

1992 IRCS TECHNICAL REPORT ABSTRACTS

Curved Path Walking

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Research on biped locomotion has focused on sagittal plane walking in which the stepping path is a straight line. Because a walking path is often curved in a three dimensional environment, a 3D locomotion subsystem is required to provide general walking animation. In building a 3D locomotion subsystem, we tried to utilize pre-existing straight path (2D) systems. The movement of the center of the body is important in determining the amount of banking and turning. The center site is defined to be the midpoint between the two hip joints. An algorithm to obtain the center site trajectory that realizes the given curved walking path is presented. From the position and orientation of the center site, we compute stance and swing leg configuration as well as the upper body configuration, based on the underlying 2D system.

Interactive Image Display for the X Window System

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This report describes the program xv, which is an interactive color image display program for workstations and terminals running the X Window System. The program displays images saved in a variety of popular formats. It lets you arbitrarily stretch or compress the size of the image, rotate the image in 90-degree steps, flip the image around horizontal or vertical axes, crop off unwanted portions of the image, and measure pixel values and coordinates. Modified images can be saved in a variety of formats, or sent to a PostScript printer.

Multiple Instantiation of Predicates in a Connectionist Rule-Based Reasoner

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Shastri and Ajjanagadde have described a neurally plausible system for knowledge representation and reasoning that can represent systematic knowledge involving n-ary predicates and variables, and perform a broad class of reasoning with extreme efficiency. The system maintains and propagates variable bindings using temporally synchronous --- i.e., in-phase --- firing of appropriate nodes. This paper extends the reasoning system to incorporate multiple instantiation of predicates, so that any predicate can now be instantiated with up to k dynamic facts, k being a system constant. The ability to accommodate multiple instantiations of a predicate allows the system to handle a much broader class of rules; the system can even handle limited recursion (up to k levels). Though the time and space requirements increase by a constant factor, the extended system can still answer queries in time proportional

to the length of the shortest derivation of the query and is independent of the size of the knowledge base.

Generating Human Motion by Symbolic Reasoning

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This paper describes work on applying AI planning methods to generate human body motion for the purpose of animation. It is based on the fact that although we do not know how the body actually controls massively redundant degrees of freedom of its joints and moves in given situations, the appropriateness of specific behavior for particular conditions can be axiomatized at a gross level using commonsensical observations. Given the motion axioms (rules), the task of the planner is to find a discrete sequence of intermediate postures of the body via goal reduction reasoning based on the rules along with a procedure to discover specific collision-avoidance constraints, such that any two consecutive postures are related via primitive motions of the feet, the pelvis, the torso, the head, the hands, or other body parts. Our planner also takes account of the fact that body motions are continuous by taking advantage of execution-time feedback. Planning decisions are made in the task space where our elementary spatial intuition is preserved as far as possible, only dropping down to a joint space formulation typical in robot motion planning when absolutely necessary. We claim that our work is the first serious attempt to use an AI planning paradigm for animation of human body motion.

Goals and Actions in Natural Language Instructions (Dissertation Proposal)

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Human agents are extremely flexible in dealing with Natural Language instructions: they are able both to adapt the plan they are developing to the input instructions, and vice versa, to adapt the input instructions to the plan they are developing. Borrowing the term from [Lewis 79], I call this two-way adaptation process accommodation.

In this proposal, I first define accommodation in the context of processing instructions. I then provide evidence for the particular inferences I advocate, and for the further claim that such inferences are directed by the goal to achieve which a certain action is performed. The evidence I provide comes from my analysis of naturally occurring instructions, and in particular of purpose clauses and of negative imperatives.

Finally, I propose a computational model of instructions able to support accommodation inferences. Such a model is composed of: a speaker/hearer model of imperatives, based on the one presented in [Cohen and Levesque 90]; an action representation formalism based on a hybrid system, a' la

KRYPTON [Brachman et al. 83], whose primitives are those proposed in [Jackendoff 90]; and inference mechanisms that contribute to building the structure of the intentions that the agent develops while interpreting instructions.

Collision-Free Path and Motion Planning for Anthropometric Figures

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This paper describes a collision free path planning and animation system for anthropometric figures. It can also take into consideration the strength limit of human figures and plan the motion accordingly. The algorithm breaks down the degrees of freedom of the figure into Cspace groups and computes the free motion for each of these groups in a sequential fashion. It traverses the tree in a depth first order to compute the motion for all the branches. A special playback routine is then used to traverse the tree in a reverse order to playback the final motion. Strength value measures are incorporated directly into the searching function so that path computed will obey strength availability criteria. The planner runs in linear time with respect to the total number of Cspace groups. The planner can interface with other simulation techniques to simulate complex human motions. We believe that the planner would find a path in most cases and is fast enough for practical use in a wide range of computer graphics applications.

Superquadric Library, User Manual and Utility Programs

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Superquadrics are a family of parametric shapes that have been used as primitives for shape representation in computer vision and computer graphics. They can be used for modeling tapering and bending deformations and are recovered efficiently by a stable numerical procedure.

This document introduces the superquadric library, SQ-lib, developed at the GRASP Lab at the University of Pennsylvania.

The manual is organized into three parts. The first part provides the reader with a description of superquadrics models and deformations that can be performed. Furthermore, it introduces the coordinate systems conventions which are used in the library. The second part presents some examples of applications on how one can use the functions defined in the library. It also lists utility programs which have been developed while conducting research. They provide a good source of examples for the application of the library.

Finally, the last part describes the datatypes and each of the functions which are supported in the library. The library itself

is organized in two sets Fundamental and Auxiliary functions. A quick reference to all the functions and an index is provided.

Some of the functions and examples supplied perform data preprocessing and are connected to the PM image description also available from the GRASP Lab. These functions are provided in isolation from the remaining body of the library and can easily be excluded in the actual compilation of the library. Furthermore, routines for the visualization of the data, using X11, are also provided.

