Representing and Analyzing Temporal Complexity in Children's Story Books

by

Madleina C. Scheidegger

Submitted to the Department of Electrical Engineering and Computer Science
in partial fulfillment of the requirements for the degrees of

Bachelor of Science in Computer Science and Engineering

and

Master of Engineering Electrical Engineering and Computer Science

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

August 2004

Author . . . .
Department of Electrical Engineering and Computer Science
August 5, 2004

Certified by . . . .
Patrick H. Winston
Professor
Thesis Supervisor

Accepted by . . . .
Arthur C. Smith
Chairman, Department Committee on Graduate Students

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Abstract

In this thesis, the temporal complexity in children's stories is analysed to better understand the development of children's perception of time and to determine the appropriate reading material for a grade level. Tools to analyse, and visualise, the temporal complexity are developed and are then used to demonstrate an increase in temporal complexty as the grade level increases. The temporal complexity increase both in greater deviations from a chronological presentation of events, as well as an increase in the different kinds of temporal relations between events. Both can be seen visually when the network is displayed. The results from this work show the increase in temporal complexity, are a first step in integrating semantic contents into assessments methods for determinig the grade level of a story and give a better understanding of time perception.

Thesis Supervisor: Patrick H. Winston
Title: Professor

Acknowledgments

This work would never have been finished without the help and support of a few key people. I thank my supervisor for allowing me to follow my ideas and for giving me advice and feedback. Ursula Scheidegger gave me moral support based on her own recent experiences and she helped me find the right words to express my ideas. Christine Robson was instrumental in allowing this work to communicate my ideas effectively. Lastly my thanks go out to Michele Oshima and Anne Hunter who volunteered to proof-read my work.

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Chapter 1

Introduction

Human intelligence has always interested people, and today there are many disciplines that focus on understanding intelligence. Just as important as understanding intelligence is understanding how children's intelligence differs and how children grow into adult intelligence. This research focuses on one aspect of intelligence and looks at both the child's understanding of this aspect, as well as how this understanding changes as the child grows older.

This thesis report discusses children's perception of time and temporal order. The aim is to further our understanding of how children perceive the order of events in time. This thesis examines primary school level story books and measures the complexity of the temporal order of events in the texts. The results provide not only insights into time perceptions of different age groups but also allow educators, librarians, and parents to assess the complexity of stories in order to determine the appropriate reading material for a particular age group.

Interestingly, the time complexity in children's story books is not a research area which has received much attention. The scarceness of findings not only proves the need for this investigations but also justifies further research efforts. Current methods for measuring children's perception of time and event order are not standardized. The currently employed methods of assessing the grade level of story books rely solely on the complexity of the words and sentences and do not consider the semantic contents of the story. These methods do not consider the relationship between age and comprehension of temporal elements. This thesis aims at bridging this gap and providing further insights into children's ability to understand time complexity in a specific story. It also aims at demonstrating the need to look at the semantic contents of the story when determining the appropriate grade level of a story. This subject is discussed in more depth, with other background topics, in chapter 2.

Creating an appropriate representation for temporal ordering is the core feature of this research. Specifically the challenge was to create a representation that allows assessing of the complexity of events within certain time frames and in relation to a specific temporal order in children's books. One obstacle in this context was depicting time in children's books; in many stories there is considerable uncertainty about the exact relation between events. In addition, time frames in stories differ considerably from "real world time" and it is common for stories to jump back and forth in time reference. Another problem is specificity: language is generally vague and does not usually provide enough clues to determine the exact timing and order of events. Thus it was necessary to design a temporal representation with the utmost flexibility. A detailed discussion of this temporal ordering representation is provided in chapter 3.

The temporal complexity of story books, events and their relations are analyzed by the Measuring Temporal Complexity (MTC) software package. The MTC software was developed for this thesis to help analyze the stories by looking at various key features using the temporal representation discussed in chapter 3. MTC gives a visual display of the temporal complexity in the story, to give the user a sense of it. The MTC software and the analyses it performs are discussed in chapter 4.

A collection of children's stories was evaluated for this thesis by using the methods described above. As the software can only assess the complexity, but not assign it to a grade leve', an initial set of stories was selected from the *Spectrum Reading Series* for grades 1 through 4 by McGraw-Hill to calibrate the software. As predicted, analyses of these books revealed that the time complexity increases with the books' grade level. From the results we can see that first grade stories were almost completely successive, which assess if events appear in chronological order, while grade 4 stories had the most complex relations. The successivity of stories decreases as one increase in grade level.

Grade 1 stories have only two relations, but grade 4 stories have usually at least five different kinds of edges showing another temporal complexity increase. A thorough analysis of these children's books is provided in chapter 5.

A further set of books for evaluation was drawn from a list of recommended summer readings for grades 1 through 4, provided by the Children's Room of the Boston Public Library. The methods and software developed for this thesis were used not only to measure the time complexity of the stories, but also to assess the appropriate age group of potential readers. chapter 6 provides insights into these examinations and their evaluations.

This thesis demonstrates a clear progression of time complexity in children's story books which correlates with increasing grade level. In addition, the methods and software developed provide tools to measure these complexities. The visual display also gives a sense of the complexity without doing any calculations. The results help to determine appropriate reading material for children, based on their age and ability of understanding time complexities. It also shows the need for a new way of determining the appropriate grade level of a story by looking at the semantic contents instead of just the word and sentences complexity. Finally and most importantly, this research furthers our understanding of how children develop time perception, in order to assess the ability of a particular age group to perceive time, temporal order, and their different levels of complexity.

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Chapter 2

Background

2.1 Perception of Time

The perception of time can be divided into three sub-topics: duration, succession and temporal perspective. Duration indicates the length of a particular event, succession is also called temporal ordering and it deals with sequences of events. Temporal perspective refers to a person's perception and experiences of the past, present and future.

2.1.1 Duration

Duration deals with the length of an event, but primarily refers to people's perception of a particular event's duration. People's perception of time is highly variable depending on personal and cultural dispositions. Time can fly or crawl depending on what we are doing. Judgements of time tend to be accurate only for relative short periods of time, usually less than a minute as mentioned in [3]. Only a small number of people have the ability to accurately judge the duration of longer events. Another fairly well documented phenomenon is that retrospectively, people tend to have erratic recollections regarding the duration of events which is also discussed in [3]

More research has been done on duration, than on any other sub-topics of time perception. It includes not only individual time perceptions but also strategies about how to actively stimulate and use an ”internal clocks”, for example.

2.1.2 Succession

Succession refers to the temporal order of events and is an area that has not enjoyed extensive exploration. However, studies have tried to determine the shortest interval necessary between two events such that people are able to recognize and perceive two distinct events. These experiments are described by Block [4], and included both visual and audio stimuli. The participants are asked if they perceived only one stimuli or two. When using audio stimuli a break more than a few milliseconds between signals is enough for people to perceive two events. Between visual events the difference has to be larger than 44 milliseconds.

Another field of temporal ordering that is fairly well studied is conditioning. Most studies use animals as research subjects and were closely linked to memorization, in particular long-term memory. Not only animals, but also human beings are able to internalize a particular temporal ordering of events and if it is repeated they are able to anticipate what is going to happen. The most famous of these experiments were conducted by Ivan Pavlov[15]. He started studying conditioning in 1902 and contiuned to do so for nearly 30 years.

2.1.3 Temporal Perspective

Temporal perspective is highly variable and only a limited number of studies have been done in this area. Lera Boroditsky's investigations of time perspective revealed that people imagine time in one of two ways, and is described in [5]. Either they are moving along a time line, or they are sitting still while time rushes at or past them. These two time perceptions,“ego moving” and“time moving”, respectively, are shown in figure 2-1, taken from [5].

During one of Boroditsky's experiments[7], people were told they had a meeting on wednesday that was“moved up two days” They were then asked what day the

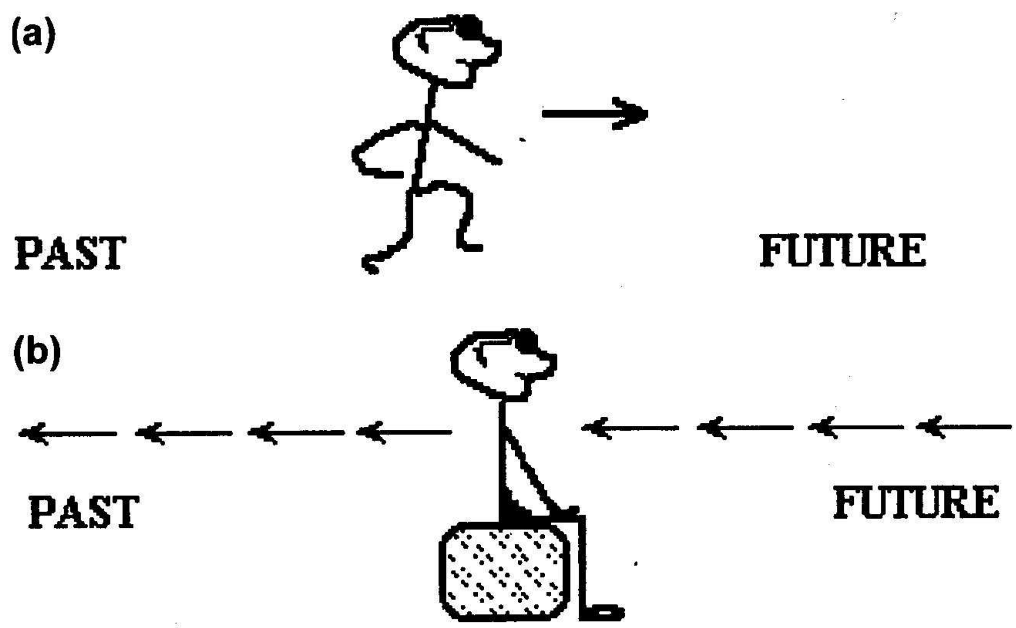

Figure 2-1: Time Presepctives a) ego moving b) time moving from [5]

meeting is. If a person uses the "ego moving" pattern then he will answer friday, but if someone uses the "time movin" pattern he will answer monday. Boroditsky also showed that people's circumstances influences which time perspective they use. In this study people waiting in a line for food were used and their position in line affected the answer they gave. The individuals closer to the front were more likely to use the "time moving" perspective while at the back of the line the "ego moving" perspective was prominent.

Temporal perspectives are influenced by the linguistic context of an individual's upbringing as Boroditsky [6]. English speakers tend to imagine time as a horizontal line. In contrast Mandarin speakers have a vertical perception of time. Even if Mandarin speakers answer questions in English, they retain their vertical image of time. Temporal perceptions vary not only between individuals, but are also influenced by linguistic symbols used in communication about time.

2.2 Temporal Cognitive Development in Children

Children's perception of time develops and becomes more differentiated as they get older. With increasing age, children are able to assimilate more concepts and eventually reach adult-level reasoning capabilities. Research in this area was first conducted by Jean Piaget in the 1960*s*. Since then, other researchers began examining and critiquing Piaget's work in this field.

2.2.1 Piaget's Research

The psychologist Jean Piaget, well known for his contributions to child development, investigated time perceptions in children. Most of Piaget's experiments focused on a child's ability to judge duration, however, a few studies also concerned temporal ordering as the following example shows. Piaget published these findings in his book[16].

The Flask Experiments

Piaget's experiments involved two flasks of equal size where one was placed on top of the other. It was possible to fill the top flask from the top and to control the flow of water to the bottom flask. The experiment started with the top flask being full and the bottom one being empty. At fixed intervals the water was allowed to flow from the top flask to the bottom flask until all of the liquid was in the bottom one. The child was given an image of the flask apparatus and crayons. The child was told to mark the picture with the water levels in the two flasks.

After shuffling the drawings, each child was asked to arrange their own drawings in the right order. If the sequence was incorrect Piaget asked the children prompting questions until they found they fully corrected themselves. Piaget said that children as old as five had trouble putting their own drawings into the correct order. From these results, and those from an earlier study on children and stories told in pictures, Piaget concluded that children have to learn how to put events into a linear time line and the concept of successive pictures.

From the previous experiment Piaget was able to determine which children could order events. His next experiment attempted to determine if children could order two simultaneous events without getting confused. Taking the drawings from the first experiment, Piaget cut them in half so that the top and bottom flasks were on different sheets of paper. The child was then asked to order all of the top flasks and bottoms flasks in the correct order at the same time. Most children found this difficult. Children understood the correlation between dropping water levels in the top and rising water levels in the bottom flask and that the total water quantity remained constant before they were able to create the correct sequence of the drawings. The average age when children are able to create the correct sequence without any prompting around seven years old. Piaget concluded from these results that children have to learn how to correctly correlate two events that depend on each other and happen simultaneously.

Conclusions

Piaget concluded from these sets of experiments that children have to learn about the concept of successive and simultaneous events. He also determined that before children fully understand successive events children are able to correctly answer questions about the order of events. Simultaneous events are learned after successive events. The exact age of when a child learns these concepts seems to vary among children. Piaget found that children learned the concept of successiveness around five years old. By the age of seven most children had successfully grasped the concept of simultaneous events.

