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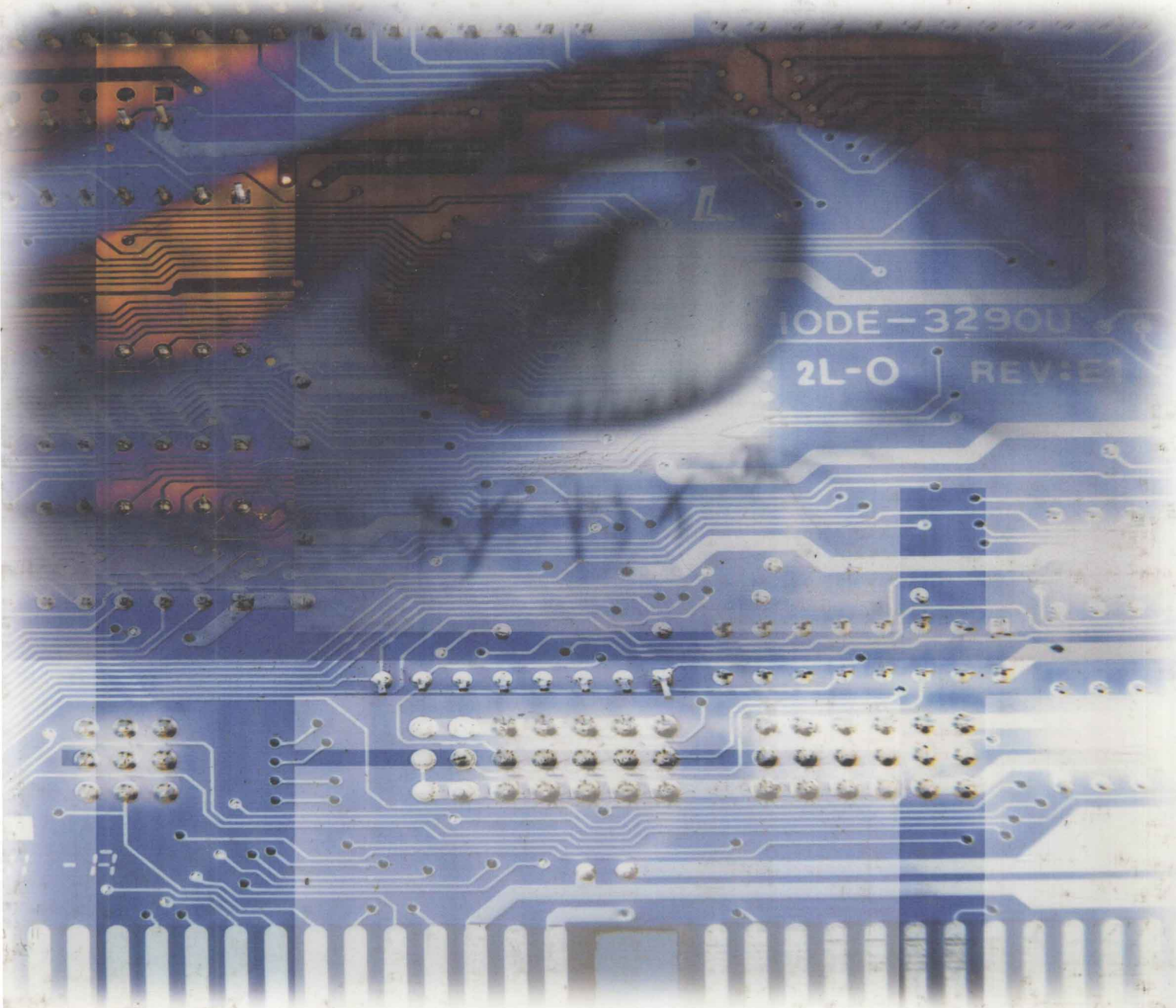
Visual Languages for Interactive Computing

DEFINITIONS AND FORMALIZATIONS



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Visual Languages for Interactive Computing:
Definitions and Formalizations

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Cover Design:	Lisa Tosheff
Printed at:	Yurchak Printing Inc.

Published in the United States of America by
Information Science Reference (an imprint of IGI Global)
701 E. Chocolate Avenue, Suite 200
Hershey PA 17033
Tel: 717-533-8845
Fax: 717-533-8661
E-mail: cust@igi-pub.com
Web site: http://www.igi-pub.com/reference

and in the United Kingdom by
Information Science Reference (an imprint of IGI Global)
3 Henrietta Street
Covent Garden
London WC2E 8LU
Tel: 44 20 7240 0856
Fax: 44 20 7379 0609
Web site: http://www.eurospanonline.com

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Library of Congress Cataloging-in-Publication Data

Visual languages for interactive computing : definitions and formalizations / Fernando Ferri, editor.

p. cm.

