Foreground and background text in retrieval

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Abstract

Our hypothesis is that certain clauses have foreground functions in text, while other clauses have background functions and that these functions are expressed or reflected in the syntactic structure of the clause.

Presumably these clauses will have differing utility for automatic approaches to text understanding; a summarization system might want to utilize background clauses to capture commonalities between numbers of documents while an indexing system might use foreground clauses in order to capture specific characteristics of a certain document.

Topic in text for information access

This paper gives a short description of a series of experiments we have performed to test our hypotheses that clauses have different functions in transmitting the information flow of text, namely the functions often called topicality or thematic structure. The application area we chose to evaluate our hypotheses through is that of analysis of texts for the purposes of information retrieval.

Topicality, foreground, and background

There is an entire body of research put into uncovering the topical structure of clauses and texts. There is a long tradition of semantic and pragmatic study of clause structure from the Charles University in Prague (e.g. Hajičová, 1993), there are several results supporting our hypotheses using the general theory of transitivity (Halliday, 1967, 1978; Hopper, 1979), there are numbers of algorithms for anaphor resolution which touch clausal categorization, there are studies of automatic summarization algorithms, and there are studies of text grammars which all have bearing on our work. However, no studies have been made specifically on clausal categorization for topical analysis, and the empirical validation of these ideas have been held back for lack of effective tools.

Transitivity and clauses

Transitivity is one of the most basic notions in the system of language, but ill formalized in the formal study of language.

Clauses in language represent events and processes of various kinds, and transitivity is that characteristic of a clause which models the character of the process or event it represents. This systemic model was first formulated by Halliday (1967) and has since been elaborated by Hopper and others in a theoretic sense: very little empirical study on large numbers of texts has been performed, and no systematic let alone quantitative evaluation of the theories has even been proposed.

One of the basic conceptual structures of language in use is that actions are done by people and affect things. How the action is performed, by whom, and on what are all encoded in the clause by various syntactic mechanisms, in a general system of transitivity. For most non-linguists, transitivity is only explicitly mentioned in foreign-language classes when classifying verbs as transitive or intransitive, meaning if the verb in question takes a direct object or prefers not to. This is of course central to the task of modeling action and effect, but transitivity covers more than this one aspect of process structure. Halliday's model mentions a number of specific factors or "systems" that cover the more general "system" of transitivity: Number, type, and role of participant: human or not? Agent? Benefactive?; Process type: existence, possession, spatial/locative, spatial/mobile (e.g. 1978, p. 118). These aspects of clausal organization hook up with factors such as temporal, aspectual, or mood systems to produce a clause. This clause not only carries information about the event or process it represents, but it also crucially builds a text, together with adjacent clauses. In Halliday's model (most comprehensively delineated in his 1967 publication) a clause is the confluence of three systems of syntactic choice: transitivity, mood and theme. Transitivity, he writes, is the *set of options relating to cognitive content*, mood being the system for organizing the utterance into a speech situation, and theme being the system for organizing the utterance into a discourse.

While there is ample psycholinguistic evidence that the syntactic form of a clause is discarded after being processed by the hearer or reader (e.g. Jarvella, 1979), the communicative structure of the clause is retained to organize the information content of the text or discourse. The structure of a clause is not arbitrary, and cannot be determined in isolation from other clauses in the vicinity and other events, processes, and participants represented and mentioned in the

Table 1: Transitivity characteristics.

Feature	High	Low
Participants	2 or more	less
Kinesis	action	non-action
Aspect	completed	partial or imperfect
Punctuality	punctual	continuous
Volitionality	volitional	non-volitional
Polarity	affirmative	negative
Reality	real	non-real
Agency	potent agent	non-potent agent
Effect on object	totally affected	not affected
Individuation	individual object	non-individual object

text.

Transitivity has been and is being studied only as a very theoretical construction, and little work has been done which would be of direct implementational quality. The theoretical work concentrates on syntactic modeling of languages of which there is rather little knowledge yet, as a first stage towards building a more complete description. Practical clues as to how to make use of transitivity are mainly due to Hopper and Thompson (Hopper, 1979; Hopper and Thompson, 1980). Hopper argues for the distinction between background and foreground in narrative, signaled by variation along the qualities of the subject - such as animacy or humanness, the predicate verb - such as aspect or tense marking, and the voice of the clause. Many or even most of these factors cut across language divides (see e.g. Dahl and Karlsson, 1976). Hopper and Thompson then propose a number of characteristics along which transitivity is measured, some of which are directly quantifiable as shown in the table below. These factors we can make use directly in our implementation effort.

