

Diagram Understanding in Geometry Questions

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Abstract

Automatically solving geometry questions is a long-standing AI problem. A geometry question typically includes a textual description accompanied by a diagram. The first step in solving geometry questions is diagram understanding, which consists of identifying visual elements in the diagram, their locations, their geometric properties, and aligning them to corresponding textual descriptions. In this paper, we present a method for diagram understanding that identifies visual elements in a diagram while maximizing agreement between textual and visual data. We show that the method's objective function is submodular; thus we are able to introduce an efficient method for diagram understanding that is close to optimal. To empirically evaluate our method, we compile a new dataset of geometry questions (textual descriptions and diagrams) and compare with baselines that utilize standard vision techniques. Our experimental evaluation shows an F1 boost of more than 17% in identifying visual elements and 25% in aligning visual elements with their textual descriptions.

1 Introduction

Designing algorithms that can automatically solve math and science questions is a long-standing problem in AI (Feigenbaum and Feldman 1963). In this paper, we focus on geometry questions where the question text is accompanied by a diagram. More specifically, we address the problem of diagram understanding in geometry questions (Figure 1), a prelude to more sophisticated diagram understanding in scientific textbooks.

Diagram understanding is the problem of discovering visual elements, their locations, their geometric properties in the diagram, and their alignment to text. For example, understanding the diagram in Figure 1 entails identifying the location and the area of the circle O , secant AB , their geometric relations, and aligning pixels in the diagram to the corresponding textual mentions (color coded in the figure).

By and large, previous work in diagram understanding has studied the problems of text analysis and diagram understanding separately. Several algorithms have identified individual shapes such as circles (Zhang and Sun 2011),



Figure 1: Diagram understanding: identifying visual elements in the diagram and aligning them with their textual mentions. Visual elements and their corresponding textual mentions are color coded. This Figure is best viewed in color.

lines (Climmer and Bhatia 2003), triangles or rectangles (Li et al. 2013; Jung and Schramm 2004) from images, but ignore other shapes in the diagram, and do not attempt to discover them as we do. Furthermore, little attention has been paid to identifying shapes in a diagram by also utilizing the corresponding text.

Inspired by the growing body of work that has coupled textual and visual signals (e.g., (Gupta and Mooney 2010)), we present a novel method G-ALIGNER for diagram understanding in geometry questions by discovering visual elements and aligning them with their corresponding textual mentions. Our G-ALIGNER method identifies visual elements by maximizing the coverage of explained pixels of the diagram, the agreement between visual elements and their textual mentions, and the coherence of the identified elements. G-ALIGNER can identify a wide range of shapes including lines, circles, polygons, and other shapes composed from visual primitives (see Section 5).

We show that G-ALIGNER's objective function is submodular. This observation allows us to devise a greedy but accurate approximation procedure to identify visual elements in diagrams and align them with text. G-ALIGNER has another key advantage in being much more robust than standard vision techniques like the Hough transform (Stockman and Shapiro 2001). Whereas standard vision techniques require parameter tuning when moving from one diagram to the next, based on factors like the number of shapes in the diagram and their size, G-ALIGNER does not.

To evaluate G-ALIGNER, we manually compiled a dataset of geometry questions (textual descriptions and diagrams)

Diagram Understanding In Geometry Questions

LL Leslie

A decorative graphic element consisting of a light blue horizontal bar with a rounded right end, and a red circular shape partially visible behind it.

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Table of Contents Diagram Understanding In Geometry Questions

1. Understanding the eBook Diagram Understanding In Geometry Questions
 - The Rise of Digital Reading Diagram Understanding In Geometry Questions
 - Advantages of eBooks Over Traditional Books
2. Identifying Diagram Understanding In Geometry Questions
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Diagram Understanding In Geometry Questions
 - User-Friendly Interface
4. Exploring eBook Recommendations from Diagram Understanding In Geometry Questions
 - Personalized Recommendations
 - Diagram Understanding In Geometry Questions User Reviews and Ratings
 - Diagram Understanding In Geometry Questions and Bestseller Lists
5. Accessing Diagram Understanding In Geometry Questions Free and Paid eBooks
 - Diagram Understanding In Geometry Questions Public Domain eBooks
 - Diagram Understanding In Geometry Questions eBook Subscription Services
 - Diagram Understanding In Geometry Questions Budget-Friendly Options

6. Navigating Diagram Understanding In Geometry Questions eBook Formats
 - ePub, PDF, MOBI, and More
 - Diagram Understanding In Geometry Questions Compatibility with Devices
 - Diagram Understanding In Geometry Questions Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Diagram Understanding In Geometry Questions
 - Highlighting and Note-Taking Diagram Understanding In Geometry Questions
 - Interactive Elements Diagram Understanding In Geometry Questions
8. Staying Engaged with Diagram Understanding In Geometry Questions
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Diagram Understanding In Geometry Questions
9. Balancing eBooks and Physical Books Diagram Understanding In Geometry Questions
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Diagram Understanding In Geometry Questions
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Diagram Understanding In Geometry Questions
 - Setting Reading Goals Diagram Understanding In Geometry Questions
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Diagram Understanding In Geometry Questions
 - Fact-Checking eBook Content of Diagram Understanding In Geometry Questions
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
 - Integration of Multimedia Elements

- Interactive and Gamified eBooks

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