Summary: "This book presents problems and methodologies related to the syntax, semantics, and ambiguities of visual languages. It defines and formalizes visual languages for interactive computing, as well as visual notation interpretation"--Provided by publisher.

Includes bibliographical references and index.

ISBN 978-1-59904-534-4 (hardcover) -- ISBN 978-1-59904-536-8 (ebook)

1. Interactive computer systems. 2. Visual programming languages (Computer science) 3. Visual programming (Computer science) I. Ferri, Fernando.

QA76.9.I58V59 2007

005.1'18--dc22

2007007281

British Cataloguing in Publication Data
A Cataloguing in Publication record for this book is available from the British Library.

All work contributed to this book set is new, previously-unpublished material. The views expressed in this book are those of the authors, but not necessarily of the publisher.

Preface

INTRODUCTION FROM THE EDITOR

This book gathers the contributions of authors working in the area of visual languages from countries as diverse as Spain, Italy, United Kingdom, Australia, Greece, Canada, Brazil, and the USA.

It consists of 22 chapters written by a total of 54 different authors to provide an in-depth investigation of new approaches and methods for visual language theory, visualisation techniques, aesthetic computing, and usability.

I hope that academics, researchers, technicians, and students in computer science will find this book a valuable contribution to their knowledge of this important research area.

In normal life, people organise a complex structure of signs to communicate with the world around them. The brain acts as an interface between the sign system and the environment, orienting the individual in space. Visual languages systemise the visual representation of concepts in a formalised language using visual objects such as images or pictorial objects and possibly formal visual expressions. They are based on simple visual elements, which construct symbols that can be grouped to form structured visual sentences.

THE OVERALL OBJECTIVE OF THIS BOOK

The main objective and mission of this book is to present problems and methodologies concerning the syntax, semantics, and ambiguities of visual languages. Various syntactic techniques can be used to define visual languages, which differ significantly in the way they conceptualise a visual notation and describe its syntactic structure. From the semantic point of view, the precise meaning of a visual language is required in order to use it effectively. Finally, ambiguity is one of the main problems of visual languages. A visual configuration expressing a sentence or a visual action may be interpreted in a number of ways producing ambiguity. Visual languages offer an intuitive and incremental view of sentences, but may give different interpretations of the same sentence.

ORGANISATION

The book contains 22 chapters split into five sections. Section I examines the theory underlying visual languages. Section II discusses different approaches to and methods for visual languages on specific domains. Section III describes visual languages for the semantic Web. Section IV examines visual interfaces for standard languages. Finally, Section V considers several topics closely related to visual languages such as visualisation, aesthetic computing, and usability.

Section I. Visual Languages Theory

Section I opens with a chapter by Bottoni, Costabile, Levialdi, and Mussio, introducing the *Theory of Visual Sentences* by highlighting their main concepts, presenting some problems central to the definition of a theory of visual languages, and describing current developments. After an informal overview of the main components of the theory, the authors explore the characteristics of interactive processes and the modelling of visual transformations by visual rewriting systems. They go on to examine the dynamics of visual sentences, focusing on the relationship between constancy and variability in visual sentences, enabling and disabling mechanisms and coordination of transformations. The chapter ends with a discussion of how the theory's components can be integrated to provide a framework for the design of interactive visual systems before drawing some conclusions.

Chapter II, by Meyer and Bottoni, traces progress in *Visual and Diagrammatic Languages: The Logic Perspective*. The chapter starts by outlining the grammatical approach to visual language specification highlighting its shortcomings as a basis for this research plan. It then revisits the history of logic approaches to diagrammatic languages and details the comparative advantages and disadvantages of the different types of logic formalisation. Finally, it develops a new approach based on linear logic, which avoids most of these shortcomings and completely subsumes the grammatical approach.

Chapter III, by Bottoni, Frediani, Quattrocchi, Rende, Sarajlic, and Ventriglia, proposes a *Transformation-Based Metamodel Approach,* which enables an abstract view of the semantic roles that visual elements can play with respect to the process being described. More specifically, the chapter proposes an integrated framework and interactive environment based on a collection of metamodels in which it is possible to express both syntactical characterisations of diagrammatic sentences and their semantic interpretations.