Clauses and Topic

There is a large number of approaches to textual modeling with very varying basis in theories of language or syntax. Most models of text are statistically based, or have some high-level model of argumentation to follow irrespective of syntax; some take recourse to cue phrases or expressions specific to some domain to build a text model. Some use syntactic analysis as a low-level building block, but discard what is left of the syntactic analysis after the argument structure of the clause has been established.

Local coherence

Much of topical study centers on local coherence of discourse or text, such as research models of *theme-rheme* or *topic-comment*, or research strands such as recent projects in modeling *centering* (Grosz et al, 1995). In these approaches, topic is a feature of the clause, and is carried over to the next clause through relatively overt syntactic mechanisms such as argument organization, anaphor, or ordering. These types of model of local coherence, where some have a fairly sophisticated theoretical base rather along the lines of Halliday's theme system, will well benefit from using transitivity as a factor.

Narrative models

Other studies try to understand topic from the top down, building argument structures or narrative frames (e.g. Lehnert, 1980). Lehnert, for instance, discussing application to summarization, argues that we must have a picture of plot progression throughout a text, with a model of mental states of an implied reader which the text affects in various ways. This high-level type of approach, most often with less psychological modeling involved, was typical during the knowledge-based systems projects of the late eighties. The failings of such systems are often that they have too little actual text processing capacity, and stumble on text processing as a task. Many systems attempt to generate rhetorical structures of various flavors based on local coherence models (e.g. Marcu, 1997 or 1998; Corston-Oliver, 1998; Liddy, 1993), but quite often need more syntactic competence. Simpler models, with a form-filling approach (e.g. Strzalkowski et al, 1998) perform quite well, up to a point, with much less investment in discourse modeling. There is a span of such models, ranging from completely general templates and very strictly task-oriented and tailored extraction patterns; the middle ground between them is claimed by hybrid approaches, which indeed are just that: combinations of both rather than bridges between them (Kan and McKeown, 1999). The greater effort in building a narration or discourse model has yet to prove useful: the bridge from text to discourse model has not been usefully closed yet. It is in this type of model our contribution most clearly would be of benefit: these systems need to form a clearer understanding of the informational rationale of syntax.

Lexical chains

Several approaches try to establish lexical chains in text as a basis for understanding content for either indexing for retrieval or summarization tasks. Lexical units in the text are picked out by some algorithm, possibly after the text is segmented (e.g. Barzilay and Elhadad, 1997), and relations between units are established using terminological models. Many of these models utilize text segmentation algorithms, based on occurrence statistics (e.g. Hearst, 1994 or Reynar, 1994), or thesauri and terminological databases, or cue or trigger phrases of some sort (e.g. Boguraev and Kennedy, 1997). These types of model tend to be quite successful, but are often quite a-theoretic and will be difficult to improve using theoretical add-on models.

Open Research Questions and Bottlenecks

The first research question for us is "What makes a text a text?" This is a question others have asked before. Current work in text understanding is plentiful and partially successful. Most of the work in our field — that of language engineering — is based on statistical models of term occurrence, whether along lexical chains, in sentence extraction algorithms, or using thesauri as a domain model. The main exception is centering and other related and non-related anaphora resolution approaches. Most of the effort being put into text analysis today is along the lines of the theme system in Halliday's analysis.

The arguably primary aspect of the clause is that of its cognitive content, and its relation to the other systems: this is measured using very simple statistically based models or thesaurus-based models of lexical cohesion. The study of transitivity would raise the sophisitication of this system to match that of the study of theme and topicality per se. This gives us the task of primarily concentrating on transitivity as a high level description of clause content, function, and structure; when we do it can be connected to the discourse through the efforts of other projects as outlined above — and as an end result gain more knowledge of the structure of texts.