2.2.2 Recent Experiments

William Friedman's Memory Experiments

William Friedman[12] investigated both children's ability to recall the time of a specific event and the specific event that happened at a point in time. He discovered that four year old children can remember the time and event occurred only within the past few days. Children can remember events that happened earlier, but not when they happened. However if the child is provided with a particular time they can recall what event happened at that time.

Sound Perception Experiment

Demany, McKenzie and Vurpillot[11], conducated a study which investigated the age of children when they were first able to successfully distinguish between two different temporal patterns. The study was conducted with repetitive sound patterns played to very young children. It was found that children as young as two and a half months were successful at distinguishing between different sound patterns.

Jacques Montangro's drawing experiment

Jacques Montangro's experiment[14], involved drawings of past and future events and investigated the development of children's time perceptions between eight to eleven years of age. There were a number of variations on this experiment. In one study, children were given a picture of a sick tree and asked to make enough drawings of the tree before and after its sickness to understand what happened and will happen. Examples drawings are shown in figure 2-2. The goal was to see how well children understood what happened and will happen to the tree. Older children produced many more drawings than their younger counterparts depicting the same events. Montangro concluded that children are able to differentiate between more temporal events with increasing age.

Stavroula Samartzis' Comparison Experiment

Stavroula Samartzis[17] conducted experiments concerning beginning, duration and end of events to study the development of time perception. Samartzis looked at three types of problems: "equality", "inequality decidable" and "inequality undecidable". "Equality" refers to events beginning or ending at the same time or having the same duration. "Inequality decidable" refers to events where neither beginning, end nor duration were at the same time. "Inequality undecidable" refers to time frames so

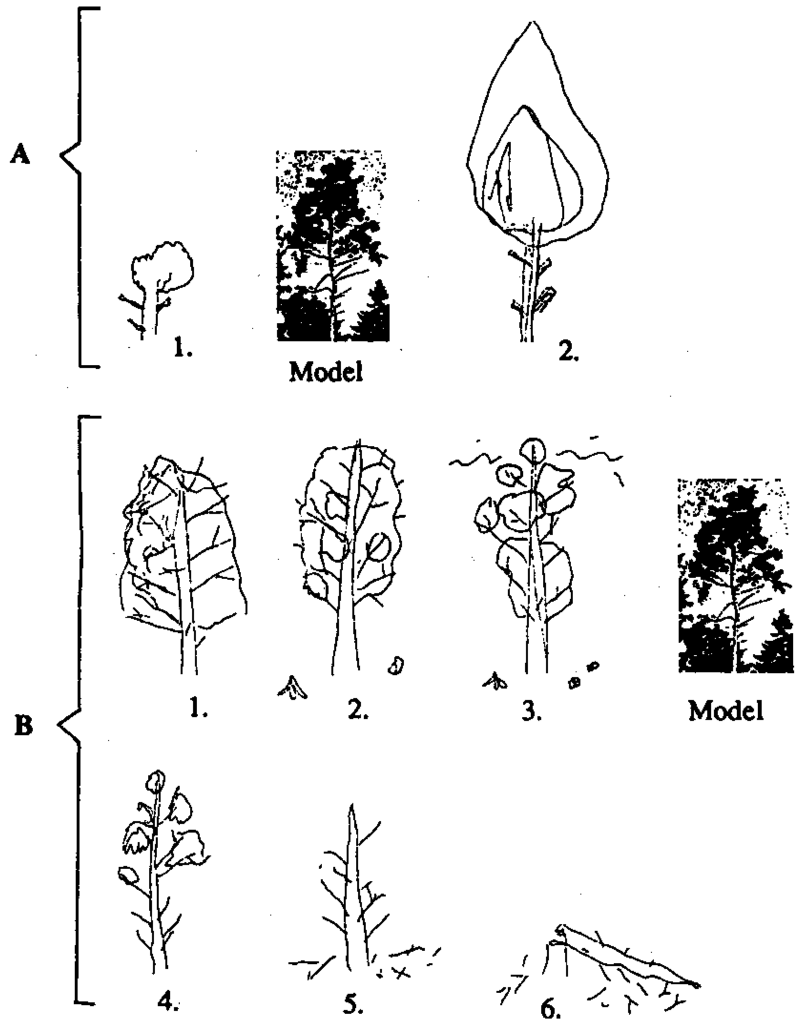

FIG. 1

Figure 2-2: Example drawings of the lifetime of a sick tree of a) 8 year old and b) 11 year old from [14] vague that several answers to posed questions are possible. This is specifically different from "equality" and "inequality decidable" since it provides a situation where there is more than one correct answer.

Samartzis described sample situations from the three types of problems to several subjects of varying ages and asked them questions about the situations. He then used the average frequency of correct responses and related it to the age of participants. With increasing age the correct number of answers increased. Unfortunately Smartzis compared only ten, fourteen and twenty-five years old subjects, which does not provide information about younger children.

2.3 Story Books

This section examines children's stories. In particular this section seeks to highlight the differences between children's story books and adult reading material, as well as inherent aspects of stories for children.

2.3.1 Characteristics of Story Books

Children's stories have to contend with several factors. When children are young they are still learning how to read and their vocabulary is limited. Moreover children are still developing their cognitive abilities. One way that story books address these issues is with illustrations depicting the story. The stories are often written in a simple, repetitive manner which is easy for children to grasp. In addition limited vocabulary is employed.

Another characteristic of children's stories at a young age is that most of the stories have very simple grammar. Most of the sentences have only one clause, and it is only at about grade 3 that sentences with multiple clauses become common. Similarly the story line is simple in story books for younger children. This helps younger children who are not able to remember a long and complex story line.

2.3.2 Classification of Story Books

Methods for classifying children's story books into appropriate grade levels are not standardized. Two readability measurements are commonly used in America: the Flesch-Kincaid Grade Level and the Flesch Reading Ease score.

The Flesch-Kincaid Grade Level scores children's books using a formula which combines average sentence length and the average number of syllables per word. The Flesch Reading Ease score uses similar measures, but a different calculation to score books. Neither of these techniques evaluates the contents of the story, or the complexity of the story line.

As is clear from studies into children's temporal perception and understanding of complex events, some story lines, however simply written, are difficult for young children to understand. This thesis seeks to provide an enhanced measuring tools for story books which will take into account the story line's complexity.

2.4 Representing Time

The struggle to understand and measure time has always been at its heart a struggle to represent time. From ancient calendars to atomic clocks the representation of time has always been key. In modern modeling of timed systems and event ordering, computers have been used as an aid to keep track of temporal data. Several temporal representations have been introduced to model different aspects of time. This section examines a selection of temporal representation schemes used today.

2.4.1 Dating Schemes

Dating schemes are representations that use absolute dating to represent either an instantaneous event or a pair of absolute dates to represent an interval. Absolute dates provide sufficient information to determine with certainty the exact time of an event, for example 3rd of March 1990 at 18 : 40 and 30 seconds.

Dating schemes are usually employed only in situations where the exact time of

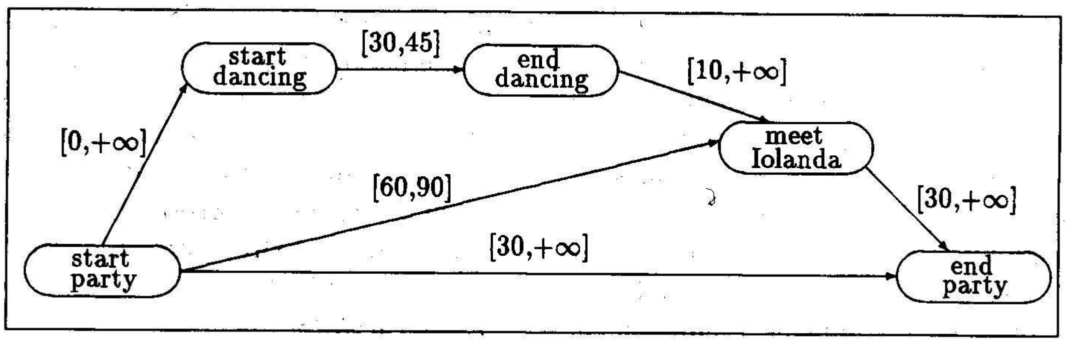

Figure 2-3: Example of a Point-based Representation from [20]

all events are known. As such they are most useful for scientific data collection and historical records.

2.4.2 Logical Schemes

Logical representation schemes encompass a broad class of temporal ordering schemes based loosely on mathematical logic. The most relevant examples for this system is reified temporal logic. Consistent with most logical representations, based on different formulas and different patterns of combinations enable the extraction of more information. The basic purpose of the logical representation is to determine when events happen by employing mathematical logic constructs which evaluate to true at the correct time. The exact syntax and the formulas combining this syntax are specific to each computer language. Various logical schemes are presented in [20]

2.4.3 Point-based Representation

Point-based representation were proposed by McDermott[10]. His representation seeks to put time windows on events, depicting the minimum or maximum duration separating two points in time.

Point based representations are usually stored in a network, where each edge represents the separation and each node is a point. Figure 2-3, taken from [20], shows an example network.

2.4.4 Interval-based Representations

James Allen's time representation is one of the most popular interval-based representations. The basis of his representation is to determine the exact relation between two intervals. Allen limited the number of relations to thirteen. Out of the thirteen relations, six are the inverse of each other; the last relation "equals" is its own inverse. The thirteen relations are: "equals," "before," "after," "meets," "met by," "starts," "started by," "during," "contains," "finish," "finished by," "overlaps," and "overlapped by." Figure 2-4 shows all thirteen relations.

Allen suggested a mechanism to represent uncertainty, however he never employed this model in one of his systems as it is quite cumbersome. Allen's more recent work has concentrated on the temporal algebra derived from his representation and on including instantaneous events into his representation.

2.4.5 Constraint Networks

Commonly, temporal relations are integral parts of constraint networks, because these networks are suitable for storing and using any temporal information. Within constraint networks the edges are the constraints ensuring that any information in the networks is constantly and consistently updated. Constraints are conditioned to react to changes in one of two nodes and update the other accordingly.

In general, within representations, most of the calculations are done when new information is added to the network. All existing constraints update themselves, and then new inferences are calculated and added. Furthermore the network ensures the consistency of the information. These factors facilitate information queries and retrievals from the data stored in the network, which is the main reason why constraint networks are so widely used.

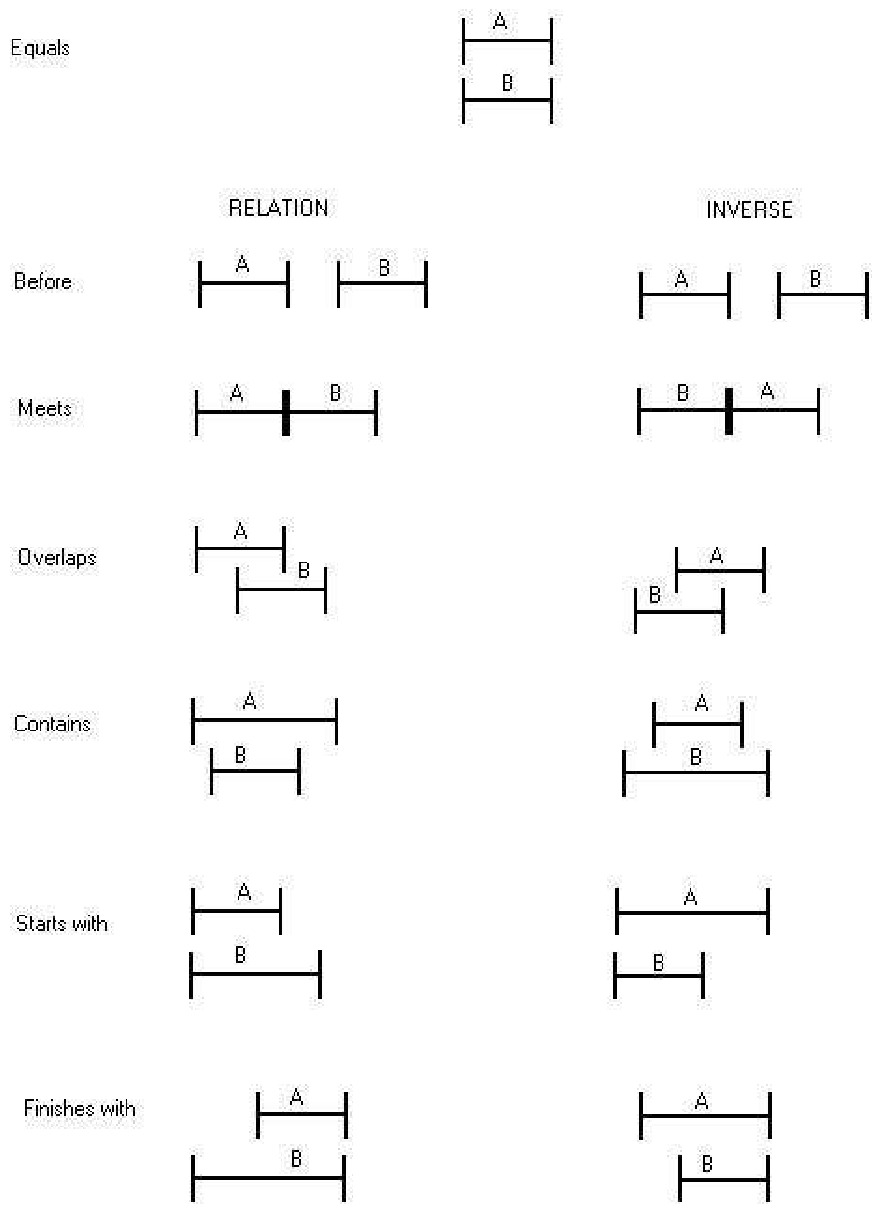

Figure 2-4: Allen's Thirteen Relations

Chapter 3

Temporal Representation

Fundamental to the understanding of time and its complexity is the representation used. This research relies on gauging time and the relationship between events in time. In this thesis, the core feature of the representation is temporal ordering. The following chapter presents a strategy which not only facilitates measures of temporal ordering, but also allows assessing uncertainties and inaccuracies of temporal events in children's stories.