Robotic Exploration of Surfaces and Its Application to Legged Locomotion

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Material properties like penetrability, compliance, and surface roughness are important in the characterization of the environment. While concentrating on issues of geometry and shape, researchers in perceptual robotics, until recently, have not quite addressed the issue of the extraction of material properties from the environment. The goal of this research is to design and implement a robotic system that will actively explore a surface to extract its material characteristics. Further, the relevance of material properties in the legged locomotion of robots is also recognized and our research objectives are extended towards building a robotic system for exploration such that it actively perceives material properties during the process of legged locomotion. The chosen approach to the design and implementation of such a robotic system is to first select an appropriate environment model and then to design exploratory procedures salient to each attribute of interest. These exploratory procedures are then implemented through an experimental setup and the results show that material properties can be reliably measured. The design, implementation, and results of a framework for surface exploration to recover material properties are presented.

Further, the exploratory procedures for exploration are integrated into an active perceptual scheme for legged locomotion. The perceptual scheme is designed around creating the ability for the robot to sense variations in terrain properties while it is walking, so that it may be able to avoid sinking, slipping, and falling due to unexpected changes in the terrain properties, and make suitable changes in its foot forces to continue locomotion. Finite element simulations of the foot-terrain interaction are used to justify some of the strategies used in this active perceptual scheme. The active perceptual scheme is implemented by simulating a leg-ankle-foot system with a PUMA arm-compliant wrist-foot system and an accelerometer mounted on the foot to detect slip. Details of implementation and experimental results are presented.

Using Sound to Solve Syntactic Problems: The Role of Phonology in Grammatical Category Assignments

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One ubiquitous problem in language processing involves the assignment of words to the correct grammatical category, such as noun or verb. In general, semantic and syntactic information have been cited as the principal cues for grammatical category assignment, to the neglect of possible phonological cues. This paper examines one theoretical reason for this neglect, namely the tradition of describing linguistic structure and knowledge in terms of rules. Given that syntactic rules provide sufficient information for grammatical category assignments, imperfect phonological cues seem superfluous. However, this conclusion is not necessary since perceptual domains exist in which probabilistic information is used to solve certain problems even when other information sufficient for the task is also available. Promising results from connectionist models of language processing also support the potential importance of probabilistic information. This paper therefore examines the evidence that phonological correlates for grammatical class are available, and that human beings are sensitive to them. In particular, I will claim that: (1) numerous correlations between phonology and grammatical class exist, (2) some of these correlations are large and can pervade the entire lexicon of a language, and hence can involve thousands of words, (3) experiments have repeatedly found that adults and children have learned these correlations, and (4) some explanations for how these correlations arose can be proposed and evaluated. These phenomena indicate that the neglect of phonology could provide a useful domain for exploring how adults and children solve the grammatical category assignment problem. Finally, implications of these phenomena for language representation and processing are discussed.

The Meaning of Additive Reaction-Time Effects: Tests of Three Alternatives

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Additivity of the effects of experimental manipulations on mean reaction time (RT) has been taken to suggest that the underlying mechanism can be divided into independently changeable, serially arranged operations (Stage Model, additive-factor method; Sternberg, 1969). We consider two other explanations of the same additive pattern of means: a model with independently changeable alternate pathways, and the McClelland-Ashby Cascade Model. In all three models, additivity results from selectivity of the influence of experimental factors on mental operations. Among the tests we develop are comparisons of entire RT distributions. Applied to the results of four diverse experiments (overlapping tasks, classification, identification, and detection), analyses of distributions and variances support the Stage Model and contradict the Cascade and Alternate-

Pathways models. One set of distributional analyses, based on a suggestion by Ashby and Townsend (1980), supports the Stage Model remarkably well.

Recognition Memory Assessed by Looking versus Reaching: Infants' Performance on the Visual Paired Comparison and Delayed Non-Matching to Sample Tasks

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Infants of only 4 months prefer to look at something new when given the choice of looking at a stimulus shown earlier or looking at something new, even after a delay of several seconds (the visual paired comparison task). However, if infants must reach and displace a stimulus to retrieve a reward, infants as old as 18 months respond randomly when given the choice of reaching to the stimulus shown earlier or to something new, even after a delay of only 5 sec (the delayed non-matching to sample task). Why is there such a big difference in results? To investigate this we modified the delayed non-matching to sample task to make it more similar to visual paired comparison. We did this by using the stimulus as its own reward; no rewards were hidden under any stimuli. We allowed infants time to grow bored with looking at the sample object (visual paired comparison) or with looking at and handling the sample (delayed non-matching to sample [stimulus = reward]), and then assessed how long afterward they would still choose to look at (in visual paired comparison) or reach for (in delayed non-matching to sample [stimulus = reward]) a new object rather than the object to which they had habituated. 120 infants were tested: 60 (20 each at 4, 6, & 9 months) on visual paired comparison and 60 (20 each at 6, 9, & 12 months) on delayed non-matching to sample (stimulus=reward). The same 10 pairs of stimuli were used on both tasks. Each subject was tested twice at all 5 delays (10, 15, 60, 180, & 600 sec.). We found that even at the youngest age at which reaching was tested (6 months), infants showed evidence of recognition memory on the reaching task at delays as long as those at which they demonstrated recognition memory on the looking task. Thus, when subjects reached, not in order to obtain something else, but to obtain the stimulus itself, they succeeded on a recognition memory task even at delays 10 min. long very early in life.

A Template Matching Model of Subthreshold Summation

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A template-matching model is developed to account for the detailed properties of subthreshold summation displayed by the human visual system in contrast-detection tasks with widely separated stimuli. Monte Carlo simulations reveal that the model can quite successfully match the performance of human observers, and in particular, the dependence of summation parameters on amount of orthogonal uncertainty. The success of the model does not require the assumption of several different families of sensors, each family tuned to different orientations or spatial frequencies. However, it does

seem to require that observers are capable of using only certain types of templates.

BiDirectional Context-Free Grammar Parsing for Natural Language Processing

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While natural language has been normally analyzed from left to right, bidirectional parsing is very attractive for both theoretical and applicative reasons. In recent times analysis has been put on the similarity of natural language to context-free languages; a formal framework is here proposed for dealing with bidirectional tabular parsing of nondeterministic context-free languages. The framework is general and permits a comparison between known approaches and the specific algorithms outlined in the paper. In particular a detailed characterization of the redundancy problem is given and a technique is provided that allows one to improve the performance of bidirectional tabular parsers (in an average case perspective) still maintaining the flexibility of bidirectional strategies. An algorithm for island-driven parsing is studied. The latter permits to start analyses from any dynamically chosen positions within the input sentence and combines without restrictions bottom-to-top and top-down processing, still avoiding analysis redundancy.