Since our hypothesis is that clauses bear different roles in a text, and that these roles at least in part are communicated through their semantic role structure, this is where we should concentrate our efforts. The mechanisms modeled by transitivity are strongly encoded in syntax, and thus largely language specific in their encoding. However, their function is not: we expect the transitivity of clauses to bear on the difference between foreground and background in text. This is likely to be genre- and culture-specific, but not specific to languages. The utility of building a transitivity-based model of text will be bound to cultural areas, but independent of language.

There seems to be great promise to see our work to provide empirical data towards building more syntactic analysis tools with ambitions towards building a more complete yet practical model of text. Transitivity on the clause level is one of the key factors in understanding information organization on the textual level, and as of now, an untapped resource.

People do not know foreground from background

To gain first knowledge of how people understand textual information organization we performed a short experiment to determine if human judges can agree on foreground and background clauses. We gave three judges were given ten news items each and instructions to mark foreground sentences. The instructions were deliberately left vague so as not to give judges too specific criteria for determining foregroundness. The three judges were all trained linguists and quite experienced in making textual judgments — they were not selected to be representative of the population at large but to gain some understanding of what sort of judgments can be expected. Using standard measures for calculating judge agreement we found agreement only marginally better than chance. Not even trained linguists can agree on what foreground sentences are.

Foreground clauses are special

We did find some common characteristics on those clauses where they did agree: most strongly, the clauses where all judges agreed on marking them foreground were *longer* than other clauses, as a basic indication of their higher complexity syntactically (by Mann Whitney U; $p > 0,95$). These data give some encouragement to continue studying the criteria given in the literature to see if they give purchase for predictive analysis.

Evaluation by information retrieval

Pure retrieval systems usually invest a fair amount of effort into completely ignoring text as text. Some exceptions include experiments to statistically process syntactic relations in text (e.g. Strzalkowski et al, 1997) to find typical relations entities engage in (in a sort of small-scale version of extraction technology) and others trying to establish reference chains in text (e.g. Liddy, 1994) to sort out occurrence frequencies obscured by anaphor. Information retrieval systems typically have neither textual models nor local coherence models to guide their analysis of texts; word occurrence statistics are good enough for the tasks these systems are used for at present. While the prospects of impressing information retrieval system engineers with syntactic and semantic niceties will be unlikely, the evaluation framework provided by information retrieval systems is useful enough for us to test our future algorithms for this purpose.

An efficient system for marking semantic roles

To get further, we need automatic analysis for marking large text corpora. Basic syntactic analysis can today be provided by several different tools: for our purposes dependency analysis is the most appealing and most closely vectored to the information we wish to find in text. The Conexor Functional Dependency Grammar Parser produces dependency-based functional descriptions for a number of languages[1](Tapanainen and Järvinen, 1997). The parser produces surface-syntactic functional descriptions — subject, object, verb chain, various adverbials and so forth — that allow us to extract linguistic correlates of foregrounding and backgrounding: we started by those properties that were automatically recognisable using the syntactic parser and selected *voice*, *ordinance*, and *aspect* for further study.

Voice and aspect are the traditional mechanisms to control the distribution of information in sentences. The analyser recognises active (ACT) and passive (PSS) voice and classifies the predicates accordingly. For the time being we have not implemented any systematic purely aspectual classification scheme, which would require lexical information not available in the system. The coding of aspectual phenomena is based on the morphosyntactic properties of English. Therefore, the possible values in the *aspect* column are progressive (PROG), and as possible values for non-progressive forms, future (FUTU) and past (PAST).

By the term *ordinance* we mean syntactic government between clauses. Initially, we made a distinction between the main clauses (MC) and subordinate clauses (SC). Basically, the main clauses are foreground and subordinate clauses, especially the adverbial clauses, describe the circumstances of the action reported in the governing clause.

Two additional types were distinguished: report clause (RC) and the main clause (cMC), because in these clause types governance relations are supposedly reversed with respect to foreground vs. background distinction.

In addition to sentential properties, we examined the distribution and form of the main elements of the sentence.

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[1]There is an online demo of the English FDG parser at http://www.conexor.fi/parsers.html

Table 2: Syntactic features and roles produced by the system

name	explanation	comments
pred	predicate	
voice		ACT — PASS
ord	ordinance	MC — SC — RC — cMC
aspect		PROG — PAST — FUTU
meta		clause adverbials
actor		
isa-s	predicative	
theme		
benef	benefactive	
man	manner	mapped on FDG output
loc	location	mapped on FDG output
goa	goal	mapped on FDG output
sou	source	mapped on FDG output
temp	temporal	mapped on FDG output
wrds		base forms
sent		running text tokens

To achieve better correspondences with the distribution of the content words, we aim to go beyond the mere surface distributions and syntactic functions. An additional component called *SemRole* uses the data structures produced by the FDG parser to recognise the semantic roles of the elements.

