTAX framework and argues for the development of benchmarks that take throughput into consideration, as well as single-query response time.

Matthias Westphal and **Stefan Wölfl** (University of Freiburg, DE):
GQR: A Fast Solver for Binary Qualitative Constraint Networks .

Abstract. Qualitative calculi are constraint-based representation formalisms that allow for efficient reasoning about continuous aspects of the world with inherently infinite domains, such as time and space. GQR (Generic Qualitative Reasoner) is a tool that provides reasoning services for arbitrary binary qualitative calculi. Given qualitative information expressible in a qualitative calculus, GQR checks whether this information is consistent w.r.t. the calculus definition. GQR employs state-of-the-art techniques in both qualitative and constraint reasoning, such as heuristic search and usage of known tractable subclasses. In contrast to specialized reasoners, it offers reasoning services for a variety of calculi known in the literature, which can be defined in a simple specification language. The main focus in the design and implementation of GQR is to provide a generic and extensible solver that preserves efficiency and scalability.

Diedrich Wolter (University of Bremen, DE):
SparQ — A Spatial Reasoning Toolbox.

Abstract. SparQ is a toolbox for qualitative spatial reasoning. Interpreting reasoning in a broad sense, SparQ covers mapping information from quantitative to qualitative, applying constraint reasoning to qualitative information, reasoning about calculi, and mapping qualitative information back to the quantitative domain. The toolbox is designed for extensibility and released under the GNU GPL public license for free software.

Short Presentations

Shyamanta M. Hazarika (Tezpur University, IN):
Qualitative Spatial Change in Mereotopology: Mining Spatio-temporal Patterns.

Abstract. Spatial configurations tend to change. Dealing with spatial representations often means dealing with changing representations. Existence itself is a fundamental change. There are many other dimensions of change viz. change in shape, location etc. Notions of spatio-temporal continuity hold a key. Even though continuity is basic to our understanding of physical processes and change, it remains an implicitly assumed notion. The work described here is concerned with developing a mereotopological spatio-temporal theory

based on space-time histories and formalizing an intuitive notion of spatio-temporal continuity for a qualitative theory of spatial change. Within the mereotopological theory an abductive framework for mining spatio-temporal patterns is formulated. Abductive reasoning may yield more than one possible explanation and is accompanied by some preference criteria expressed through heuristics. Here, the abductive technique of circumscription is used to implement the heuristic that changes should occur only when forced to.

Sanjiang Li (University of Technology, Sydney, AUS):
Combining RCC-8 with Qualitative Direction Calculi: Algorithms and Complexity.

Abstract. Increasing the expressiveness of qualitative spatial calculi is an essential step towards meeting the requirements of applications. This can be achieved by combining existing calculi in a way that we can express spatial information using relations from both calculi. The great challenge is to develop reasoning algorithms that are correct and complete when reasoning over the combined information. Previous work has mainly studied cases where the interaction between the combined calculi was small, or where one of the two calculi was very simple. In this paper we tackle the important combination of topological and directional information for extended spatial objects. We combine some of the best known calculi in qualitative spatial reasoning (QSR), the RCC8 algebra for representing topological information, and the Rectangle Algebra (RA) and the Cardinal Direction Calculus (CDC) for directional information. Although CDC is more expressive than RA, reasoning with CDC is of the same order as reasoning with RA. We show that reasoning with basic RCC8 and basic RA relations is in P, but reasoning with basic RCC8 and basic CDC relation is NP-complete.

Debasis Mitra (Florida Institute of Technology, Melbourne (FL), USA):
Explanation Generation over Temporal Interval Algebra.

Abstract. Temporal interval algebra has generated strong interest for both theoretical and practical reasons. All its maximal tractable subalgebras (MTS) have been identified. One of the uses of this understanding could be to develop a formalism for classifying an input temporal network into one of these MTSs, or decide the input's intractability. We have proposed a linear algorithm for checking consistency when the input belongs to one of the seventeen MTSs, and for finding out the constraints responsible for inconsistency in case the network is unsatisfiable.

James Pustejovsky (Brandeis University, USA):
The Qualitative Spatial Dynamics of Motion as Expressed in Language.

Abstract. Language models of qualitative spatial relations and motion tend to focus on cross-linguistic differences and semantic universals of spatial concepts. But how do the logical interpretations of spatial expressions in language translate into spatial logics for reasoning, inferencing, and planning tasks that are addressed routinely in the QSR

community? In this talk, I examine this issue, focusing first on translating the meaning of motion expressions into topological transformations within the Line Region Intersection calculus, and then providing a model within a first order dynamic interval temporal logic.

Joe Steinhauer (Massey University, NZ):
A Representation Scheme for Description and Reconstruction of Object Configurations Based on Qualitative Relations.

Abstract. One reason Qualitative Spatial Reasoning (QSR) is becoming increasingly important to Artificial Intelligence (AI) is the need to achieve a "natural" interaction between autonomous agents and people about objects and their whereabouts. In this presentation I describe the techniques and ideas forming the object configuration reconstruction process that is part of the representation scheme QuaDRO (Qualitative Description and Reconstruction of Object configurations). The process is cognitively easy and backtracking free, and reconstructs an object configuration from a sequential qualitative description of intrinsic object relationships into a global frame of reference. During the development of QuaDRO several decisions had to be made whether to favor, for example, cognitive adequacy vs. general correctness with regard to the task, or the ease of use for a person vs. the expressibility of the representation scheme. It was also necessary to classify existing qualitative spatial calculi regarding these and other features.

STATEMENTS OF INTEREST

Q1. What do you expect from the symposium (results, cooperations, etc.)?

Q2. What do you think are the most interesting (mid- or even long-term) challenges in the field of qualitative reasoning?

Q3. Which resources could you provide to other researchers in the field (tools, applications, data sets, etc.)?