3.1 Challenges of Children's Story Books

When analysing children's story books and thinking about how to represent time there are a number of challenges. First, in children's story books and in general, language describing temporal events is inaccurate and vague, making it difficult to assess the time and duration of an event. In addition in children's book the presentation of time becomes more complex. For first graders, the information conveyed is simple, straightforward and in short sentences. No tenses or words depicting temporal order such as "while" or "before" are used. Stories for older children become more complicated, with time settings differeing from the past to the present and the future, and in the vocabulary used to describe the temporal events. This work aims to demonstrate and help visualise the correlation between increasing grade level and the growing ability to understand complexities of temporal order in stories. The time representation must show the temporal order of events and how they change relative to the target reader group.

Secondly, linguistic vagueness and scarce information render it difficult to determine the exact relation between two events. In addition, the same words can have different connotations depending on the context, which influences degree, accuracy and value of the information conveyed. For example, “while” is an imprecise time delimitation, mostly used to refer to simultaneous events without indications about their respective duration. Under certain circumstances more information can be deduced. For example, consider the sentence “while Mary cooks, John takes off his boots in the bedroom”. Most people will assume that “Mary cooks” takes longer than “John takes off his boots in the bedroom” a conclusion based on common sense. Readers of books and stories are able to deal with this lack of precision and so should a flexible temporal representation.

Thirdly, there is the difficulty of determining the exact moment of an event happened. It is rare in fictional work to encounter references to an event’s exact date and time. Interpretations of time settings are often left to the reader. The impossibility of determining the exact time of an event poses a further challenge for the representation.

Finally, another characteristic of children’s books is that most stories develop over a period of time. The events in the stories usually have duration to them and are not instantaneous. This is particularly the case with stories for grades 1 and 2. It follows that any representation has to reflect, deal with, and reason about events with an unknown duration.

3.2 Deciding on a Representation

A core feature of any representation is its ability to handle uncertainties. Fiction in general, including children’s stories, provides only vague information regarding the different temporal aspects of events. Despite these limitations it is possible to develop strategies based on the little information and time indication available. However, it illustrates the need to handle the different manifestations of uncertainty effectively. To face this challenge, uncertainty has to be integrated into the representation.

There are three choices for the basic unit of the representation: the use of points, of intervals, or of both points and intervals. In children's stories a recurring feature is limited concrete time information, such as the beginning or end of an event. The use of points seems unsuitable to generate reliable measurements based on so much imperfect information. In addition, most events are not instantaneous thus for point-based representations it is necessary keep track of start and end point pair for each events. Given these problems, using points as the basic unit was rejected.

In contrast, an interval-based representation does not face these problems. If intervals are built into the representation, there is no need to keep track of pairs of points forming the respective intervals. In addition, intervals facilitate the reasoning and evaluation of overlapping events. Interval-based representations can be created to deal with uncertain start and end points of an event.

Having established that interval-based representations are an applicable solution to this problem, evaluating the combined points and interval representation is still necessary. Points are clearly the better choice for instantaneous events. However, instantaneous events are rare in books for grades 1 through 4, and in fact none were found in any of the books used in this work. Despite the preference given to an interval-based representation for this thesis, the inclusion of points should not be rejected but rather be considered as a potential addition to the representation in the future.

3.3 Temporal Representation Scheme

3.3.1 Properties of a relation

The relation between two events is based on four different properties. First, the relation between the two start points; secondly, the relation between the end points; thirdly, the possibility of overlapping events; lastly, the possibility that the events

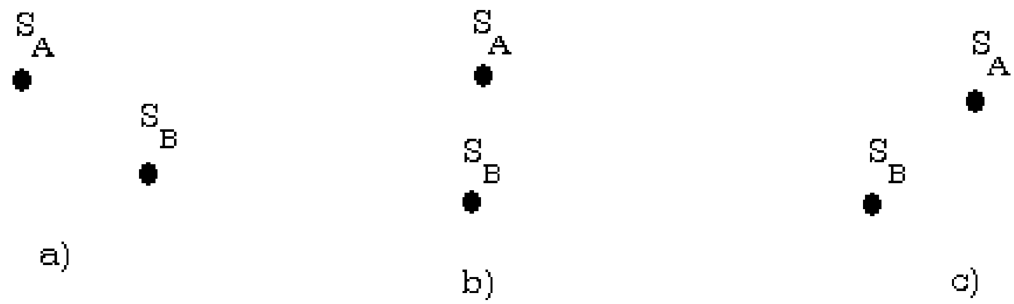

Figure 3-1: Three Possibilities of Start Point Relations

meet. Three additional options break down the first property. Either event A starts before event B, or event A starts at the same time as event B, or event A starts after event B. These three cases are shown in figure 3-1. The same options apply to the relation between end points. The last two properties differentiate between a total of three possible cases, where the start and end points have the same relation in each case. The three cases are: one event is before another event, two events meet each other, or two events overlap. The three cases are shown in figure 3-2.

3.3.2 Representing Uncertainty

To ensure the flexibility of this representation requires the ability to represent uncertainty. In particular it is necessary to differentiate between three different states: events are true, events are false, or there is uncertainty whether an event is true or false. To represent the three certainty states the following convention is used: 1 represents a true state, and 0 represents a false state and ? represents uncertainty about whether the state is true or false.

3.3.3 Using the Relation properties

To represent the four properties of relations between events, it was important to limit each field's different possible states to the three certainty stages described in

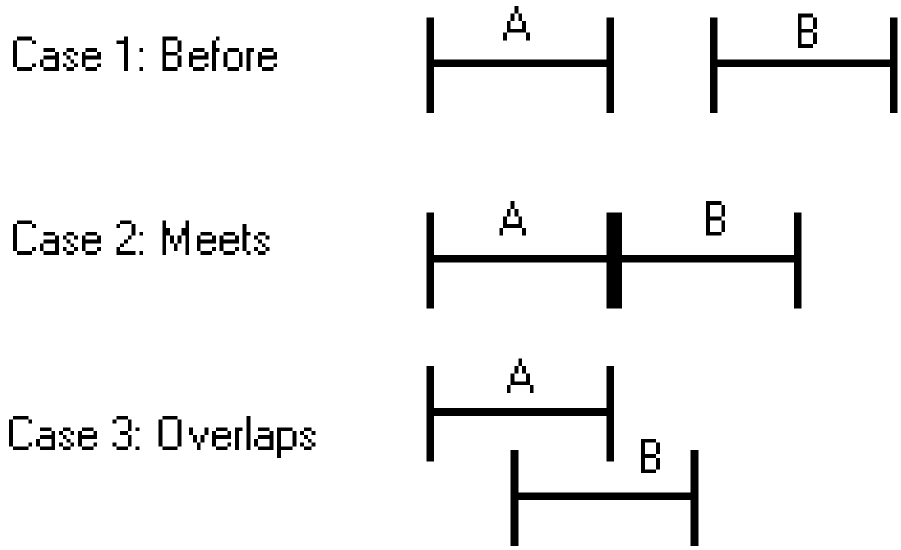

Figure 3-2: Three Events with the Same Start and End Point Relation

$S_A < S_B \quad S_A = S_B \quad S_A > S_B \quad E_A < E_B \quad E_A = E_B \quad E_A > E_B \quad O \quad M$

Figure 3-3: Order of fields

section 3.3.2. To achieve this, the start and end point property had to be separated into three fields in the final representation, each representing one possible relation shown in figure 3-1. The overlap and meet properties of events can each be a field as is, as each property only differentiates between the three certainity states.

The following order of fields was selected: first, listing the three start relations, secondly, listing the three end relations, thirdly, the overlap fields, and lastly, the meet fields. The start and end fields are listed in the order they were initially presented. Figure 3-3 represents this order, where S_A and E_A represent the start and end point of event A respectively. O refers to the overlap field and M refers to the meet field.

To display a relation, without using a diagram, such as in figure 3-4, one can just list the value of the field in order. For example the relation in figure 3-4 could be written as ?0??0???. More examples, with intervals depicting the actual relations or

$S_A < S_B$	$S_A = S_B$	$S_A > S_B$	$E_A < E_B$	$E_A = E_B$	$E_A > E_B$	O	M
?	0	?	?	0	?	?	?

Figure 3-4: An Example Relation

set of relations, are show in in figure 3-5.

3.3.4 Evaluation

In a perfect information settings, this scheme matches Allen's thirteen relations scheme, discussed in section 2.4.4. This supports the decision to employ this scheme in the thesis project, because Allen's scheme has been proven mathematically. However, this scheme only corresponds to Allen's scheme in a perfect information setting without any instantaneous events. If there is uncertainty the mathematical proofs no longer hold.

This thesis could be considered an improvement on Allen's scheme because it provides for the inclusion of uncertainty into the representation. In addition, the improved scheme has the potential to add points to the system, and thus instantaneous events, as well as being able to add duration to events and use that information when reasoning.

3.4 Using the Scheme for Children's Books

The use of the representation for children's books requires a choice of how to structure the information. Specifically there are two possible network models which could be employed for this task: simple networks and constraint networks.

Constraint networks provide a single additional feature to simple networks. Existing information is updated and new inferences are calculated every time new inputs are added to the network. This feature is most useful for planning and reasoning systems because of time constraints. This however is not a concern in this research and thus simple networks are employed to structure the temporal information.

The specific application to the modelling of children story books is discussed in

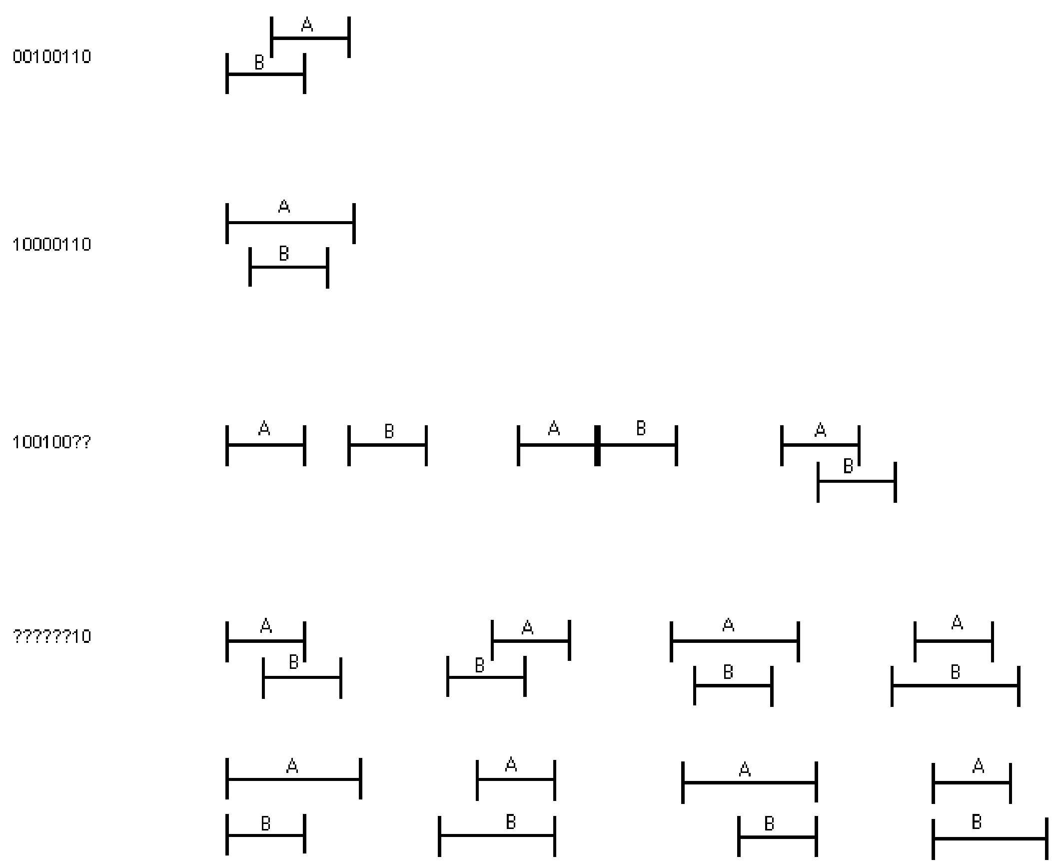

Figure 3-5: Example Relations

greater details with examples in chapter 5.