This is in fact what the parser produces for the adverbial elements. The important syntactic distinction is between the actants vs. circonstants (see Hajičová, 1993, Tésniere, 1959). The actantial roles *actor*, *theme* and *benefactive* are the participants in the action and the circumstantial roles such as *locations* and *goal*, *source* and *temporal functions* usually describe the background of the action. We expect the distribution of the sentential elements to correlate with the foreground vs background distinction.

The FDG parser as built today produces surface syntactic functions only and the semantic roles are extracted from the analysis through a system developed specifically developed for this purpose. Table 6 shows a simplified matrix featuring some pieces of information produced by the *SemRole* program. The input sentence is given in the last column. The first column shows the **predicate**, second column voice (active or passive), third column the semantic subject, or **actor**, fourth column the second argument, or **theme**, fifth column the recipient or **benefactive**. Some can be extracted directly from the functional description, such as adverbial elements.

The analysis used for these experiments contains only a few, selected pieces of the morphosyntactic information produced by the parser. For example, the part of speech information is generally not used. The actor field shows the tag PRON for a pronoun, which is a possible feature of foregrounding. There is ample room for improvement.

Sample analysis

The analysis of the sentence below is presented in Table 7.

"Dependent on the state for most of its mental health money, county officials said they reluctantly ordered the closures when the mental health budget plunged hopelessly in the red after the state failed to provide the county enough money to keep the system afloat.

Evaluating relevance of clause type variation

Given that we have a mechanism for distinguishing different types of semantic roles in text, we use that information to rank clauses according to foregroundness. One of our underlying hypotheses is that foregrounded clauses contain more relevant and topical content than do background clauses.

We ran a series of experiments using a number of queries from the Text Retrieval Conference TREC, where a large number of texts are judged against a set of retrieval queries. Our method was to calculate if clauses with a large number of foreground markers contain more relevant content words in texts judged relevant texts than in texts judged irrelevant. The rationale for this experiment is that texts that treat a subject in foreground would be more likely to be relevant for an information retrieval query than texts that mention something in passing, as a background fact.

We examined the distribution of highly relevant content words (for query 332, e.g., "tax", "income" "evade" "evasion" in their different forms) over the clause arguments in the example texts, and used these findings to define and fine-tune a clause weighting scheme based on the analysis provided by the semantic role parser program. The objective was to find a weighting scheme to rank foreground clauses highly so that the difference between foreground and background could be used in retrieval systems for weighting content words appropriately.

The adverbials of manner, location, and time are lexically categorized into more or less situation-bound: "quickly" and "surprisingly", "here", "today" e.g. are more situation-bound and specific and less stative than are e.g. "eventually", "never", "while", and "well". Most of the lexical argument slots are in themselves more situation-bound: if no argument is given, the clause has a more specific character than general clauses without actor, beneficient, or explicit goal. The voice and tense of the clause also are graded: future tense is more situation-bound than is progressive tense or passive voice. If the agent is human — a personal pronoun or a person name, it is more grounded in the situation.

We find that content word-containing clauses have more foreground characteristics (statistically significant difference by the Mann Whitney U test for rank sum). After some manual tuning — a task for which machine learning algorithms would be a natural tool — we settled on an ad-hoc weighting as shown in Table 3.