Chapter IV, by de Lara and Guerra, presents an approach for the definition of *Multi-View Visual Languages (MVVLs)*. These are made up of a set of different diagram types, which are used to specify the different aspects of a system. The chapter introduces two techniques to define MVVL environments: Meta modelling and graph transformation. The former is used to describe the syntax of the language as a whole. A meta-model for each of the language's diagram types (*viewpoints*) is defined as a restriction of the complete MVVL meta-model. Consistency between views is ensured by translating each one into a unique *repository* model, which conforms to the meta-model of the language as a whole. The translation is performed by automatically generated graph transformation rules.

Chapter V, by Costagliola, Deufemia, and Polese, presents an overview of *eXtended positional grammars* (XPG), a grammar formalism for modelling visual notations, which represents an extension of context-free grammars and describes the XpLR parsing methodology. XPG and XpLR extend positional grammars (PG) and the associated pLR parsing methodology. These extensions have enabled the modelling and efficient parsing of a wide class of notations. The associated parsing algorithm is the XpLR parser based on the well-known LR parsing technique. The benefits of the formalism of a visual language include easier customisation and modification as well as maintenance and debugging, code and report generation by definition of suitable semantic productions, and implementation of visual and textual languages within a common framework.

Chapter VI, by D'Ulizia, Grifoni, and Rafanelli, classifies the *Different Kinds of Ambiguities* that can arise in visual sentences, distinguishing between lexical and syntactic ambiguities. When an image associated with a visual sentence is unable to express exactly (be completely faithful to) the user's intentions, the system may produce an erroneous interpretation. Ambiguities are generally produced by (1) the language, which can produce such one-to-many relationships, (2) imprecision introduced by the

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interaction behaviour producing the visual sentence. In the first case, an image can assume more than one meaning. The second case is connected with incorrect/imprecise information that does not permit an unequivocal interpretation of the image produced by the drawing actions.

The final chapter in this section, by Caschera, Ferri, and Grifoni, proposes *Different Kinds of Solutions to Ambiguities* that can arise in visual sentences. This chapter deals with ambiguities related to the system's interpretation function and methods to resolve them. These methods can be grouped in three classes: prevention of ambiguities, a-posteriori resolution, and approximation resolution methods. Prevention methods consider only a predefined set of possible system configurations, avoiding ambiguous configurations. A-posteriori resolution methods are based on mediation techniques, which enable the user to disambiguate his or her intention by dialogue. In contrast, approximation resolution methods are based on theories such as Fuzzy Logic, Markov Random Field, and Bayesian Networks and do not require user disambiguation.

Section II. Approaches and Methods for Specific Domains

Section II opens with the chapter by Caschera, D'Ulizia, and Tininini, which analyses the main characteristics of VQLs, concentrating on *visual languages to Query Conventional Relational Databases* but also examining information systems with a less rigid structure such as Web resources storing XML documents. It considers two main VQL classifications: the adopted visual representation technique (e.g., based on forms and tables, diagrams, icons, sketches, or combinations thereof) and the underlying data model (e.g., visual languages to query relational databases, object-oriented databases, collections of XML documents, and languages specifically designed for particular data such as geographic and multidimensional data).

Chapter IX, by Cavalcanti, Schiel, and de Souza Baptista, focuses on the specific category of *Visual Query Languages for Spatio-Temporal Databases,* which enable formulation of queries involving both spatial and temporal dimensions. Current papers treat these dimensions separately with only a few integrated proposals. This chapter presents a VQS called spatio-temporal visual query environment (S-TVQE), which allows the formulation of conventional, spatial, temporal, and spatio-temporal database queries in an integrated environment. With S-TVQE, the user, instead of querying the database by textual query languages, interacts with the system by visual operators to state the query conditions.

Chapter X, by Fogli, Marcante, Mussio, Provenza, and Piccinno, considers that the knowledge relevant to the design of an interactive system is distributed among several stakeholders: domain experts, software engineers, and human-computer interaction experts, and presents a *Multi-facet Design of Interactive Systems*. Each community describes an interactive system through visual sentences of a visual language (VL). This view results in an approach to VIS design based on the definition and use of three visual languages. Each VL permits user-system interaction process to be specified from a different point of view and for a different audience.

The chapter by Deray and Simoff starts from the assumption that although interaction is the core of interactive computing, its mechanisms remain poorly understood. The tendency has been to examine interactions in terms of the results they produce rather than to provide mechanisms explaining how interactions unfold in time. The authors present a framework for creating visual languages to represent interactions using human movement as a source for the language's core concepts. The approach is motivated and supported by evidence from research on kinaesthetic thinking that constructs based on human movement support higher-level cognitive processes and can be intuitively recognised by humans.