Chapter 4

MTC Network software

To use the representation described in chapter 3, I wrote a computer program as part of this thesis. The software allows the analysis of the temporal complexity of stories and enables users to determine the appropriate grade level of a story. Furthermore the representations generated by the software can be used as part of a larger system to represent and reason about temporal ordering.

The Measuring Time Complexity (MTC) software package includes all of the components necessary to represent the temporal relation between events, store all of the information in the form of a network, display the network, ask question about the information in the network and finally calculate the complexity of the temporal information in the current network. The software was written in Java 1.4.2 using Swing for the graphical display.

MTC contains three components that provide all the functionality. The first component is the representation of the relation; this is all of the necessary functions for representation of the temporal relation between two events. The representation was discussed in details in chapter 3, and the details of the component are discussed in section 4.1.

The next component is the network that stores all of the relations and all of the events. It allows both quick retrieval of the stored information, and for new information to be calculated from the relations presented. The details of the implementation are presented in section 4.2.

The third, and last component, is the graphical interface. It displays the information contained in the first two components and allows the user to easily interact with the software package. The graphical display also gives a sense of the temporal complexity of the story. This component contains the necessary infrastructure to create a new network, add new relations, store the network, load stored networks, and query the network about its information. Additionally it allows the user to get statistics and color certain edges in the network. The details of each function are presented in section fourthree.

4.1 Representation

The representation scheme used by the MTC software package is described in chapter 3. The first component of the software package not only stores the relation, but also contains a wide number of functions. These functions include: maintenance functions; functions that check whether the relation is legal; functions that combine two relations; and inference functions.

Checking the legality of the relations involves making sure that there are no contradictions within the relation. The most basic criterion is that only three of the fields are true. The start and end points can only have on possible relation, shown in figure 3-2, and thus only one field can be true. The overlap and meet field cannot be true at the same time, as intervals that meet each other cannot overlap at the same time. Another criteria is that at least two fields are true. One of the start and end fields has to eventually be true once all of the uncertainty is removed. Another consideration is that some combinations of start/end point relation indicate that the intervals have to overlap. For example if the events start at the same time, the events have to overlap. The full list of rules are listed in Appendix A.

Combining two intervals is only used when a relation is added to the network and that relation already exists. The combination is, for the most part, trivial and is done on a field-to-field basis. If both fields have the same value that value is carried over to the combined relation. If one of the fields is not known then the other field determines

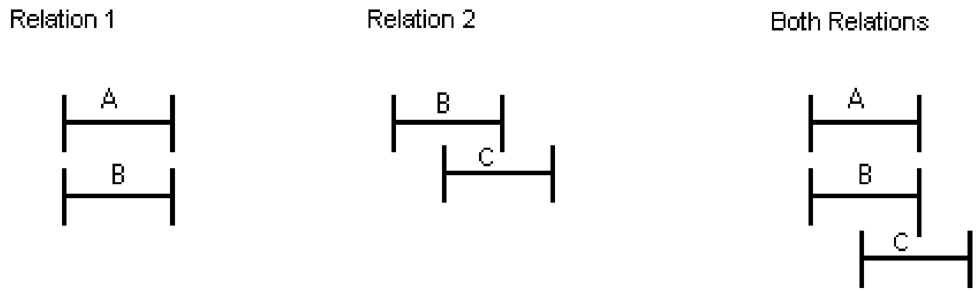

Figure 4-1: Inferences with two events happening simultaneously

the value. For example if the two fields are ? and 1 the field in the combined relation is 1. Currently if there is a contradiction, one field has a 1 and the other has a 0, then the field is set to unknown.

An example where all three rules are used is presented here. The original relation is 1000011? and the new relation is 00100110. The first bit is 1 in the original relation and 0 in the new relation producing a ? in the combined relation as they contradict each other. The next six fields all have the same value in both relations, and thus that value is also used in the combined relation. The last bit has a ? in the original relation and thus the last field of the new relation determines the value in the combined relation. The combined relation is thus ?0000110.

The inference process can be broken down into three cases which can be considered separately. The first case is if at least one of the relations is the same relation, meaning that both of the events happen at the same time. In that case the other relation determines the inferred relation. An example of such a relation is shown in figure 4-1.

The next case is if at least one relation has the meet field set to 1 or has the overlap field set to 0. Information can be primarily inferred if the start points and end points have the same relation between them. This means that in both cases either event A is before event B, or event A is after event B. Figure 4-2 shows both a case where information can be inferred and a case where no information can be inferred.

The last case deals with cases where both intervals overlap, or there is uncertainty

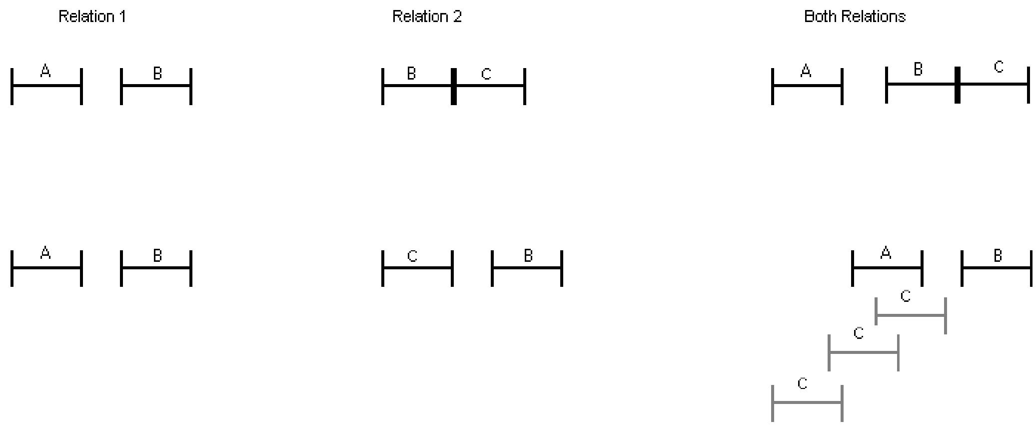

Figure 4-2: Inferences events meet each other or are not overlapping where in A) an inference is possible and in B) no inference is possible

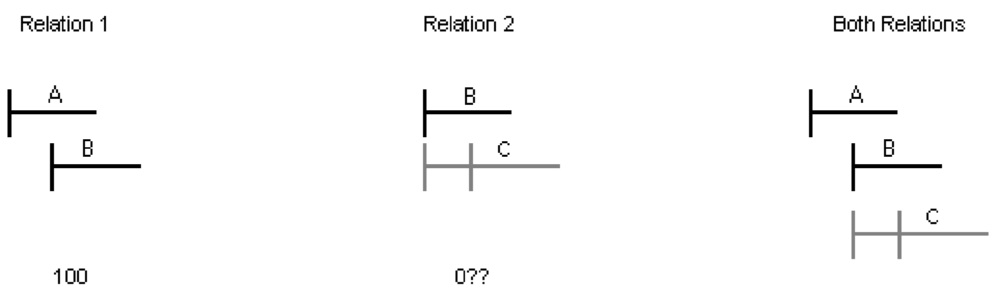

Figure 4-3: Inferences using overlapping events

about whether they overlap. For this case the start and end points can be considered separately, but using the same rules, which makes the inference easier. An example of inferences in this case is shown in figure 4-3. The specific rules for all three cases of the inference function are listed in appendix B.

4.2 Network Component

The next component to the MTC software is the storage of the relations and events in a network. The network contains and maintains the relations and events. The events are the nodes in the network and the relations are the edges between the nodes. To allow the software package to be widely used there are two minimal constrains on the events in the network. The first is that the event can be distinguished from other events and the other is that they contain a useful print function. All of the maintenance functions for the network are defined as well as an inference function. The inference function first finds a path between the two events before trying to make an inference along that path using the inference function described in section 4.1. If the inference is unsuccessful a new path is sought. This continue until there are no more paths to investigate or a valid inference is made. Thus a breadth-first algorithm was used to find the path.

4.3 Display

Correct representation is not enough- they key to quickly understanding the complexity of these stories comes from a good user interface displaying easy to understand networks. As always, it is the visual representation that is the easiest to grasp. Thus, this is the most important feature for novice users. The graphical component provides a visual display of the information and a graphical interface to all of the functionality of the previous two components. Figure 4-4 is a screenshot of a typical session showing a fairly complex network. The areas that are marked will be explained individually in the next few paragraphs.

In figure 4-4 the area A shows currently a network of 32 nodes. The order of the nodes is the order that they were added to the network. As not all nodes would fit on one line, the line of nodes is continued on a new line and in this case there are five lines of nodes. The lines between the nodes, such as the line between node A and node B, in figure 4-4, indicates that there is a relation between those two nodes. By default all kinds of edges are the same color, but this can be changed and is explained in detail below.

The area B in figure 4-4 above, is the input area. Through this text field new relations can be added to the current network. Inputs should be added in the form '*eventA eventB* relation'. The relation is the string of characters that describes the

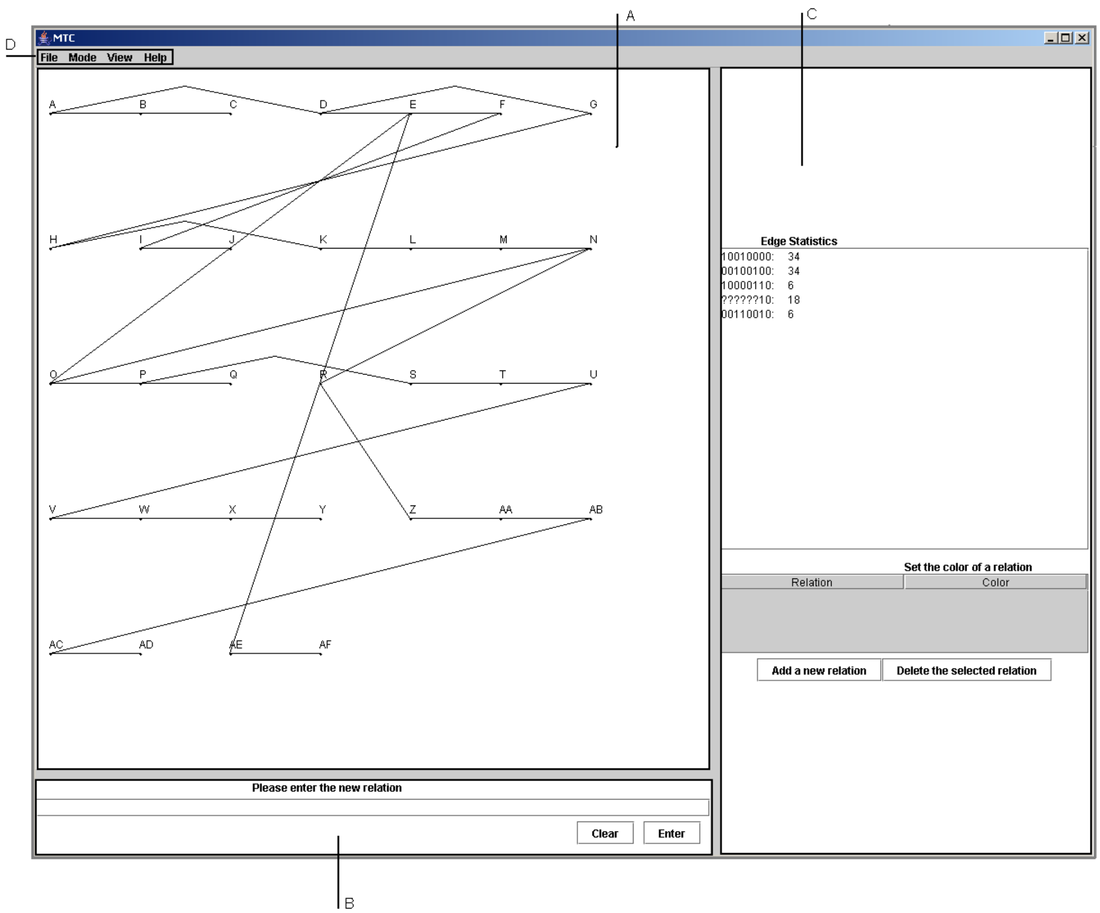

Figure 4-4: Screenshot of a typical session

relationship between the events, for example, 100100?0. Information is checked for validity before it is added to the network. The network display automatically updates after the new info is added to display the new piece of information. To spare the user from reentering the data every time, the interface allows them to save and load the network. The network is stored in a simple text file, which lists the order of the nodes, and then follows it by listing pairs of nodes and the relation between the two nodes.

