

Communicative role of trees in Computer Science Textbooks

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1. Introduction

Tree-based illustrations are widely used in Algorithms and Data Structures (ADS) textbooks to explain hierarchical structures and algorithms. Prior research has shown that diagrams support reasoning and learning [1], while studies in computer science education have examined algorithm visualisations [2] and explanatory diagrams in programming textbooks [3]. However, little research has examined the communicative role of tree-based illustrations in ADS textbooks. This study investigates that gap.

2. Research Questions

- **RQ1:** What communicative functions do tree-based illustrations serve?
- **RQ2:** How do illustration practices vary across textbooks and topics?

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3. Methodology

A qualitative thematic analysis was conducted on 135 tree-based illustrations collected from three ADS textbooks. The analysed topics included general trees, binary trees, binary search trees, AVL trees, and heaps. Illustrations were coded iteratively using a framework based on a combination of

- Mayer's multimedia learning theory [4]
- Duval's theory of semiotic representations [5]
- Levin's functional taxonomy of illustrations [6]

Important dimensions:

- **Signalling:** the extent to which visual cues direct the reader's attention toward relevant information.
- **Register shift:** is there content-related difference between the illustration and other representations?

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Algorithm postorder( $T, p$ ):
  for each child  $q$  of  $p$  do
    recursively traverse the subtree rooted at  $q$  by calling  $\text{postorder}(T, q)$ 
  perform the "visit" action for node  $p$ 
  
```

Code Fragment 7.12: Algorithm postorder for performing the postorder traversal of the subtree of a tree T rooted at a node p .

The name of the postorder traversal comes from the fact that this traversal method visits a node p after it has visited all the other nodes in the subtree rooted at p . (See Figure 7.8.)

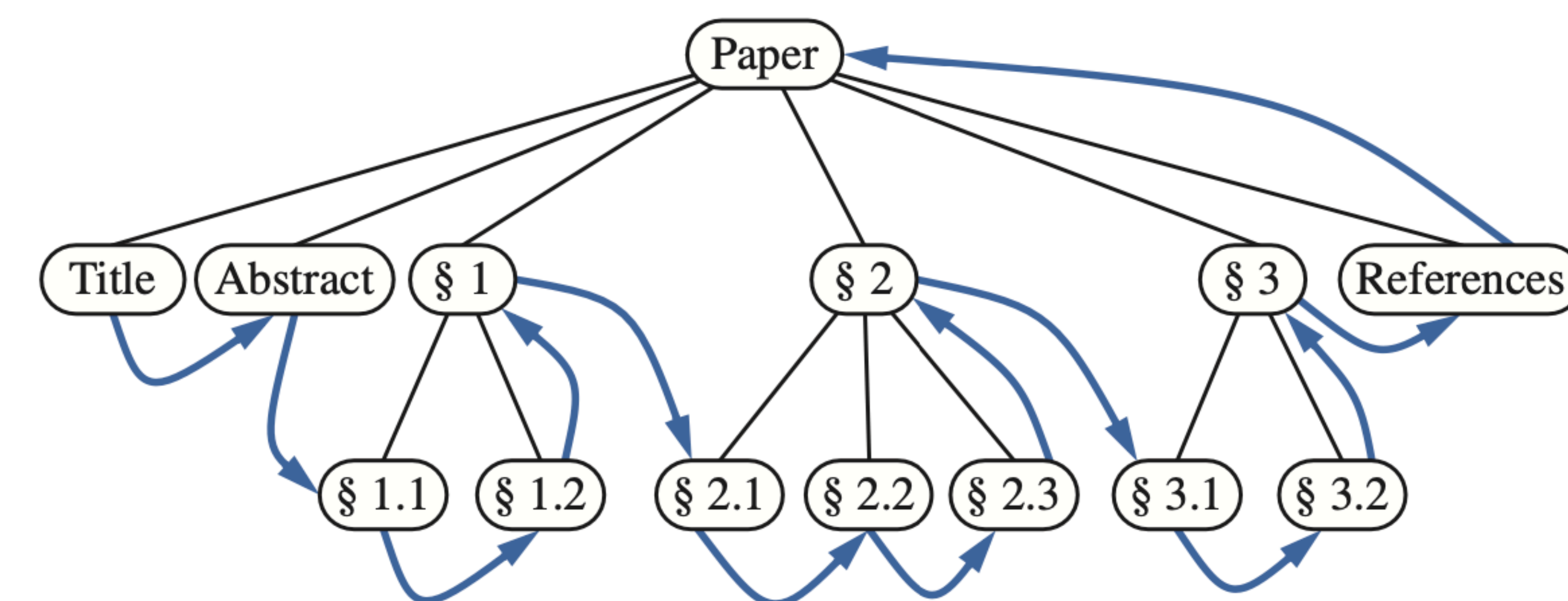


Figure 1. Strong signalling and complex register shift

6. Discussion

The findings highlight the importance of illustration design in ADS education and suggest that visual features such as signalling may play a role in helping learners connect multiple representations. Future work could investigate the relationship between signalling and register shift in greater detail and evaluate the effectiveness of different illustration strategies through empirical studies involving students.

4. Theme 1: How information is distributed between illustrations and text

1- Signalling extends what trees can communicate

Tree diagrams naturally represent hierarchical relationships, but they do not inherently show procedural information. Across the analysed textbooks, signalling techniques were used to make algorithmic behaviour visible.

2- Signalling and register shift co-occurrence

A relationship was observed between signalling and register shift. Signalling extends what tree diagrams can communicate by making process and change visible within a static illustration. As a result, part of the explanatory burden can shift from the accompanying text to the illustration itself, resulting in a register shift.

Table 1. Co-occurrence of signalling and register shift

Signalling/ Register Shift	No Shift	Single Shift	Complex Shift
None	6	6	2
Weak	33	18	5
Strong	11	37	17

5. Theme 2: Textbooks employ different visual languages

While all books cover the same topics, they differ in the visual conventions they use. The differences suggest that there is no single accepted visual language for representing trees in ADS education. Instead, authors make different choices about what information should be communicated visually and what should be left to textual explanation.

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