#### Diagram Understanding in Geometry Questions

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#### Abstract

Automatically solving geometry questions is a longstanding 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 preliade 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),

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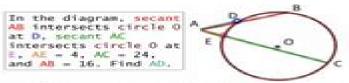


Figure 1: Diagram understanding: identifying visual elements in the diagram and aligning them with their textual mentions. Visual elements and their corresponding textual mentions are color coded. This Figure is best viewed in color.

lines (Climer 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**

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