The user can also switch into a questioning mode, in order to get information from the network. This is done by selecting *Question Mode* under the *Mode* options in the main toolbar, which is labeled D in figure 4-4. The input box in area B of figure 4-4 now accepts text queries of the form '*eventA eventB*.' The programs responds by printing out the relation in the textbox if one exists. If there is not direct relation between the two events, then the relation is inferred from the relations already in the network, using the method described in section 4.2.

The area C in figure 4-4 is the where information and additional controls are located. There is a panel displaying the statistics about the edges in the network. It shows the kinds of edges that are in the network, and the percent of the total network each edge represents.

Area C in figure 4-4 also contains options to color edges by type. This allows users to quickly grasp the complexity of the network. Currently colored edges are listed with their respective colors. An example of a network with colored edges, and the table displaying the colors, is shown in figure 4-5.

Figure 4-5 shows how a graphical display helps understand the temporal complexity of the story. With a quick glance, a first impression is gained by looking at the two criteria that are used to analyze the complexity of the story: successivity, looks at the chronological order of events, and diversity of edges, which looks at both the number of kinds of edges and the distribution. Both are described in detail in chapter 5.

The visual signs of non-successivity are edges between non-adjacent nodes. In figure 4-5 the edge between A and E is an example of this. nother feature to look at for successivity is for two, or more, strings of nodes that branched off each other. This happens in stories that have multiple timelines. In figure 4-5 one

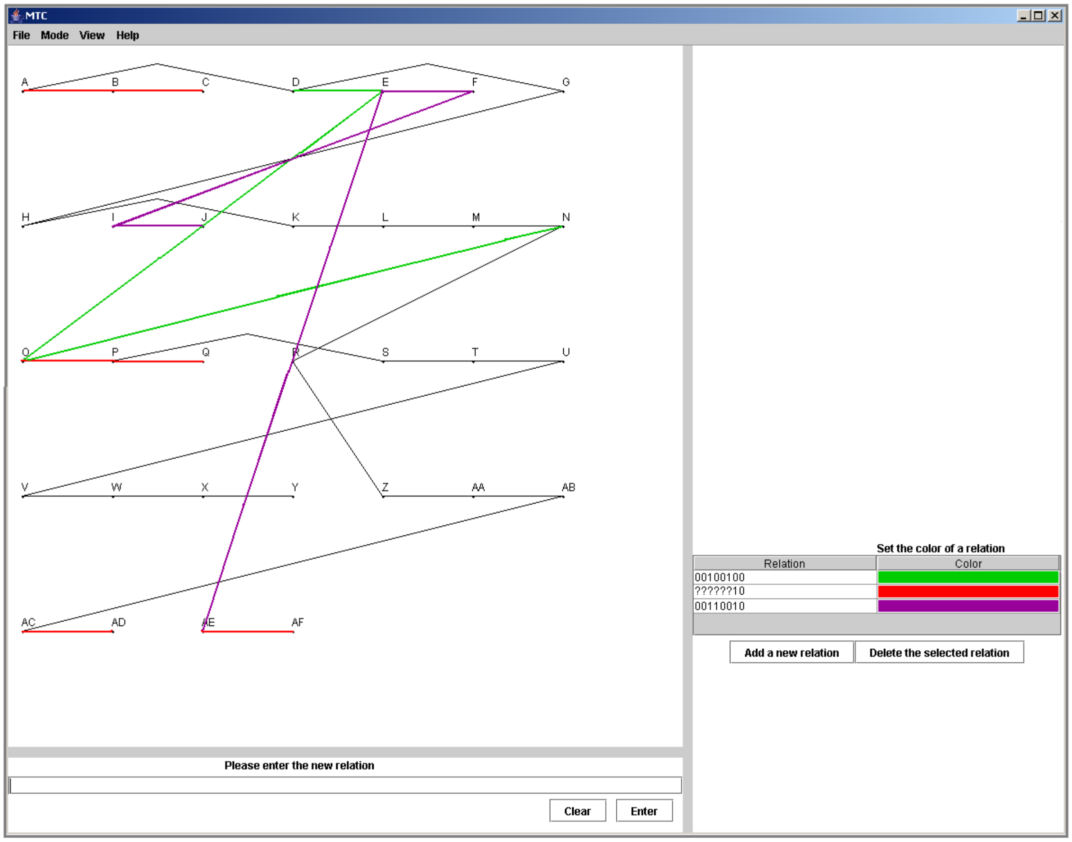

Figure 4-5: Screenshot of a typical session

such split happens at node D which has an edge to both E and G. In fact there are three time lines in the network shown in fgure 4-5. One such line is A,B, C,D,G,H,K,L,M,N,R,Z,AA,AB,AC and AD. B and C might appear to be a separate time line as there is a split at A, but since the relation between A and B is overlapping they are part of this time line.

Diversity of edges is best seen by coloring the different types of edges in the graph. The number of different colors gives an impression of how many different kinds of edges there are. In figure 4-5 there are four different colors, and thus four different relations in the graph. A slightly better impression of the diversity of edges, and how complex the story is, can be gotten by also looking at how common each color is. In figure 4-5 black is by far the most common, but it looks as if about half of the edges are in color. All three colored edges seem to have a similar amount of edges, since none of them really jump out as being more common.

Both the successivity of the displayed network in figure 4-5 and the diversity of the relations points to a high temporal complexity in this children's story. More importantly this shows how much information can be gained from a displayed network showing the temporal relations in the story, without doing any calculations. As is often the case, the right visual display conveys a lot of information to the user.

4.4 Overview

The MTC software package has been designed with modularity in mind. The functionality built into the system allows the user to have easy access to all the tools necessary to visualize and analyze the temporal complexity in a children's story book. This includes creating, storing and querying the information about the temporal relations between the events. The information can be seen visually at all times helping the user keep track of the information already in the graph, as well as help understand the complexity of the information in the book.

The software is not limited to analyzing and visualizing children's stories, but it can also be used to solve other problems. It allows one to represent, reason and visualize time from a source other than stories, for example journalistic articles, video images or musical patterns. The components also have the ability to be used individually to solve problems relating to research in planning, understanding and problem solving. The software built in this thesis can thus be applied to a very large scope of problems.

Chapter 5

Analysis of rated Children's books

The Measuring Time Complexity (MTC) software package allows the analysis of children's books to determine grade level, however it requires calibration before it can be used. Specifically, the software can measure complexity, but not assign that complexity to a particular grade level. In order to calibrate the software, several children's stories with already determined grade levels were analyzed, by looking at the successivity of the story as well as the diversity of the edges in the network. Once the pattern has been found in these well-classified stories, the results can then be used with other stories that have not been classified to help find appropriate books for a given grade.

Two criteria are important when analyzing temporal complexities and assign reading material to appropriate grade level. The first criterion is successivity, which looks at the order of events in the story and assesses if events appear in chronological order. The second criterion is the diversity of relations between events. This diversity is easily displayed in list, where each edge type is listed with their respective percentages. To establish a set of control measures both criteria were assessed and calculate by using classified stories. The resulting statistics allow now for comparison with and the application to unclassified stories.

5.1 Choosing stories

The stories were chosen from the *Spectrum Reading Series* published by McGraw-Hill. These books are aimed at children in grades K through 6 in a number of school subjects. The goal of the reading series is to improve reading and comprehension skills. This series is a good source, because each grade has an assigned book containing a large selection of stories deemed appropriate for a given grade.

The assessment of time complexities with the MTC software begins with grade 1. This is because stories suitable for Kindergartners are too simple. The upper limit of the software package is grade 4. This is because the difference in time complexity is insignificant between stories for grades 4 and 5. Books for grades 1 through 3 are broadly divided into two parts, in the first half of the book stories are generally shorter and simpler than in the second half of the book, where readings are more challenging. In contrast, books for grade 4 have only one set of stories and a number of stories were descriptive and educational with relatively few events. The complete list of stories for grades 1 to 4 used in this thesis can be found in appendix C. The readings are listed in the same order as their statistics are presented in this chapter.

5.2 Network Creation

The issue of generating networks is a key concern, as the networks need to be consistent for the results to be useful. Rather than parsing the story in from straight text, which considering the limitations of text parsers in comprehending the story would result in inconsistent graphs which would influence the results, the story books were analyzed by hand. Thus any results found in this thesis would be clouded by only the investigator's bias, which hopefully is slight and consistent.

The first step for the graph's creation was to read the story and identify all events. It was imperative to ensure that only active events are included and that static events as well as desires were excluded. The reason to exclude static events such as "it was a sunny day" as well as wants and desires is that often these events are not mentioned again in the remaining part of the story. There are some stories were states are in fact tracked and in those they could be included in the networks, but this was not the case in any of the books used in this research.

The second step for the creation of the graph was to assess the relations between events based on different temporal criteria. The default setting was based on the chronological order, which allows contrasting events that overlap or are in a non-chronological order, for example reference to events in the past or future. In addition, it was important to be aware that in stories telling about events from the past the correct timeline is assigned.

Overlapping events are easily spotted because they are usually accompanied by key words such as “while” and “during”. However, it is difficult to extract further information regarding time aspects of these overlaps. More precise cases of simultaneity can be determined by looking at the specific events in question and assessing, whether they happened at the same time or not. Finally, a last aspect is to analyze whether one event encompasses another. Usually in the stories that were considered in this work, this was only the case when an event was first mentioned and then details are added. For example a book might first say, “he searched for Max” and then continues that “he looked in the cabinets”. In this case the second event elaborates on the first and is thus a subevent of the first event.

5.3 Successivity of Children’s Stories

Successivity refers to the order of events and if they are presented in the order they happened. Often in stories, reference to the past or future disrupts the chronological order of events. The reader has to order the events chronologically. The experienced reader is able to keep track of several strands of a story before their temporal relations are known and it becomes possible to establish a complete order. It is not surprising that stories for young and inexperienced readers have little or no deviation from the chronological order. Only with increasing grade level and experience do larger deviations from successivity become the norm. It follows that in stories for grade 1

	1	2	3	4	5	6	7	8	Av.
%	100.00	100.00	100.00	100.00	92.00	89.00	92.00	93.00	95.75

Figure 5-1: Grade 1 Successivity Scores

	1	2	3	4	5	6	7	8	9	10	Av.
%	93.75	87.5	92.31	88.23	92.31	88.23	83.33	92.80	92.30	91.30	90.206

Figure 5-2: Grade 2 Successivity Scores

there is usually a direct correlation between the order of the sentences and the order of events and in stories for grade 4 multiple time lines can be found.

In the analyses for this study, purely successive events are the focus. With overlapping events it is often impossible to assess which event happened first. Therefore, all overlapping events are not considered to be successive. In addition, events that are presented in a chronological order but outside the temporal context of the story are omitted, as they are not an integral part of the story's successivity. For example, if in a story events are told that happened the day before, they are not part of the successivity even if they are told in a chronological order. The events happening in a chronological order are compared with the total number of events in a story to find the percent of successive events. Below are the statistics drawn from the sample of stories for each grade. The numbers in the top row refer to the stories, and are presented in the same order as in the appendix C.

The successivity scores can be seen for individuals grades in figures 5-1, 5-2,5-3 and 5-4. All of the statistics are combined in figure 5-5.

The higher the percentage, the more successive is the story. As it was expected, temporal complexity increases in books for older readers as can be seen by the decrease in the the percentage of successive events in a story. In addition, it is surprising, that the difference between grades 1 and 2 is modest in comparison to clearly marked differences between grades 2 and 3, and grades 3 and 4.