Japanese Discourse and the Process of Centering

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This paper has two aims: (1) to generalize a computational account of discourse processing called CENTERING and apply it to discourse processing in Japanese, and (2) to provide some insights on the effect of syntactic factors in Japanese on discourse interpretation. We argue that while discourse interpretation is an inferential process, that syntactic cues constrain this process, and demonstrate this argument with respect to the interpretation of ZEROS, unexpressed arguments of the verb, in Japanese. The syntactic cues in Japanese discourse that we investigate are the morphological markers for grammatical TOPIC, the post-position wa, as well as those for grammatical functions such as subject, ga, object, o, and object2, ni. In addition, we investigate the role of speaker's empathy, which is the perspective from which an event is described. This is morphologically indicated through the use of verbal compounding, i.e. the auxiliary use of verbs such as kureta, kita. Our results are based on a survey of native speakers of their interpretation of short discourses, consisting of minimal pairs, varied by one of the above factors. We demonstrate that these syntactic cues do indeed affect the interpretation of zeros, but that having previously been the topic and being realized as a zero also contribute to an entity being interpreted as the topic. We propose a new notion of topic ambiguity, and show that centering provides

constraints on when a zero can be interpreted as the topic.

CLiff Notes: Research in Natural Language Processing at the University of Pennsylvania

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The computational linguistics feedback forum (CLiFF) is a group of students and faculty who gather once a week to discuss the member's current research. As the word "feedback" suggest, the group's purpose is the sharing of ideas. The group also promotes interdisciplinary contacts between researchers who share an interest in Cognitive Science.

There is no single theme describing the research in Natural Language Processing at Penn. There is work done in CCG, Tree adjoining grammars, intonation, statistical methods, plan inference, instruction understanding, incremental interpretation, language acquisition, syntactic parsing, causal reasoning, free word order languages, and many other areas. With this in mind, rather than trying to summarize the varied work currently underway here at Penn, we suggest reading the following abstracts to see how the students and faculty themselves describe their work. Their abstract illustrate the diversity of interest amount the researchers, explain the areas of common interest, and describe some very interesting work in Cognitive Science.

This report is a collection of abstracts for both faculty and graduate students in Computer Science, Psychology and Linguistics. We pride ourselves on the close working relations between these groups, as we believe that the communication among the different departments and the ongoing inter-departmental research not only improves the quality of our work, but makes much of that work possible.

A Robotic System for Learning Visually-Driven Grasp Planning

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We use findings in machine learning, developmental psychology, and neurophysiology to guide a robotic learning system's level of representation both for actions and for percepts. Visually-driven grasping is chosen as the experimental task since it has general applicability and it has been extensively researched from several perspectives. An implementation of a robotic system with a gripper, compliant instrumented wrist, arm and vision is used to test these ideas. Several sensorimotor primitives (vision segmentation and manipulatory reflexes) are implemented in this system and may be thought of as the "innate" perceptual and motor abilities of the system.

Applying empirical learning techniques to real situations brings up such important issues as observation sparsity in high-dimensional spaces, arbitrary underlying functional forms of the reinforcement distribution and robustness to noise in exemplars. The well-established technique of non-parametric projection pursuit regression (PPR) is used to accomplish reinforcement learning by searching for projections of high-dimensional data sets that capture task invariants.

We also pursue the following problem: how can we use human expertise and insight into grasping to train a system to select both appropriate hand preshapes and approaches for a wide variety of objects, and then have it verify and refine its skills through trial and error. To accomplish this learning we propose a new class of Density Adaptive reinforcement learning algorithms. These algorithms use statistical test to identify possibly "interesting" regions of the attribute space in which the dynamics of the task change. They automatically concentrate the building of high resolution descriptions of the reinforcement in those areas, and build low resolution representations in regions that are either not populated in the given task or are highly uniform in outcome. Additionally, the use of any learning process generally implies failures along the way. Therefore, the mechanics of the untrained robotic system must be able to tolerate mistakes during learning and not damage itself. We address this by the use of an instrumented, compliant robot wrist that controls impact forces.

On the Study of First Language Acquisition

Daniel Osherson

Scott Weinstein

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Human languages are immensely complicated systems for pairing sounds with meanings, yet most infants can acquire any one of them from a few years of sustained, casual contact. However difficult it is to give sharp expression to this phenomenon, few students of language have failed to be impressed by the child's achievement. It is thus not surprising that many questions about language acquisition have been posed and investigated, including the following:

(1) (a) From among the vast class of logically possible languages, which can in fact be assimilated by children on the basis of the kind of linguistic experience typically afforded the young? That is, which languages are "natural"?

(1) (b) What is the mental mechanism upon which language acquisition rests?

Question (1a) requests an illuminating characterization of the class of learnable languages, for example, by formally specifying a class of grammars rich enough to represent any such language but none others. Question (1b) requests information about the program embodied by the child's nervous system, the program allowing children to arrive at a

stable and accurate representation of the ambient language in case the latter is of the human sort.

Both questions presuppose familiar idealizations of linguistic competence that have been discussed many times. Rather than reexamine these idealizations, we intend to rely upon them for the purposes of projecting (1)a,b into a recursion theoretic framework. The framework will allow us to represent developmental psycholinguistics as a process of theory-discovery within a formally defined paradigm of empirical inquiry. It will then be possible to consider in mathematical terms the prospects for success in this enterprise.

The idealizations inherent in our study prevent it from yielding definitive information about the outcome of linguistic research. Nor do the results imply that some particular avenue of empirical inquiry is more promising than others. Rather, our aim is the more modest one of shedding light on a particular aspect of Cognitive Science by examining its scope and limits under simple, formal assumptions.

Color Perception and Neural Encoding: Does Metameric Matching Entail a Loss of Information?

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It seems intuitively obvious that metameric matching of color samples entails a loss of information, for spectrophotometrically diverse materials appear the same. This intuition implicitly relies on a conception of the function of color vision and on a related conception of how color samples should be individuated. It assumes that the function of color vision is to distinguish among spectral energy distributions, and that color samples should be individuated by their physical properties. I challenge these assumptions by articulating a different conception of the function of color vision, according to which color vision serves to partition object surfaces into discrimination classes.