The final chapter of Section II, by Deufemia, considers *Sketch Understanding*. This is a particularly difficult task as the symbols of a sketched diagram can be drawn with different stroke orders, numbers,

and directions. The recognition process is often made even harder by lack of precision and ambiguities in messy, hand-drawn sketches. The chapter presents a brief survey of sketch understanding techniques and tools.

Section III. Visual Languages for the Semantic Web

Chapter XIII, by Catarci, Kimani, and Lodi, examines *User-Interface Formalisation in Visual Data Mining*. A formal specification facilitates the description of the system properties without touching on implementation details, and enables fundamental design issues to be detected before they are manifested in the implementation. An approach for the formalisation of the visual interface of a core data mining system is given.

Chapter XIV, by Kontopoulos, Bassiliades, and Antoniou, discusses the *Visualisation of Defeasible Logic Rules* in the semantic Web domain. Logic plays an important role in the development of the semantic Web and defeasible reasoning seems a very suitable tool. However, it is too complex for end users who often need graphical traces and explanation mechanisms for the derived conclusions. The chapter proposes an approach that uses directed graphs to assist the user by offering the notion of direction, which appears highly applicable to the representation of rule attacks and superiorities in defeasible reasoning.

The last chapter in the section, by Vrakas, Hatzi, Bassiliades, Anagnostopoulos, and Vlahavas, is concerned with *Knowledge Representation for AI Planning Problems*, especially those related to semantic Web service composition. It discusses current approaches in encoding planning problems and presents ViTAPlan, a user-friendly visual tool for planning.

Section IV. Visual Interfaces for Standard Languages

Chapter XVI, by Almendros-Jimenez and Iribarne, shows how to use and specialise *UML Diagrams for Describing the User Interfaces* of a software system considering three specialised UML diagrams called user-interaction, user-interface, and GUI-class diagrams. It also examines code generation to implement the system's user interfaces through GUI-class diagrams and user-interaction diagrams. A case study of an Internet book shopping system is introduced to test and illustrate the proposed user interaction and interface design technique.

Chapter XVII, by Campi, Martinenghi, and Raffio, describes a visual framework, XQBE that covers the most important aspects of *XML Data Management*, spanning the visualisation of XML documents, query formulation, the representation, and specification of document schemata, the definition of integrity constraints, the formulation of updates, and the expression of reactive behaviours in response to data modifications.

Section V. Visualisation Aesthetic Computing, and Usability

Chapter XVIII, by Voudouris and Marsh, discusses how cartography, GIS, and HCI shape aspects of *Geovisualisation* can support decision-making. The chapter analyses the relationships among geovisualisation, human computer interaction (HCI), geographic information systems (GIS), and cartography as a means of supporting decision-making. It emphasises the importance of data modelling and associated visualisations in terms of what the user can do by way of analysis and the methods by which he or she can undertake the analysis.

The following chapter, by Skhiri and Zimanyi, presents a *Graph Layout Algorithm for Drawing Biochemical Networks*. Due to the huge amount of information available in biochemical databases, biologists need sophisticated tools to accurately extract the information from such databases and interpret it correctly. Those tools must be able to dynamically generate any kind of biochemical subgraph (i.e., metabolic pathways, genetic regulation, signal transduction, etc.) in a single graph. The visualisation tools must be able to cope with such graphs and take account of the particular semantics of all kinds of biochemical subgraphs. The chapter presents an algorithm designed for the generic representation of biochemical graphs, in which users can present knowledge about how to draw graphs in accordance with the biochemical semantics.

Fishwick discusses the *Aesthetic Computing Method.* The purpose of aesthetic computing is to apply the theory and practice of art and design to the field of computing. The range of aesthetics within the arts is broader than in mathematics and computing where aesthetics is often synonymous with optimality criteria. This chapter introduces aesthetic computing for the multimedia representation of formal structures.

Chapter 21, by Costa, Grings, and Santos, presents *Documentation Methods for Visual Languages*. Visual programming languages (VPL) are generally self-documenting; this chapter analyses their use for the design and documentation of real world applications. Finally, the chapter proposes new tools and approaches for the documentation of data flow for VPL.