	1	2	3	4	5	6	7	8	9	10	11	Av.
%	85.70	85.00	75.57	77.40	83.33	77.14	83.33	79.41	65.50	77.77	75.86	78.73

Figure 5-3: Grade 3 Successivity Scores

	1	2	3	4	5	6	7	Av.
%	71.43	69.23	73.1	80.44	46.88	43.00	55.55	62.89

Figure 5-4: Grade 4 Successivity Scores

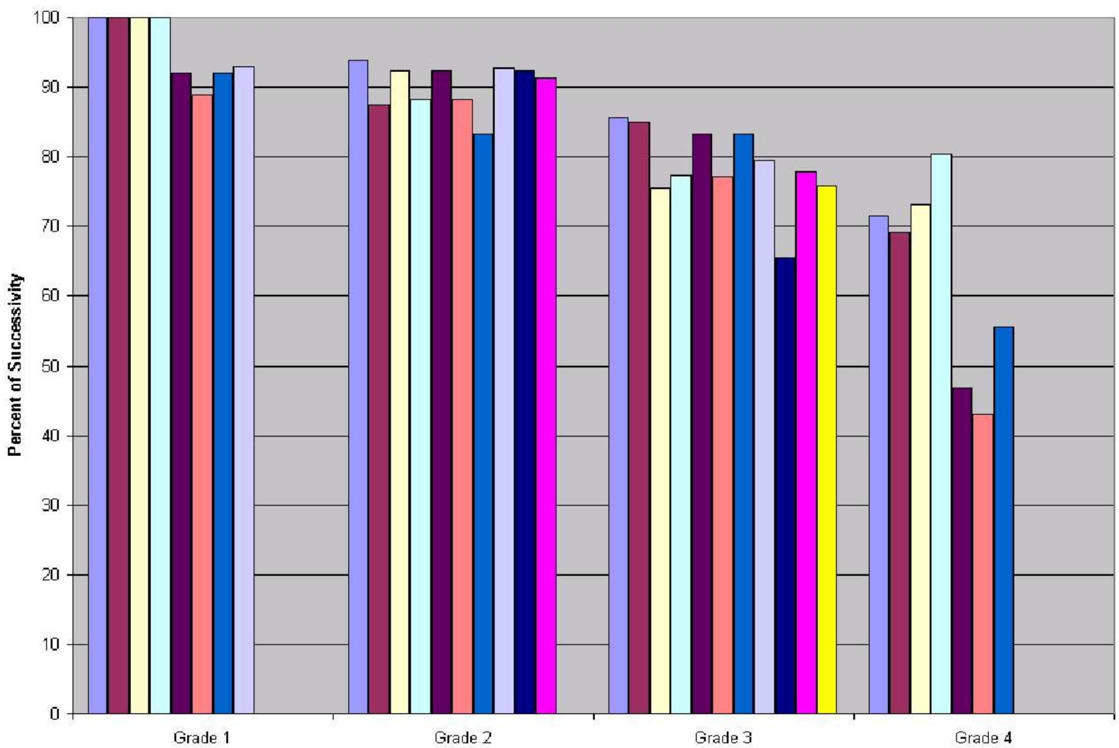

Figure 5-5: Successivity Scores

One of the features that only appears in grade 3, and becomes more pronounced in grade 4, is the introduction of multiple timeline. These stories have a very low successivity score, as is the case with 9 in grade 3 and story 5 of grade 4. Usually one of the character tells of events that happened in the past inn these stories. In story 9 of the grade 3 stories, one of the characters tells of when she was a little girl and fell off a horse. In story 5 of the grade 4 stories, a character tells of her visit to St Helen's and her brothers experience of when it erupted. This story in fact has three timelines: the timeline where she tell the story, her visit to St Helen, and the eruption of the volcano.

Looking at the boundary line between grades 1 and 2, it is not easy to determine where the division lies. The reason is partially due to fewer events in stories from grade 1. The boundary line is set at 95% as no stories in grade 2 are above that mark.

The boundary line between grades 2 and 3 is easier to define. With the exception of one story, the stories of grade 2 readings are above 85% and with the exception of one story that is slightly higher, all the stories for grade 3 readers are below that mark and thus 85% seem to be an appropriate division between grades 2 and 3. 70% were chosen as the boundary line between grades 3 and 4, because with the exception of one story all stories of grade 4 fall under a mark of 70% and only one grade 3 stories falls below it.

5.4 Diversity of Edges

The other key criterion concerns the diversity kinds of edges. Since complexity increases as children get older, it is expected that the number of different kinds of edges, representing different relations, also increases. Certain types of simple relations should become less frequent in story books for older children and more complex relations become more common.

Figures 5-6, 5-7, 5-8, and 5-9 and their associated graphs (figures 5-10,5-11, 5-12, and 5-13 respectively) show the diveristy of edges. In the network, when a relation between event A and B is added, a relation between event B and A is also added. For

	1	2	3	4	5	6	7	8
10010000 (Before)	50.00	50.00	50.00	50.00	50.00	44.00	50.00	50.00
00100100 (After)	50.00	50.00	50.00	50.00	50.00	44.00	50.00	50.00
??????10 (Overlapping)						12.00		

Figure 5-6: Grade 1 Diversity of Edges Statistics

	1	2	3	4	5	6	7	8	9	10
10010000 (Before)	46.67	50.00	50.00	44.12	50.0	47.05	45.45	46.15	45.83	45.45
00100100 (After)	46.67	50.00	50.00	44.12	50.0	47.05	45.45	46.15	45.83	45.45
??????10 (Overlapping)	6.67			11.76		5.89	9.00	7.69	8.33	9.00

Figure 5-7: Grade 2 Diversity of Edges Statistics

	1	2	3	4	5	6	7	8	9	10	11
10010000 (Before)	42.60	44.70	46.40	44.80	43.10	41.2	42.3	44.00	41.10	30.80	32.10
00100100 (After)	42.60	44.70	46.40	44.80	43.10	41.2	42.3	44.00	41.10	30.80	32.10
??????10 (Overlapping)	14.80	10.50	7.00	10.30	10.3	17.6	17.4	8.00	10.70	15.50	14.30
01001010 (Simultaneously)					3.00			3.00	7.00	3.00	3.00

Figure 5-8: Grade 3 Diversity of Edges Statistics

	1	2	3	4	5	6	7
10010000 (Before)	39.39	41.67	41.67	43.20	37.50	43.10	42.30
00100100 (After)	39.39	41.67	41.67	43.20	37.50	43.10	42.30
???????10 (Overlapping)	12.12	12.50	16.67	12.50	18.70	11.11	7.69
01001010 (Simultaneously)	9.09	4.16					7.69
00110010 (Completely Encompassing)					1.56	1.38	
10000110 (Completely Contained In)					1.56	1.38	

Figure 5-9: Grade 4 Diversity of Edges Statistics

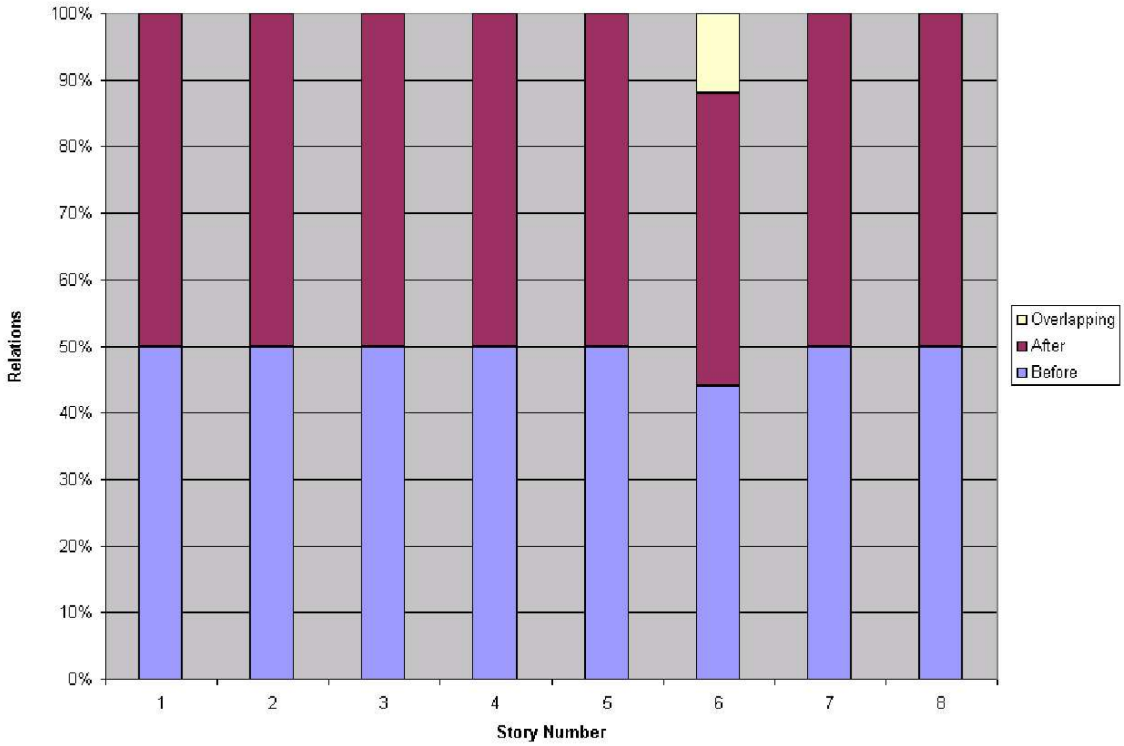

Figure 5-10: Diversity of Edges Graph for Grade 1

this reason in a purely successive graph, which just contains before/after relations, 50% of the edges are the before relation and 50% of the relation are the after relation. Figure 5-10 shows this quite clearly.

There is a clear increase in the number of different kinds of relations as the grade level increases. It is also apparent that the distribution of the edges becomes broader and the percentage for the basic before and after edges decreases. Most grade 1 stories have only two kinds of edges. In grade 2, overlapping events start being used. A typical example of overlapping events are "I was eating lunch in the clover field, when the sky turned dark." In grade 3 readings, there are a significant number of overlapping events, including at time the more specific simultaneous relation. An example of simultaneous events is "when he picked up the string, the block of ice came up with it." Grade 4 readings introduce completely overlapped events. An example of completely overlapped events is "When we flew inside the crater of the volcano, I did close my eyes!"

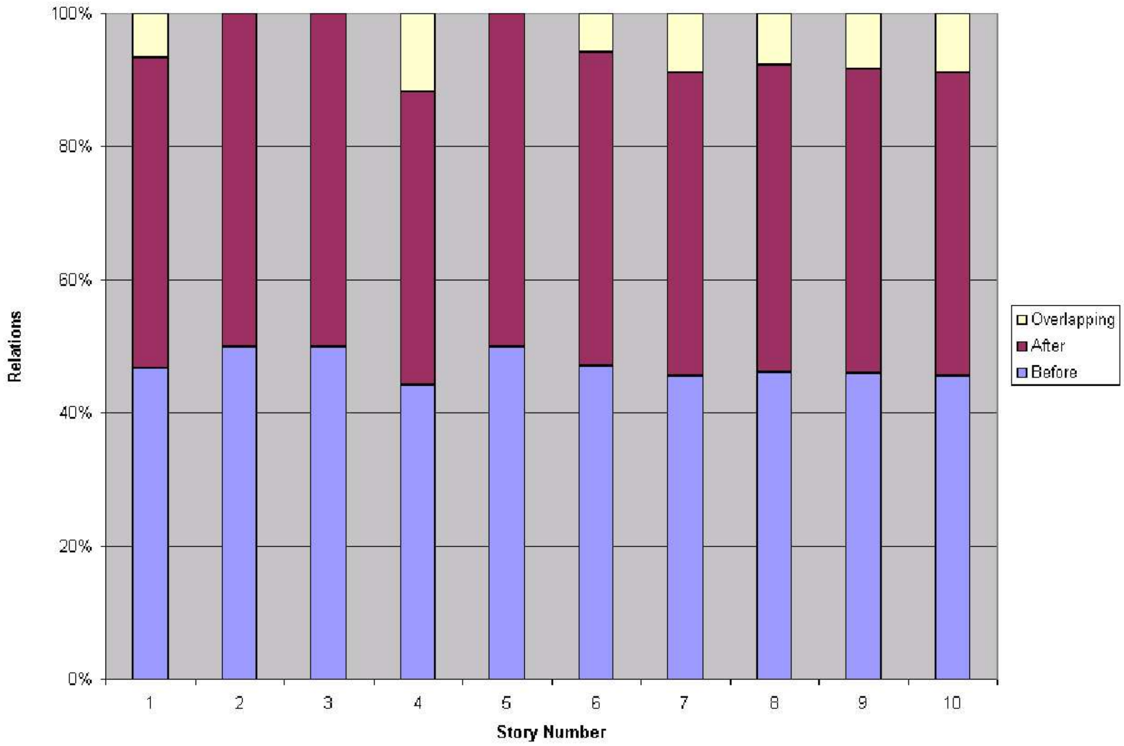

Figure 5-11: Diversity of Edges Graph for Grade 2

Looking at the frequencies of different types of event relations the before, or after, relations are the most important for comparison. Most grade 1 stories have 50% of event relations being successive. The boundary line between grades 2 and 3 is at 45%. The boundary line between grades 3 and 4 is at 40% with at least 10% of relations overlapping.

5.5 Summary

In this chapter the software package developed for this thesis had to be calibrated before it can be used with children's books. The stories used for this calibration were from the *Spectrum Reading Series* by McGraw-Hill. The calibration was done using two separate criteria that together determine the appropriate age group of readers.