The Negation Relation: Semantic and Pragmatic Aspects of a Relational Analysis of Sentential Negation

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Sentential negation is a two-place relation, expressing the nonelementhood of an entity in a particular set. This relation-element-set structure of a proposition also underlies nonnegative utterances. The structure is conveyed by a combination of positional and stress features and has both a semantic and pragmatic interpretation. The semantic interpretation of this structure determines truth conditions for a negative sentence which are equivalent to a wide-scope, unary propositional operator. The pragmatic interpretation conveys information structure, the speaker's belief about the hearer's knowledge or awareness. Alternatives to the element constituent of the structured proposition may be required by either the semantic or pragmatic interpretation or neither.

The paradigm of focus particles such as *only* and their association with a partner must be extended to allow for association with a nonfocal partner. The extended paradigm covers all cases of sentential negation and *only*. The analogy between negation and *only* supports the logical relation-element-set structure of utterances. Partners, information-focus and stress-focus are distinct phenomena, although highly correlated. Both the partner of a focus particle and information-focus are often marked by a stress-focus. The uniform interpretation of stress-focus is that it structures the proposition by marking the element in the relation-element-set structure. In addition, a proposition may be structured by purely positional features marking the element. Partners and information-focus constitute an element in a structured proposition and may therefore be marked by either stress or positional means.

Infinitary Logic and Inductive Definability over Finite Structures

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The extensions of first-order logic with a least fixed point operator (FO + LFP) and with a partial fixed point operator (FO + PFP) are known to capture the complexity classes P and PSPACE respectively in the presence of an ordering relation over finite structures. Recently, Abiteboul and Vianu [Abiteboul and Vianu, 1991b] investigated the relationship of these two logics in the absence of any ordering, using a machine model of generic computation. In particular, they showed that the two languages have equivalent expressive power if and only if $P = PSPACE$. These languages can also be seen as fragments of an infinitary logic where each formula has a bounded number of variables, $L_1^!$. We investigate this logic of finite structures and provide a normal form for it. We also present a treatment of the results in [Abiteboul and Vianu, 1991b] from this point of view. In particular, we show that we can write a formula of FO + LFP that defines and orders of the $L_1^!$ types uniformly over all finite structures. One consequence of this is a generalization of the equivalence of FO + LFP and P from ordered structures to classes of structures where every element is definable. We also settle a conjecture mentioned in [Abiteboul and Vianu, 1991b] by showing that FO + LFP is properly contained in the polynomial time computable fragment of $L_1^!$, raising the question of whether the latter fragment is a recursively enumerable class.

Ellipsis and Discourse

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This proposal concerns a computational investigation of Verb Phrase ellipsis: a construction in which a Verb Phrase is elided, its position marked only by an auxiliary verb. In my

dissertation, I propose to explore the consequences of the hypothesis that VP ellipsis is resolved at the level of meaning. This hypothesis conflicts with standard approaches, which resolve VP ellipsis in terms of the form, rather than the meaning, of the antecedent. I show that there is a body of evidence that remains unaccounted for in these approaches, and I show that a meaning level account better explains the data, and leads to significant simplifications in the overall grammar. I describe a computational model of the approach, based on the Incremental Interpretation System of Pereira and Pollack. A computer implementation of this model is envisioned, as well as plans for testing the model on several hundred naturally occurring examples.

Pronominal and Null Subject Variation in Spanish: Constraints, Dialects, and Functional Compensation **Richard Cameron** **IRCS-92-22**

The occurrence of phonetically null subjects in languages such as Spanish has resulted in wide-ranging research in generative syntax and discourse analysis. However, neither discipline accounts for the statistical variability inherent in the alternation of null and lexical subjects. Working within the variationist approach to language description and explanation, the purpose of this study is to discover the significant constraints on the alternation of pronominal and null subjects in the Spanish spoken in San Juan, Puerto Rico and Madrid, Spain. In addition, I seek explanations for why these two dialects differ in the rate of subject pronoun expression. This includes investigation of the functional compensation hypothesis for Puerto Rican Spanish (Hochberg 1986) in a socially stratified study of the San Juan speech community. According to this hypothesis, a connection exists between pronominal expression and the variable deletion of second person inflectional /S/. Using strategies from both syntax and pragmatics, I first provide an explicit statement of those contexts in which pronominal and null subject variation is prohibited in order to define where such variation may occur. In turn, because Switch Reference is the central constraint on variation, a working definition of the scope and limitations of Switch Reference is provided. The major constraints which emerge include Switch Reference, Reference Chains, Set-to-Elements Saliency, Morphological Ambiguity when intersected with a switch in reference. Using multivariate analysis, the speakers from San Juan and Madrid show great similarity in the verbal weights assigned to these constraints. However, they show a reverse effect associated with the referential specificity of second person TU. Whereas in San Juan Nonspecific TU favors pronominal expression, in Madrid it disfavors pronominal expression in relation to Specific TU. Finally, despite the appearance of functional compensation for Specific TU in the San Juan groups of female speakers, lower class speakers, and speakers interviewed in groups, this does not result in a difference in the rate of pronominal expression and those which do not. Therefore, the functional compensation hypothesis finds no clear support.

Linguistic Variation in Urban Jamaican Creole: A sociolinguistic study of Kingston, Jamaica
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This study of a mixed-class neighborhood in Kingston (Jamaica's capital city) draws a synchronic profile of a speech community in quantitative variationist terms, examining urban mesolectal speech and mapping the creole continuum on phono-lexical, phonological, morphological and syntactic dimensions. Based on a year's fieldwork by a near-native speaker, the tape-recorded speech of 15 individuals who span the continuum is investigated for 3 variables: the palatalization of velars below low vowels (/kya/), the simplification of final consonant clusters ending in /-t/ or /-d/, and past-marking in preterite verb-phrases. The last considers separately the classic creole pre-verbal past-markers /ben/, /did/ and /neva/, on the one hand; and variation between inflected and unmarked past-reference verbs, on the other; examining the role of stativity, anteriority, and clause-type. The speech community is described in terms of its history, demographics, local categories, and social geography. The linguistic variables are subjected to a quantitative sociolinguistic analysis that takes into account speakers' social class, sex, rural/urban orientation, occupation, education and age; these social criteria are used primarily to interpret the patterning of speakers on the linguistic continuum.