Experimental material

We used material only from the Los Angeles Times section of the TREC collection in order to minimize the risk of source-dependent stylistic variation swamping the distinctions between foreground and background, and used queries 301 to 350 in the TREC test battery. We ran two experiments, once with all fifty queries, and once where we discarded queries with five or fewer relevant documents in the

Table 3: Weighting of semantic role fields

Function	Foreground weight
Predicate verb	Any: +1
Voice	-
ord	Future: +1
Aspect	-
meta	-
Actor	If a pronoun or name: +1
Theme	Any: +1
Beneficient	Any: +1
Manner	Any: +1 plus extra point for any member of list of "punctual" adverbs.
Location	Any: +1 plus extra point for "here", "there" or potential names.
Goal	Any: +1
Source	Any: +1
Time	Any: +1

Table 4: Average precision

Full set of all 50 queries	
Morphology only	0.0729
Morphology and semantic roles	0.0815
Trimmed set of 31 queries	
Morphology only	0.0967
Morphology and semantic roles	0.1166

LA times subcollection[2], leaving thirty-one queries to work on. The assumption was that evaluating the results on the basis of very few relevant documents would lead to results being swamped by other types of noise in the material — as it turns out, a correct assumption. Discarding the low-density queries does improve results as will be shown below.

Experiment procedure

Retrieval systems rank texts according to term occurrences. Given a clause weighting scheme, we can weight terms occurring in a foregrounded clause more than we will weight terms only occurring in background clauses.

For our test we for each query take the TREC LA Times texts with relevance judgments for that query and run a search experiment on them, in effect reranking documents that other search systems retrieved from the TREC collection.

[2]Left out were queries no.: 303 307 308 309 320 321 324 326 327 328 334 336 338 339 340 344 345 346 348

Table 5: Number of improved queries

Full set of all 50 queries	
Morphology only	17
Morphology and semantic roles	25
Trimmed set of 31 queries	
Morphology only	9
Morphology and semantic roles	19

We do this once using clause weighting, and once with same preprocessing but disregarding the clause weight, in effect only providing morphological normalization. In this experiment we do not perform complete retrieval on other documents — we aim in this experiment to see the extra effect semantic roles give a retrieval tool, not to build an entire system from scratch. We preprocess queries by including all words from title, description, and narrative fields of the TREC topics, normalize for case and exclude punctuation. Some examples are shown below.

301 international organized crime identify organization that participate in international criminal activity the activity and if possible collaborate organization and the country involved a relevant document must as a minimum identify the organization and the type of illegal activity eg columbian cartel exporting cocaine vague reference to international drug trade without identification of the organization involve would not be relevant

313 magnetic levitation maglev commercial use of magnetic levitation a relevant document must contain magnetic levitation or maglev it shall be concern with possible commercial application of this phenomenon to include primarily mass transit but also other commercial application such as maglev flywheel for car discussion of superconductivity when link to maglev and government support plan when link to maglev be also relevant

332 income tax evasion this query is looking for investigations that have targeted evaders of us income tax a relevant document would mention investigations either in the us or abroad of people suspected of evading us income tax laws of particular interest are investigations involving revenue from illegal activities as a strategy to bring known or suspected criminals to justice

The search is conducted using a simple weighted frequency index, an idf table, and a very simple search script: each word in the query word set — as shown above — is matched towards all words in all documents. If a match is found, the document score is incremented by the word weight (tf), based on its frequency of occurrence in the text *multiplied by the clause weights of clauses in which it occurs*, and also multiplied by its collection frequency (idf): the number of documents in the collection that contain the word.

The results are quite convincing. The semantic role weighting improves results. The Tables 4 and 5 show average precision for all fifty queries for the two cases and how many queries showed improved results[3]. Some queries fail to show improvement for the new weighting scheme, but most do; if queries with less than five relevant documents are discarded the difference is greater.

The experiment is a clear success, and we can conclude that semantic role based clause weighting does add information to term frequencies.

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[3]Comprehensive tables available from project web site.

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Table 6: Voice and semantic roles attached to a predicate "give" in various alternation patterns.

pred	voice	actor	theme	benef	sentence
give	ACT	he	book	-	He gave John a book.
give	PSS	-	book	John	A book was given to John.
give	PSS	-	book	John	John was given a book.

Table 7: A sample matrix produced by the analysis system.

pred	voice	ord	aspect	meta	actor	isa-s	theme	benef	man	loc	temp
say	ACT	RC	PAST	-	county official	-	cMC	-	-	-	-
order	ACT	cMC	PAST	-	they PRON	-	-	-	reluctantly	-	-
plunge	ACT	SC	PAST	-	mental health budget	-	-	-	hopelessly	red	when
fail	PSS	SC	-	-	-	-	-	-	-	-	-
provide	ACT	SC	-	-	-	-	-	-	-	-	-
keep	ACT	SC	-	-	-	-	system	-	-	-	-