The first criterion is the successivity of a story, which assesses if events in a book are presented in a chronological order. The results reveal that this criterion is not

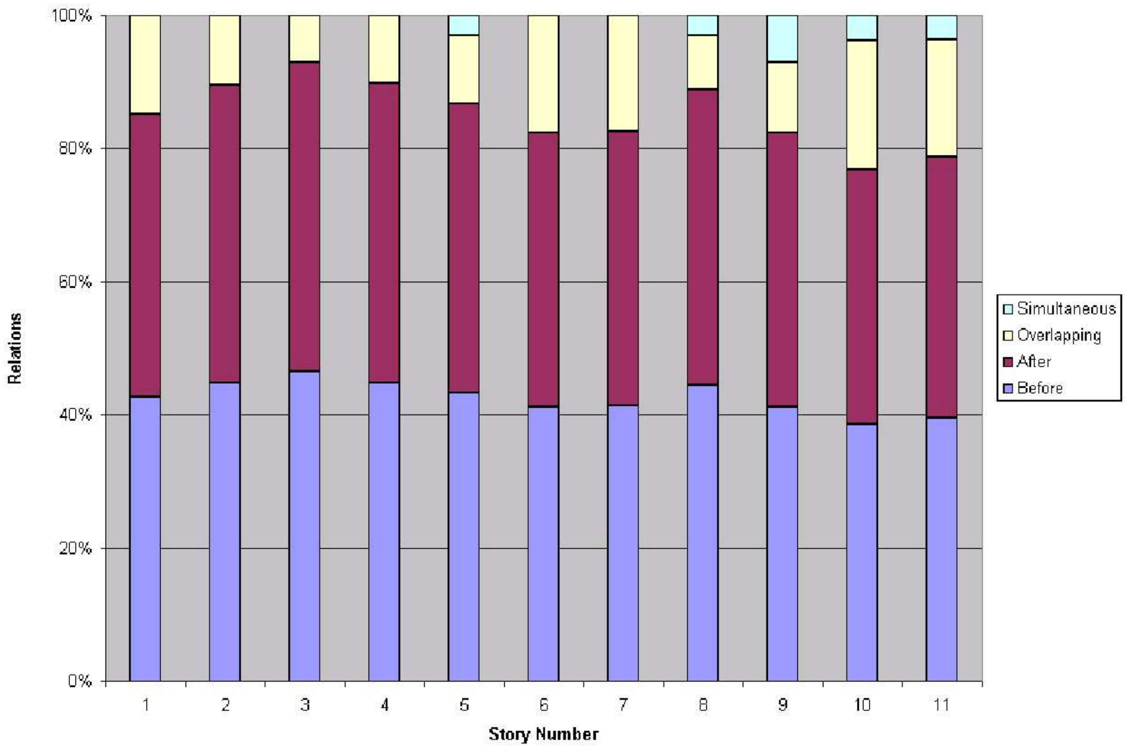

Figure 5-12: Diversity of Edges Graph for Grade 3

differentiated enough to easily define a clear boundary line between grades 1 and 2. However, the differences between grades 2 and 3 and those between grades 3 and 4 are clearly visible.

The second criterion assesses the diversity of edges, including not only different kinds of edges, but also the percentage of each kind of edges. Here it is easier to define the boundary lines between all four grades. For each grade a new kind of edge is added and the number of kinds of edges increase. In addition, the number of edges representing successive events is decreasing as the number of other edges rises.

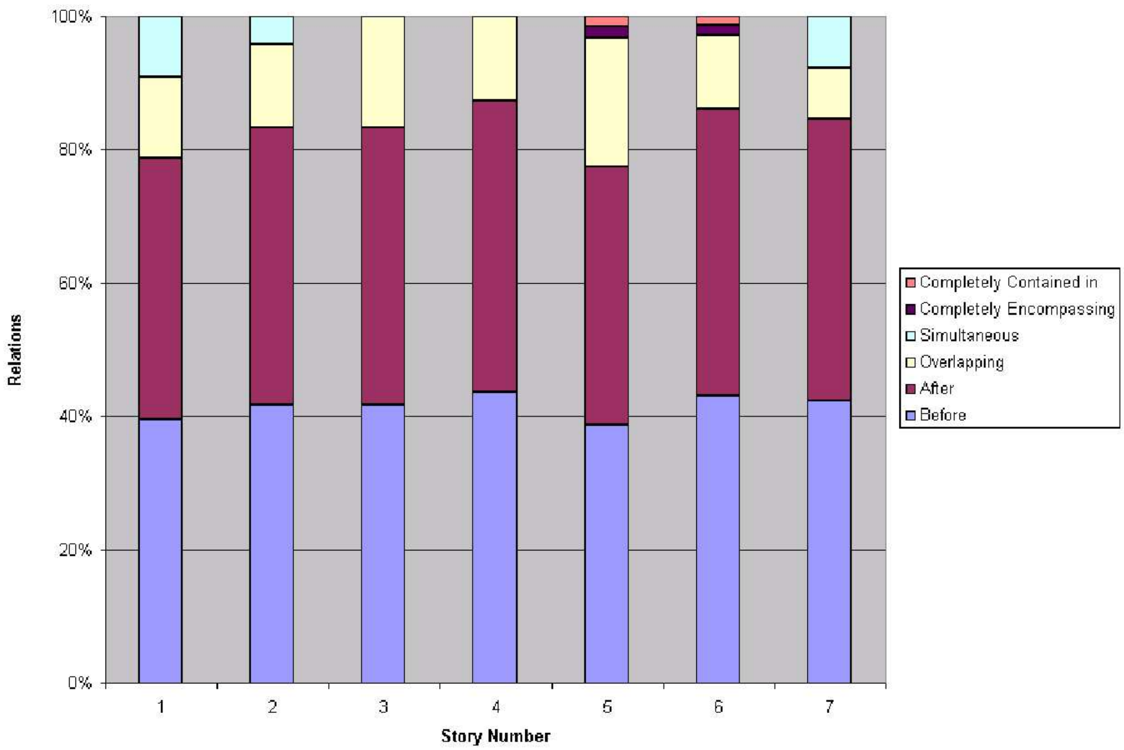

Figure 5-13: Diversity of Edges Graph for Grade 4

Chapter 6

Evaluating Children's Story Books

So far this thesis has succeeded in showing a relationship between children's abilities to comprehend temporal complexities and grade level appropriate readings. Now, the Measuring Time Complexity (MTC) software is applied to unclassified readings in order to assign stories to the appropriate grade level of readers.

Six books, unclassified by McGraw-Hill have been chosen. Out of these six, two have been previously classified by other agencies than McGraw-Hill and four have never been classified at all. The six stories were chosen from the summer reading list compiled by the Children's Room of the Boston Public Library. All books on the reading list were grouped by librarians in readings for grades K through 3 and grades 4 to 5. Out of these two age groups, the books were chosen at random, without looking at the titles and only noting the age recommendation.

These stories are much longer than the McGraw-Hill stories in chapter 5. As such, making a network of the entire story would be long and tedious. A section of each book was used comprising about 20 events. This number was chosen as a moderate sample, based on the average number of events in grade 2 stories from the *Spectrum Reading Series* by McGraw-Hill. The sections chosen start in the middle of each book, but whenever possible, coincide with the beginning of a chapter.

In the following sections, the analyses of the test books are described including a brief synopsis of the story before the statistics are presented. The statistics are calculated in the same way as in the chapter 5. They are followed by a summary of the results.

6.1 *What a trip, Amber Brown*

What a Trip, Amber Brown was written by Paula Danziger and judged appropriate for grades K through 3 by the library staff. The book is a picture book with 48 pages. The story tells of Amber Brown taking a vacation with her friend Justin and his younger brother Danny.

A section of the book beginning on page 14 was examined. This section contains 21 temporal events with 20 relations between them. Of these 21 events, 3 are not in chronological order and thus the story is 85.71% successive. This is right at the boundary line between grades 2 and 3, but since there are only 21 events, fewer than the average number in grade 3 stories, this score indicates a grade 2 reading.

Three kinds of edges are displayed in the graph: before(10010000), after(00100100), and overlapping(??????10). The overlapping relations comprise 10%, and the before and after edges each comprise 45% of the total number of edges. These indicate a grade 2 level story.

An interesting aspect of this story is its subject: family. It teaches children the value of having siblings. Even if they are annoying sometimes they are still family, and that you do not really want them to go away. There are in fact many stories that carry this theme, probably since most children have siblings and are likely to hate them at times.

6.2 *Breakout at the Bug Lab*

Breakout at the Bug Lab by Ruth Horowitz is the second book evaluated and is also considered suitable for grades K through 3. Similarly to the first book, its target group is younger readers because there are many pictures in the book to illustrate its content. The book contains 48 pages. The story tells of two young boys trying to catch a cockroach that is loose, to prevent it scaring everyone at a dedication service.

The section chosen contains 20 temporal events with 19 relations between them. 17 of the 20 events are in a chronological order, which gives the story a successive score of 85%. This is right at the boundary line between grades 2 and 3, but since there are only 20 events, fewer than the average number in grade 3 stories, this score indicates a grade 2 reading.

There are only three kinds of edges in the graph: before(10010000), after(00100100) and overlapping(??????10), which is typical of a grade 2 story. The percentage of overlapping edges is 10.5% and before and after relations each represent 44.7% percent of the total number of edges. These percentages are on the boundary line between grad 3 and grade 4, but with just three kinds of edges, this indicates a grade 3 readings. If one combines it with the percentages of successive events, the story is suitable for advanced grade 2 and early grade 3 readers.

This story illustrates the advantages and value of teamwork to face challenges and overcome problems. In the story two brothers have to work together in order to catch a cockroach before it scares everyone.

6.3 *Agapanthus Hum and the Eyeglasses*

Agapanthus Hum and the Eyeglasses by Joy Cowley is also classified as grades K through 3 reading. As the two previous books it suits reading skills of younger readers because many pictures illustrate the text. The book contains 44 pages. Agapanthus Hum is a girl who loves to cartwheel and the story shows her strategy to prevent her eyeglasses from falling off while she cartwheels.

The section chosen for the evaluation starts at the beginning of chapter 6. There are 21 temporal events and 20 relations between those events. There are 4 events that are not in a chronological order giving the story a successivity score of 80.95%. According to this measure the story is considered a grade 3 reading.

There are three kinds of relations: before(10010000), after(00100100), and overlapping(??????10). The before and after edges each represent 40%, while the overlapping edges represent 20% of the total number of edges. These percentages scores place the story on the border of grades 3 and 4, however, since there are only 3 kinds of edges the story is suitable for grade 3 readers.

The story values inventiveness in order to overcome obstacles. It is an inspiration to tackle problem; agency is better than resignation. Considering that the protagonist is a girl, it also contains a gender sensitive message.

6.4 *The Blind Men and the Elephant*

The Blind Men and the Elephant by Karen Backstein is also a considered grades K through 3 reading. Many illustrations point at a less experienced target group. The book has no page numbers. The story tells of six blind men. They hear that the sultan has an elephant and want to visit him in order to learn what an elephant actually is.

The section is drawn shortly after the beginning of the books and contains 18 events, 4 of which are not in chronological order. Thus, the successivity score is 77.78%, an indication that the story is appropriate for grade 3 readers.

There are three kinds of edges: before(10010000), after(00100100), and overlapping(??????10). The overlapping edges represent 17.65% of the total number of edges, while the before and after edges represent 41.18% each. These percentages are on the border of a grade 3 and 4 readings, however since there are only 3 kinds of edges the book is suitable for grade 3 readers.

This story is about the subjectivity of perceptions, because all six man touch the same animal in different places and associate it with different things known to them. The story emphasizes the fact that human beings are different with different perceptions and opinions, because everybody has a different approach. However, all approaches are valuable and nobody's prevails.

Relation	%
Before (10010000)	36.54
After (00100100)	36.54
Completely Encompassing (10000110)	1.92
Completely Contained in (00110010)	1.92
Overlapping (??????10)	23.08

Figure 6-1: *My Father's Dragon* Edge Statistics

6.5 *My Father's Dragon*

My Father's Dragon by Ruth Stiles Gannett is considered appropriate for readers from grades 4 and 5. In comparison to the previous books, there are fewer illustrations; in fact most of the pages contain only text. The book has 87 pages. The book tells of a small boy travelling in a fantasy land and looking for a dragon after running away from home.

The section chosen for evaluation starts with chapter 5. It contains 26 temporal events with 26 relations between them. Of the 26 events, 18 of them are chronological and the successivity score is 69.23%, making it appropriate for grade 4 readers.

In the graph, five kinds of edges are depicted. Figure 6-1 displays the percentage of each kind in comparison to the total number of edges and indicate together with the successivity score that the reading is appropriate for grade 4.

This story encourages the imagination of children. It starts with reality shifting into an imaginary world that shares many characteristics with the real world. It is sometimes easier to deal with problems or to develop life skills in an imaginary world where many more things are possible, but it is also where the distance to reality allows looking at a situation from a different perspective. In addition, imagination has a compensatory function helpful in challenging times.

Relation	%
Before (10010000)	33.33
After (00100100)	33.33
Completely Encompassing (10000110)	4.17
Completely Contained in (00110010)	4.17
Simultaneously (01001010)	4.17
Overlapping (??????10)	20.83

Figure 6-2: *The Real Thief* Edge Statistics

6.6 *The Real Thief*

The Real Thief by William Steig is also considered appropriate for grades 4 and 5 readers. It clearly aims at an older target group, illustrations are scarce and most pages contain only text. The book has 58 pages. The book tells of a goose falsely accused of a crime.

The section evaluated begins with chapter 3 and contains 25 temporal events with 24 relations. 16 of the 25 events are in a chronological order and the successivity score is 64%. This points at an appropriate reading for grade 4.

There are six kinds of edges, listed in figure 6-2 with their respective percentages. The percentages of different kinds of edges in comparison with the total number of edges indicate with the successivity score to a grade 4 reading.