Characterizations of Class Preserving Monotonic and Dual Monotonic Language Learning
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The present paper deals with monotonic and dual monotonic language learning from positive as well as from positive and negative examples. The three notions of monotonicity reflect different formalizations of the requirement that the learner has to always produce better and better generalizations when fed more and more data on the concept to be learnt. The three versions of dual monotonicity describe the concept that the inference device has to exclusively produce specializations that fit better and better to the target language. We characterize strong-monotonic, monotonic, weak-monotonic, dual strong-monotonic, dual monotonic and monotonic & dual monotonic as well as finite language learning from positive data in terms of recursively generable finite sets.

A Model of Redundant Information in Dialogue: the Role of Resource Bounds
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The proposed thesis aims to contribute to current research on cognitively and computationally accurate models of dialogue. It investigates the use of informationally redundant utterances (IRUs) in a corpus of problem-solving task-oriented dialogues.

An IRU is an utterance whose propositional content was already added to the representation of the dialogue by the IRU's antecedent, a previous utterance that realizes the same propositional content as the IRU. IRUs are clearly of linguistic interest since they appear to be counter examples to the Gricean Maxim of Quantity. Furthermore since communication is a subcase of action, the existence of IRUs is a paradox because IRUs appear to be actions whose effects have already been achieved.

An essential part of the proposed thesis is a distributional analysis of IRUs in a large corpus of naturally occurring problem solving dialogues. About 12% of the utterances in the corpus are IRUs. The distributional analysis examines the logical type of IRUs, the prosody of IRUs, and the co-occurrence of IRUs with other indicators of discourse structure such as cue words, and the location of the IRUS with respect to its antecedent. IRUs include cases of presupposition affirmation, and implicature reinforcement when the implicature is not said by the same speaker in the same utterance.

I argue that IRUs can only be explained by a processing model of dialogue that reflects agents' autonomy and limited attentional and inferential capacity. IRUs can be classified into three communicative functions and each of these functions can be related to either agents' autonomy or limited processing capacity:

- 1) Attitude: to address the assumptions underlying the inference of beliefs about mutual understanding and acceptance;
- 2) Consequence: to change the status of a belief from an implicature to an entailment, or from an implicit belief to an explicit one;
- 3) Attention: to manipulate the locus of attention of the discourse participants by making or keeping a proposition salient.

Attitude is related to agent's autonomy. The treatment of attitude has required the development of a model of mutual beliefs based on Lewis's shared environment model of common knowledge. The treatment of the communicative function of Attention is based the interaction of this model of mutual belief with Prince's taxonomy of information status and notions such as given-s or salient. Finally the treatment of Consequence also relies on developing the shared environment model of mutual beliefs to capture aspects of agents' limited reasoning ability. It isn't possible to use most existing semantics models, based on possible world semantics, because they make the simplifying assumption that agents are logically omniscient.

The explication of the paradox of IRUs has ramifications for models of dialogue, the models of mutual belief that they are based on and some basic tenets of the Gricean program. The

simulation experiments described here will provide an empirical basis for the claim that discourse strategies that utilize IRUs are more efficient than ones that don't when agents are modeled as limited processors. Under these circumstances utterances that are informationally redundant are not communicatively redundant, demonstrating that the information exchange view of dialogue is too narrow.

On the Danger of Half-truths

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Criteria of approximate scientific success are defined within a formal paradigm of empirical inquiry. One consequence of aiming for less than perfect truth is examined.

Structural Recursion As A Query Language

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We propose a programming paradigm that tries to get close to both the semantic simplicity of relational algebra, and the expressive power of unrestricted programming languages. Its main computational engine is structural recursion on sets. All programming is done within a "nicely" typed lambda calculus, as in Machiavelli [OBB89]. A guiding principle is that how queries are implemented is as important as whether they can be implemented. As in relational algebra, the meaning of any relation transformer is guaranteed to be a total map taking finite relations to finite relations. A naturally restricted class of programs written with structural recursion has precisely the expressive power of the relational algebra. The same programming paradigm scales up, yielding query languages for the complex-object model [AB89]. Beyond that, there are, for example, efficient programs for transitive closure and we are also able to write programs that move out of sets, and then perhaps back to sets, as long as we stay within a (quite flexible) type system. The uniform paradigm of the language suggests positive expectations for the optimization problem. In fact, structural recursion yields finer grain programming therefore we expect that lower-level, and therefore better optimizations will be feasible.

Categorial Grammar

Mark Steedman
IRCS-92-28
MS-CIS-92-52

The paper is a review article comparing a number of approaches to natural language syntax and semantics that have been developed using categorial frameworks.

It distinguishes two related but distinct varieties of categorial theory, one related to Natural Deduction systems and the

axiomatic calculi of Lambek, and another which involves more specialized combinatory operations.

Character Recognition Using A Modular Spatiotemporal Connectionist Model

Thomas Fontaine
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MS-CIS-92-24

We describe a connectionist model for recognizing handprinted characters. Instead of treating the input as a static signal, the image is scanned over time and converted into a time-varying signal. The temporalized image is processed by a spatiotemporal connectionist network suitable for dealing with time-varying signals. The resulting system offers several attractive features, including shift-invariance and inherent retention of local spatial relationships along the temporalized axis, a reduction in the number of free parameters, and the ability to process images of arbitrary length. Connectionist networks were chosen as they offer learnability, rapid recognition, and attractive commercial possibilities. A modular and structured approach was taken in order to simplify network construction, optimization and analysis.

Results on the task of handprinted digit recognition are among the best report to date on a set of real-world ZIP code digit images, provided by the United States Postal Service. The system achieved a 99.1% recognition rate on the training set and a 96.0% recognition rate on the test set with no rejections. A 99.0% recognition rate on the test set was achieved when 14.6% of the images.