The book ends with the chapter by Padula and Reggiori, discussing *Usability*. This does not propose a specific viewpoint on usability but rather examines numerous concepts, aspects, and potentialities, which must nowadays be taken into consideration when detailing usability and design suited systems. This topic is currently of great interest in the field of human-computer interaction as it is highly dependent on the user interface. Systems must be used by a community of users in their working activity as a whole to process material or information, modifying not only rough material but also the working environment and methods. This requires them to be considered as tools in a social context, which expects ever-greater technological progress.

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Chapter I
The Theory of Visual Sentences to Formalize Interactive Visual Messages / *Paolo Bottoni, Maria Francesca Costabile, Stefano Levialdi, and Piero Mussio* 1

This chapter introduces the theory of visual languages providing characteristics of interactive processes and the modelling of visual transformations by visual rewriting systems. The dynamics of visual sentences are discussed considering the enabling and disabling mechanisms and coordination of transformations. Finally the chapter gives, before concluding, some elements for the integration of the theory's components to provide a framework for the design of interactive visual systems.

Chapter II
Visual and Diagrammatic Languages: The Logic Perspective / *Bernd Meyer and Paolo Bottoni* 22

This chapter discusses visual and diagrammatic languages in logic perspective. The grammatical approach to visual language specification, highlighting its shortcomings as a basis for this research plan, is presented. The different logic approaches to diagrammatic languages and advantages and disadvantages of the different types of logic formalization are discussed too. An original approach, that is based on linear logic and completely subsumes the grammatical approach, is proposed to avoid most of these shortcomings.

Chapter III
A Transformation-Based Metamodel Approach to the Definition of Syntax and Semantics of Diagrammatic Languages / *Paolo Bottoni, Dino Frediani, Paolo Quattrocchi, Luigi Rende, Goran Sarajlic, and Domenico Ventriglia* 51

This chapter proposes an abstract view of the semantic of visual elements with respect to a transformation-based metamodel approach. It introduces and discusses an integrated framework and interactive

environment, which uses a collection of metamodels to express both syntactical characterisations and semantic interpretations of diagrammatic sentences.

Chapter IV
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This chapter gives an overview of extended positional grammars (XPG), an extension of context-free grammars used for modelling visual notations. The chapter describes the XpLR parsing algorithm (Costagliola, Deufemia, & Polese, 2004) based on the well-known LR parsing technique. The benefits of the formalism of a visual language include easier customisation and modification as well as maintenance and debugging, code and report generation by definition of suitable semantic productions, implementation of visual and textual languages within a common framework.

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This chapter classifies ambiguities that can arise in visual sentences into lexical and syntactic ambiguities. When an image associated with a visual sentence is unable to exactly express (be completely faithful to) the user's intentions, the system may produce an erroneous interpretation. In particular, a visual sentence can assume more than one meaning, or incorrect/imprecise user's drawing actions does not permit an unequivocal interpretation of the image produced by the.

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This chapter proposes a classification of methods to resolve ambiguities that can arise in visual sentences related to the system's interpretation function. These methods are grouped in three classes: prevention of ambiguities, a-posteriori resolution, and approximation resolution methods. Prevention methods are based on a predefined set of possible system's configurations. A-posteriori resolution methods are based on mediation techniques. Approximation resolution methods are based on theories such as Fuzzy Logic, Markov Random Field, and Bayesian Networks.

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This chapter discusses the main characteristics of VQLs analysing visual languages to query conventional relational databases and information systems with a less rigid structure such as Web resources storing XML documents. It classifies VQLs according to the adopted visual representation technique (e.g., based on forms and tables, diagrams, icons, sketches, or combinations thereof) and the underlying data model, (e.g., visual languages to query relational databases, object-oriented databases, collections of XML documents, and languages specifically designed for particular data such as geographic and multidimensional data).

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This chapter focuses on visual query languages for spatio-temporal databases. It presents a spatio-temporal visual query environment (S-TVQE) and a VQS that allows the formulation of conventional, spatial, temporal, and spatio-temporal database queries in an integrated environment. With S-TVQE, the user, instead of querying the database by textual query languages, interacts with the system by visual operators to state the query conditions.

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The chapter presents a framework for creating visual languages to represent interactions using human movement as a source for the language's core concepts. It starts from the assumption that interaction is the core of interactive computing, but poorly understood.

Chapter XII
Sketch Understanding: Issues and State of the Art / *Vincenzo Deufemia* 232

This chapter presents a state of the art sketch of understanding techniques and tools. Sketch recognition is a particularly difficult task as the symbols of a sketched diagram can be drawn with different stroke orders, numbers, and directions.

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