This story has a strong moral message. There is a high educational value assigned to morality often found either openly displayed or hidden in stories. It is a means to pass values, norms and beliefs from one generation to the next.

6.7 Summary

For the evaluation of each book the MTC software developed for this thesis and calibrated in chapter 5 was applied. Out of this random sample, only one story had the results point at two different grade, however, the difference in that cases was only one grade. These results are encouraging, because they suggest that the methods work and that they are appropriately calibrated.

The assessments done by librarians at the Children's Room of the Boston Public Library were quite accurate, because the evaluations done in this thesis correlate with the classification suggested by them. The difference is that this MTC software allows for a precise assessment, reducing subjectivity.

It is startling that none of the stories evaluated is appropriate for grade 1 readers; in particular, if one considers that many of the books were picture books. This gives rise to a concern: are the choices for grade 1 readers limited at the Boston Public Library or is differences between grades 1 and 2 readings so minimal that most grade 1 readers can tackle a grade 2 reading.

Each of these books has an educational value and transmits a specific message. These messages are common to many children's readings though the means of conveying them may be different. Each book has a designated educational content wrapped in a story line adapted to the reading and comprehension abilities of the respective age group.

Chapter 7

Contributions

7.1 Summary

The aim of this thesis was to learn about and evaluate the development of children's time perception. This in turn gives us a better understanding of how time perception works in adults. A clear progression in the temporal complexity in story books for children is shown and analysed in this work. Additionally, the necessary representation and software to achieve this goal were developed. The results of the work in this thesis help to determine the appropriate reading material for a given grade level, and indicate that semantic contents should be considered when doing the assessment.

The first step in this research was the development of a representation to better understand time and its complexity. The representation developed is interval-based and has uncertainties built in. To achieve this, four properties of the temporal relations between events are examined: how the start points relate, how the end points relate, if the events meet, and if the events overlap. Each of the first two properties is subdivided into three parts giving a total of eight fields. These eight fields are sufficient to fully represent all possible temporal relations between two events.

The next step in this project was the development of an information network. This network keeps track of all the events and relations in the story and allows access to the information. It is also possible to infer relations based on the given information.

A computer program, Measuring Time Complexity (MTC), was written to analyze stories by creating these networks. This software package allows the analysis of the temporal complexity of stories and thus enables users to find stories that are appropriate to a grade level. The graphical display gives the user a sense of the temporal complexity in the story, without calculating any statistics. Furthermore some of the components of the package can be used individually or potentially as part of a larger system to represent and reason about temporal complexity from different sources.

The software package was initially calibrated using stories with age level determined by McGraw-Hill. This provided a means for age classification of stories based on the successivity of the story as well as the diversity of the relations in the temporal events network.

The software package was then used to classify randomly selected books into appropriate reading levels. Six different books from the Boston Public Library summer reading list were successfully classified by the MTC software.

The aim of the thesis was to find a progression in temporal complexity, as well as to develop the necessary tools for evaluating temporal complexity of children's stories. The thesis succeeds in this goal and shows the progression in children's the understanding of time. In addition, this thesis is a helpful step towards better understanding of how adult time perception is developed. This work is a first step towards integrating semantic complexity into assessment methods.

7.2 Future Work

The work in this thesis was influenced by the application of the work to children's stories. However, the methods can still be used in many different contexts and for different applications than were the focus of this thesis.

One way that the thesis can be applied involves a slight change to the representation in a context where more information is known. In particular this applies where specific information about the amount of uncertainty is known. In this case, it is possible to use probabilities in place of the "unknown" flag. This representation would allow more information to be conveyed in contexts where there is enough information to make a reasonable guess at the probability of a particular field.

Another way in which the representation could be change and expanded is the inclusion of the duration of events. This would only be useful in contexts where there is enough information to know, or at least, guess about the duration of a fair number of events.

Adding duration would then allow the addition of another extension to the representation: instantaneous events. With this extra capability the representation would be able to deal with both intervals and points and be useful in broader contexts.

Another way that the work in this thesis can be expanded is by adding capabilities to the display. A part of the display that could be expanded is an additional network display. It may be useful to have other network layouts than the linear layout currently employed.

In order to make this work more useful in a different context, such as planning, it is important to minimize the time it takes to get information out of the network. To achieve this, the current simple network would have to be extended into a constraint-based network. This would allow the calculation of all new possible relations whenever new data is entered into the network. This would require a substantial change to the network component in this software.

This thesis opens up an entirely new method of categorizing children's stories by taking into consideration the cognitive development of the child and thus the semantic content of the story. It allows educators to ensure that their book choices are appropriate for the children they teach. This work allows a first semantic complexity dimension to be used in the assessment, but further work in identifying and understanding other semantic complexities is needed. Doing so would contribute greatly to our understanding of human development.

This thesis is a first step towards a better understanding of a child's perception of time. Future research could include live studies conducted over time, enabling us to learn more precisely about the development of time perception. Understanding the changes in time perceptions helps us better understand time perception in adults. This thesis is merely a small piece of the greater puzzle of human perception of time, a puzzle which we hope to some day unravel.

7.3 Contributions

A contribution of this thesis is demonstrating that time complexity changes in children's story books. As the grade level of the books increase, the time complexity increases with it. In fact two different indicators, successivity of the story and the diversity of relations, both show the increase in temporal complexity. Grade 1 stories are purely successive with only two kinds of relations, while grade 4 stories are on average only 60% successive with at least four different kinds of relations in each story.

Another contributions of this work is presenting a new temporal representation that integrates uncertainty into the representation. The temporal relation between two events is represented by tracking four properties, and which properties are known to be true, false and unknown. The four properties, the relation between the two start points, the relation between the two end points, whether the intervals overlap and whether the intervals meet, are enough to know the exact temporal relation between two events in a perfect information case.

This work further contributes by demonstrating that a graphical display of the temporal complexities of a story helps understand the temporal complexity of the story. A visual graph showing all of the events and their relations can give a sense for both the successivity of the story and the diversity of the edges in the graph. Connections between non-adjacent nodes indicates non-successivity. Multiple strings of edges indicate different timelines in the story. Displaying different kind of edges in different colors, can help give a sense for how many different kind of edges there are in the graph, as well as how common a type of edge is. In these two ways a graphical display can give a sense of the temporal complexity of the story without doing any calculations.

A further contributions is the tools that were developed in this thesis to measure, and visualise, the temporal complexity in a story. The tools give the user the ability to fully analyze the temporal complexity of the story. The statistics can be used to judge the grade level the story after calibrating the software. The software can calculate the statistics, but not assign them to a grade. Thus standard have to be set by looking at stories that are known to be appropriate for a given grade level.

The final contribution of this thesis is showing a new way of assessing the appropriate grade level of a story. Current assessment methods rely solely on the word and sentence complexity, without taking into account the semantic contents of the story. The work in this thesis suggests that assessments should be done by looking at multiple-dimensions that also measure the semantic complexity. One semantic content dimension is temporal complexity. More research needs to be done to identify the other semantic complexities that are important. Such research would eventually allow one to measure the semantic complexity of the story and choose stories that take the cognitive ability of the child into consideration.

Appendix A

Rules for Finding Illegal Relations

Here all the cases where the relation is not legal are listed

```
if more than one start field is true

if more than one end field is true

if all of the start fields are false

if all of the end fields are false

if both the meet and overlap field are true


if the meet field is one or the overlap field is false:

    if the start and end points happen at the same time

    if the start and end relation are not the same or cannot be reduce to this.

       for example ??0 and 0?? would reduce to one of the two cases above.
```

Appendix B

Rules for Inferences

```
relA and relB are the two relation an inference is made from

case 1: if either relA or relB represent simultaneous events
        then the other is the inferred relation

case 2: if either relA or relB has the meet field set to 1 or
    overlapfield set to 0
        if both of them have the meet field set to 1 or both have the
         overlap field set to 0
            if both relations have event A starting before event B
                   then the inferred relation is a before relation
            if both relations have event A starting after event B
                   then the inferred relation is an after relation



        the relation which has the meet field set to 1 or the overlap
         field set to 0 will be refeered to as relC and the other relD
if in relC eventA is before eventB
            if in relD the eventA and eventB start at the same time
```

```
                then relC is the answer
            else if in relD event A start before event B
                    then the inferred relation is a before relation
    else if relD has the overlap bit set to true and eventA
             start after eventB
                    then the inferred relation is ???100100
            else if in relD the eventA does not start after eventB
                    then the inferred relation is 1001000?

if relC eventA is after eventB
the same rules as for eventA before eventB are used
but one looks at the end points instead

case 3: same for start point as end points
        if the start points are the same
               then the other relation carries over
        else if the relations are the same
               then copy the information
        else if one of the relation is 100 and the other ??0
               then the inferrence is 100
        else if one of the relations is 001 and the other 0??
               then then inferred relation is 001
```

Appendix C

Complete Story List

C.1 Grade 1

1. *Look Out, Mack!* (p. 24)
2. *Something New* (p. 28)
3. *I See You* (p. 46)
4. *Mack Jumps In* (p. 52)
5. *Joy Can Fly* (p. 58)
6. *How do you feel?* (p. 64)
7. *Making Money* (p. 94)
8. *A New House* (p. 104)

C.2 Grade 2

1. *A New Friend* (p. 12)
2. *Get the Brush* (p. 32)
3. *A New Game?* (p. 46)

4. *Keep Away* (p. 60)
5. *Beautiful Ribbons* (p. 76)
6. *Thunder and Rain* (p. 88)
7. *The Night Hunter* (p. 110)
8. *Glenda Gives a Gift* (p. 132)
9. *The Gold Coat* (p. 156)
10. *Pokey Snail* (p. 162)

C.3 Grade 3

1. *Robot Commands* (p. 6)
2. *Too Much Trash!* (p. 14)
3. *A Pet for Carlos* (p. 34)
4. *Snowbot* (p. 56)
5. *The Dinner Party* (p. 74)
6. *Cat Bath* (p. 86)
7. *The Seven-Flavor Favor* (p. 104)
8. *Hocus-Pocus* (p. 110)
9. *The Fall* (p. 126)
10. *The Clubhouse* (p. 142)
11. *Cocoon Surprise* (p. 154)

C.4 Grade 4

1. *Good Ideas* (p. 6)
2. *World Underground* (p. 12)
3. *Whale Watch* (p. 28)
4. *Surprises at the Zoo* (p. 44)
5. *Mountain of Fire* (p. 52)
6. *The Bears of Yellowstone* (p. 78)
7. *A New Year* (p. 84)

Bibliography

[1] Karen Backstein. *The Blind Men and the Elephant*. Scholastic Inc, 1992.

[2] Richard A. Block, editor. *Cognitive Models of Psychological Time*. Lawrence Erlbaum Association, 1990.

[3] Richard A. Block. Models of psychological time. In Richard A. Block, editor, *Cognitve Models of Psychological Time*. Lawrence Erlbaum Association, 1990.

[4] Lera Boroditsky. Metaphoric structuring: Understanding time through spatial metaphors. *Cognition*, 75, 2000.

[5] Lera Boroditsky. Does language shape thought?: Mandarin and english speakers' conceptions of time. *Cognitive Psychology*, 43, 2001.

[6] Lera Boroditsky. The role of body and mind in abstract thought. *Psychological Science*, 13(2), 2002.

[7] Joy Cowley. *Agapanthus Hum and the Eyeglasses*. Penguin Group, 2001.

[8] Paula Danziger. *What a Trip, Amber Brown*. Penguin Group, 2001.

[9] Thomas L. Dean and Drew V. McDermott. Temporal data base management. *Artificial Intelligence*, 32(1), 1987.

[10] Laurent Demany, Beryl McKenzie, and Eliane Vurpillot. Rythm perception in early infancy. *Natur*, 266, 1977.

[11] William J. Friedman. Time memory and time perception. In *Time, Action and Cognition: Towards Bridging the Gap*. Kluwer Academic Press, 1992.

[12] Ruth Stiles Gannett. *My Father's Dragon*. Random House, 1979.

[13] Ruth Horowitz. *Breakout at the Bug Lab*. Penguin Group, 2002.

[14] Jacques Montangero. The development of a diachronic perspective in children. In *Time, Action and Cognition: Towards Bridging the Gap*. Kluwer Academic Press, 1992.

[15] Ivan P. Pavlov. *Conditioned reflexes*. Routledge and Kegan Paul, 1927.

[16] Jean Piaget. *The Child's Conception of Time*. Basic Books Inc, 1969.

[17] Stavroula Samartzis. Time inference rules in the child, adolescent and adult. In *Time, Action and Cognition: Towards Bridging the Gap*. Kluwer Academic Press, 1992.

[18] *Spectrum Reading Series*. Mac-Graw Hill. Grades 1 through 4 were used of this series.

[19] William Steig. *The Real Thief*. Farrar, Straus, Giroux, 1999.

[20] Lluis Vila. A survey on temporal reasoning in artificial intelligence. *AI Communications*, 7(1), 1994.