Focusing ATMS Problem-Solving: A Formal Approach

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The Assumption-based Truth Maintenance System (ATMS) is a general and powerful problem-solving tool in AI. Unfortunately, its generality usually entails a high computational cost. In this paper, we study how a general notion of cost function can be incorporated into the design of an algorithm for focusing the ATMS, called BF-ATMS. The BF-ATMS algorithm explores a search space of size polynomial in the number of assumptions, even for problems which are proven to have exponential size labels. Experimental results indicate significant speedups over the standard ATMS for such problems. In addition to its improved efficiency, the BF-ATMS algorithm retains the multiple-context capability of an ATMS, and the important properties of consistency, minimality, soundness, as well as the property of bounded completeness. The usefulness of the new algorithm is demonstrated by its application to the task of consistency-based diagnosis, where dramatic efficiency improvements, with respect to the standard solution technique, are obtained.

Progressive Horizon Planning-Planning-Exploratory-Corrective Behavior

Ron Rymon

Bonnie Webber

John R. Clarke

IRCS-92-31

MS-CIS-92-23

Much planning research assumes that the goals for which one plans are known in advance. That is not true of trauma management, which involves both a search for relevant goals and reasoning about how to achieve them.

TraumAID is a consultation system for the diagnosis and treatment of multiple trauma. It has been under development jointly at the University of Pennsylvania and the Medical College of Pennsylvania for the past eight years. TraumAID integrates diagnostic reasoning, planning and action. Its reasoner identifies diagnostic and therapeutic goals appropriate to the physician's knowledge of the patient's state, while its planner advises on beneficial actions to next perform. The physician's lack of complete knowledge of the situation and the time limitations of emergency medicine constrain the ability of any planner to identify what would be the best thing to do. Nevertheless, TraumAID's Progressive Horizon Planner has been designed to create a plan for patient care that is in keeping with the standards of managing trauma.

Surface Structure

Mark Steedman

IRCS-92-32

MS-CIS-92-51

The purpose of this paper is to show how binding and control can be captured straightforwardly in Combinatory Categorical Grammar (CCG), and to examine the interaction of the binding theory with the CCG account of long-range dependencies including "parasitic gaps" (Steedman 1987, Szabolcsi 1987a). Part I shows that a simple theory of binding and control is compatible with CCG. Part II shows that the Binding Theory interacts correctly with the combinatory account of long range dependency, correctly imposing certain constraints, including a number of asymmetries with respect to extraction between subjects and other arguments, such as "strong crossover", and the equivalent of an "anti-c-command" restriction on parasitic gaps (cf. Taraldsen). The conclusion suggests a simplifying reorganisation of the theory of grammar, via a single level of derivational syntax and a reallocation of responsibilities among the modules of the theory.

Logic Programming In A Fragment Of Intuitionistic Linear Logic

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IRCS-92-33

MS-CIS-92-33

When logic programming is based on the proof theory of intuitionistic logic, it is natural to allow implications in goals and the bodies of clauses. Attempting to prove a goal of the form $D \multimap G$ from the context (set of formulas) Γ leads to an attempt to prove the goal G in the extended context $\Gamma \uparrow D$. Thus during the bottom-up search for a cut-free proof contexts, represented as the left-hand side of intuitionistic sequents, grow as stacks. While such an intuitionistic notion of context provides for elegant specifications of many computations, contexts can be made more expressive and flexible if they are based on linear logic. After presenting two equivalent formulations of a fragment of linear logic, we show that the fragment has a goal-directed interpretation, thereby partially justifying calling it a logic programming language. Logic programs based on the intuitionistic theory of hereditary Harrop formulas can be modularly embedded into this linear logic setting. Programming examples taken from theorem proving, natural language parsing, and data base programming are presented: each example requires a linear, rather than intuitionistic, notion of context to be modeled adequately. An interpreter for this logic programming language must address the problem of splitting context; that is, when attempting to prove a multiplicative conjunction (tensor), say $G_1 \otimes G_2$, from the context Γ , the latter must be split into disjoint contexts, Γ_1 and Γ_2 for which G_1 follows from Γ_1 and G_2 follows from Γ_2 . Since there is an exponential number of such splits, it is important to delay the choice of a split as much as possible. A mechanism for the lazy splitting of contexts is presented based on viewing proof search as a process that takes a context, consumes part of it, and returns the rest (to be consumed elsewhere). In addition, we use collections of Kripke interpretations indexed by a commutative monoid to provide models for this logic programming language and show that logic programs admit a canonical model.

Grammars and Processors

Mark Steedman

IRCS-92-34

MS-CIS-92-53

The paper discusses the role of grammars in sentence processing, and explores some consequences of the "Strong Competence Hypothesis" of Bresnan and Kaplan for combinatory theories of grammar.

An Active Approach To Functionality Characterization and Recognition

Luca Bogoni

Ruzena Bajcsy

IRCS-92-35

MS-CIS-92-37

In this paper we focus on understanding and defining a methodology for object description and recognition both in terms of its geometrical, material and functional specifications. We define functionality in an object as its applicability toward the achievement of a task. We emphasize and develop an interactive and performatory approach to functionality recovery. Furthermore, we introduce the

distinction between Inherent, Intended and Imposed functionality.

By analyzing interaction and manipulation tasks as goal-oriented recognition processes we propose to identify and characterize functionalities of objects. This interaction is not only a means of verification of the hypothesized presence of functionality in objects but also a way to actively and purposively recognize the object.

In order to accomplish our goal, we introduce a formal model, based on Discrete Event Dynamic System Theory, to define a task for recovering and describing functionality. We extend the recovery process to an algebra of tasks. We describe how a more complex task can be composed from a set of primitive ones. This constructive approach allows a task to be built from simpler ones in a stepwise fashion.

Once the manipulatory task has been described in the formal model, it must be instantiated in a context. In such a context, the behavior of the system in which the interaction between a Manipulator, a Tool and a Target object must be observed. Thus, the description of tasks themselves provide must for means of addressing observability through different sensor modalities. For this purpose, we introduce the notion of Partial Observability of a task. This allows the description of a plant in which not all events and the time of their occurrence might be modelled and therefore predictable in advance.

Generalized Quantifiers and Logical Reducibilities

Anuj Dawar

IRCS-92-36

MS-CIS-92-85

We consider extensions of first order logic (FO) and least fixed point logic (LFP) with generalized quantifiers in the sense of Lindstrom. We show that adding a finite set of such quantifiers to LFP fails to capture all polynomial time properties of structures, even over a fixed signature. We also consider certain regular infinite sets of Lindstrom quantifiers, which correspond to a natural notion of logical reducibility. We show that if there is any recursively enumerable set of quantifiers that can be added to FO (or LFP) to capture P, then there is one with strong uniformity conditions. This is established through a general result, linking the existence of complete problems for complexity classes with respect to the first order translations or the elementary reductions with the existence of recursive index sets for these classes.

Proceedings of the IRCS Workshop on Prosody in Natural Speech

IRCS-92-37

Collection of papers from the Proceedings of the IRCS Workshop on Prosody in Natural Speech.

The Derivational Generative Power of Formal Systems or Scrambling is Beyond LCFRS

Tilman Becker

Owen Rambow

Michael Niv

IRCS-92-38

Scrambling is a word-order phenomenon which is “doubly unbounded” in that more than one element can move, and movement can be unbounded. Becker, Joshi and Rambow (1991) argue that scrambling is beyond the power of Tree Adjoining Grammars by assuming that elementary trees express a complete predicate-argument structure. In this paper, we formalize this notion by defining the “derivational generative capacity” of a formal system as the generative capacity given certain restrictions on the derivation. Using this notion, we show that Linear Context Free Rewrite Systems cannot derive scrambling.

Learning and Forgetting For Perception-Action: A Projection Pursuit and Density Adaptive Approach (Ph.D. Dissertation)

Marcos Salganicoff

IRCS-92-39

MS-CIS-92-87

We study learning of perception-action relations using visually driven grasping as an example task. The well-established technique of non-parametric Projection Pursuit Regression (PPR) is used to accomplish reinforcement learning by searching for projections of high-dimensional data sets that capture invariants in the distribution of reinforcement in the parameter-space. The variable resolution 2 k ? tree, a generalized quadtree, is used to represent perception-action maps based on the resulting regression function. We also pursue the following problem: how can we use human expertise and insight into grasping to train a system to select gripper approach directions and orientations for grasping, and then have it verify and adapt its skills through trial and error? To accomplish this learning we develop a new Density Adaptive Reinforcement Learning algorithm. This algorithm uses statistical tests to identify regions of the attribute space in which the dynamics of the task change and the density of exemplars is high. It concentrates the building of high-resolution descriptions in those areas.

In order to adapt the default rules to those necessary for the robot, it is necessary for the system to be able to forget previous experiences that no longer reflect the behavior of the world. A general purpose Density Adaptive forgetting algorithm has been developed that can be used as a front-end for a variety of learning methods. Additionally, by setting the forgetting parameters appropriately, an upper bound on the number of exemplars stored in the system may also be selected. This is important since all memory-based learning systems have finite memory in practice.

Verb Movement and Coordination in the Germanic Languages: Evidence for a Relational Perspective on Licensing

**Caroline Heycock
Anthony Kroch
IRCS-92-40**

The empirical problem that we address in this paper is a type of coordination found in the V2 Germanic languages. The hallmark of this type of coordination is that the second conjunct is interpreted as sharing the subject that occurs immediately after the tensed verb.

We will argue that given a number of well-motivated assumptions about coordination in general and German phrase-structure in particular, it is not possible to construct a satisfactory analysis of this construction under our current understanding of the nature of syntactic derivations. We will then propose that, rather than giving up any of our assumptions about coordination and German phrase-structure, we should instead revise our understanding of the effect of movement in a derivation. In particular, we will argue that any licensing relation satisfied by the head of a chain at S-Structure cannot in addition license a trace; consequently, given minimalist assumptions along the lines of Chomsky 1991, 1992, a trace that has had all of the licensing conditions in which it participates preempted by the head of its chain must delete. This proposal leads to a very straightforward account of SLF-Coordination that is empirically superior to other analyses that have been proposed. In addition, we show that it extends directly to subject questions in English, and provides the theoretical underpinning for an analysis of some apparently unrelated data in Yiddish and Old English.

The Licensing of CP-recursion and its Relevance to the Germanic Verb-Second Phenomenon

**Sabine Iatridou
Anthony Kroch
IRCS-92-41**

Immediate Dominance, Linear Precedence, and the Representation of Syntax

**Owen Rambow
IRCS-92-42**

In [Becker et al 1991], we argue that scrambling (the leftward movement of nominal and clausal constituents in languages such as German or Korean) cannot be handled by a simple TAG: under certain minimal assumptions about the way TAGs are used to represent syntactic structure (“co-occurrence constraints”), there are word orders which cannot be derived. We proceed to propose that two variants of TAGs can both handle the full range of variations. In FO-TAG (“Free Order TAG”), the linear precedence between nodes is relaxed. LP rules can be stated between any non-dominating nodes of a single elementary tree. Furthermore, an “integrity constraint”, written \int , can be applied to a node, with the effect that all nodes dominated by the node must either precede or follow a

given node not dominated by the node. In MC-TAG-DL (“Multi-Component TAGs with Dominance Links”), the immediate dominance between two nodes can be relaxed during adjunction so that the tree is adjoined in pieces (between which a dominance relation must hold). In this paper, I would like to investigate linguistic issues raised by this choice between two very different formalisms. Formal systems should not be rejected for linguistic analysis simply because they use unfamiliar notions of, say, phrase structure. In this paper, I will attempt to investigate the usefulness of FO-TAG and of MC-TAG-DL for the representation of syntax. I will first quickly summarize the facts of German scrambling that led to the proposal of the two formalisms, as originally presented in [Becker and Rambow 1990, Becker et al 1991]. In Section 3 I discuss a FO-TAG analysis of scrambling, and show that it makes predictions that are compatible with other analyses. I then introduce more data, namely the so-called “Third Construction” cases. In Section 5, I argue that these constructions pose inherent problems for representational paradigms such as FO-TAG. In Section 6, I show that MC-TAG-DL can handle this data. In Section 7, I very briefly address a processing-based argument that could be made in favor of FO-TAG, but I argue that the requirements of incremental generation do not imply a preference among the two formalisms.

Familiar Complements and Their Complementizers: On Some Determinants of A'-Locality

**Michael Hegarty
IRCS-92-43**

The paper addresses the generalization that adverbial wh movement and adverbial fronting is blocked out of tensed factive complement clauses, arguing that this generalization is correctly expressed not in terms of the factivity of the complement clause, whereby the complement clause is presupposed to be true, but rather in terms of a property of definite noun phrases, called familiarity, whereby the content of the complement clause is assumed by the speaker to have been evoked (for the listener) by the prior discourse or aspects of the nonlinguistic context. Adopting from Sabine Iatridou a diagnostic for the semantic or feature content of complementizers, the paper then shows that the complementizer introducing familiar complement clauses has content that the complementizer of a bridge verb complement lacks. The effects on adverbial fronting and wh movement do not obtain for familiar infinitival complements. Together, these facts pose a novel problem for extraction theory, construed here as an A'-dependency relation between an extracted constituent and the trace(s) of its movement. Moreover, assuming results of Itziar Laka, this problem is mirrored for tensed and infinitival complements of negative predicates. To solve this problem, the A'-dependency relation is captured in terms of syntactic domains whose extension is defined by processes of head movement which exist independently in the grammar and which are independently sensitive to the feature content of syntactic heads.

“Nominal” Structures and Structural Recursion

Robert Frank

Anthony Kroch

IRCS-92-44

Gerunds and nominalizations have properties in common that have led syntacticians to classify them both as nominal elements. In this paper, we adduce new evidence concerning interpretation of amount questions, licensing of parasitic gaps, and licensing of negative polarity items which distinguishes nominalizations from gerunds. On this basis, we argue that gerunds are properly classified as clausal constituents, and in particular as IPs. We show how using Tree Adjoining Grammar as a underlying formalism in which to state the theory of grammar allows us to reduce the difference in the distribution of gerunds and nominalizations to the difference in their ability to form a recursive structure with an embedding clause; gerunds involve [+V;?N] projections and therefore form a recursive structure, while whereas nominalizations as [?V;+N] projections do not.

Two classes of "any" in English and Korean

Young-Suk Lee

IRCS-92-45

There are two long-standing issues concerning the syntax and semantics of "any" in English. What licenses its occurrence? What is the right characterization of its quantificational properties?

Second Diachronic Generative Syntax Workshop, November 5-8, 1992

University of Pennsylvania, IRCS and SAS

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Syntactic Locality and Tree Adjoining Grammar: Grammatical, Acquisition and Processing Perspectives (Ph.D. Dissertation)

Robert Evan Frank

IRCS-92-47

MS-CIS-92-89

It has been widely recognized that the relations human grammar exploits are sensitive to constraints on structural locality. Indeed, much research in generative syntax has focused on the precise characterization of the locality conditions that grammatical processes respect. In this dissertation, I propose that locality reflects the underlying formal system with which grammars are represented. In particular, I argue that the formalism of Tree Adjoining Grammars (TAG) is the appropriate meta-language for grammatical principles. TAG provides a mechanism for composing phrase structure representations from small

structural domains, and in doing so, restricts the class of possible grammatical principles to those expressible over these domains. Under this view, the existence of locality conditions is not directly stipulated, but instead follows from the representational machinery which the formal grammar makes available. I consider evidence from three domains of linguistic inquiry which provide convergent support for this view.

VP Ellipsis and Contextual Interpretation

Daniel Hardt

IRCS-92-48

A computational account of VP ellipsis is described, in which VP's are represented in the discourse model as contextually dependent semantic objects. It is argued that this approach can handle examples that are not allowed by alternative accounts. An implementation is defined in terms of extensions to the Incremental Interpretation System. The treatment of VP ellipsis is analogous to that of pronominal anaphora. It is suggested that the regency and salience constraints commonly thought to apply to pronominal anaphora might apply in a similar way to VP ellipsis.

VP Ellipsis and Semantic Identity

Daniel Hardt

IRCS-92-49

While it is generally agreed that an elliptical Verb Phrase must be identical to its antecedent, the precise formulation of the identity condition is controversial. I present a semantic identity condition on VP ellipsis: the elided VP must have the same meaning as its antecedent. I argue that a semantic identity condition is superior to a syntactic condition on both empirical and theoretical grounds. In addition, I show that the proposed condition differs significantly from previously proposed semantic conditions, in that other approaches do not take into account the dynamic nature of semantic representation.

An Algorithm for VP Ellipsis

Daniel Hardt

IRCS-92-50

An algorithm is proposed to determine antecedents for VP ellipsis. The algorithm eliminates impossible antecedents, and then imposes a preference ordering on possible antecedents. The algorithm performs with 94% accuracy on a set of 304 examples of VP ellipsis collected from the Brown Corpus. The problem of determining antecedents for VP ellipsis has received little attention in the literature, and it is shown that the current proposal is a significant improvement over alternative approaches.

Negotiation, Feedback, and Perspective within Natural Language Generation
(Ph. D. Dissertation)
Robert Rubinoff
IRCS-92-51

This thesis is an investigation of how natural language generation can take advantage of the ways that language use goes beyond simple, straightforward transmission of information. The two main contributions of the work are the use of annotations to relate linguistic choice to text planning and the use of perspective to model dependence and effects on attitude and context. Placing annotations on linguistic options allow the text planner to detect and respond to interactions between linguistic choices and the communicative plan driving those choices, without conflating the planning and linguistic levels of decision-making. The explicit modeling of perspective and perspective shifts allows the perspective to influence the generator's choices; in particular, the generator can take into account the ways that particular linguistic choices can affect or alter the subsequent perspective. The use of these techniques has been demonstrated in the IGEN implementation, resulting in a generator that can take advantage of the flexibility of natural language to frame its output in a way that reinforces the underlying goals driving the generation.

On the Use of Triggers in Parameter Setting
Robert Frank
Shyam Kapur
IRCS-92-52

In some recent work of Edward Gibson and Kenneth Wexler, the existence of a trigger for each value of each parameter has been claimed to guarantee (feasible) convergence. We show that their notion of a trigger is neither sufficient nor necessary and provide alternatives which (separately) are. Even where triggers provably lead to eventual convergence, convergence in plausible time and from potentially noisy input cannot be established. We also show how a simple 2-parameter space can be parameterized in two equally plausible ways which differ with regard to the existence of triggers. We conclude with a discussion of the remaining relevance of triggers for the human grammar.