European Masters Program in Language and Communication Technologies (LCT)

Modules Handbook for Prospective Students

Chapter 1

Study Program

The Master in Language and Communication Technologies is designed to meet the demands of industry and research in a rapidly growing area. It offers education and training opportunities for the next generations of leaders in research and innovation. It provides students with profound knowledge and insight into the various disciplines that contribute to the methods of language and communication technologies and it strengthens their ability to work according to scientific methods. Moreover, the students also acquire practice-oriented knowledge by choosing appropriate combinations of modules in language technology, computational and theoretical linguistics, and computer science.

Studying in multi-national groups at two universities in Europe, with English as instruction language, accompanied by language classes in another European language, contributes to the students' preparation for the increasing globalization of science, commerce and industry. The course also prepares students for follow-up Ph.D. studies provided by the participating partners and others.

The course consists of Compulsory Modules and Advanced Modules in Language Technologies and Computer Science, complemented by a Project, and a Master thesis, for a total of 120 ECTS credits.

The Compulsory Modules and their range of possible syllabi are as specified in Table 1.1 below.

The Advanced Modules consist of 34 ECTS credits, of these at least 4 credits should be in LT and 4 in CS. These modules are based on the specific strengths in research and teaching of the partner institutions and thus vary from partner to partner. The main topics are listed in Table 1.2 below. From the 34 ECTS credits of this category of modules, 15 may be devoted to a project. The research masters thesis consists of 30 ECTS credit points.

Students within the double degree program have to study at two institutions of the consortium. As such, they are jointly monitored by two lecturers (tutors), one from each institution. Each student has to develop a study plan with her/his tutors. This plan must be submitted for approval to the Joint Committee of the Consortium. The students have to complete successfully all the written and/or oral exams of the modules selected in the aforementioned study plan. The students have to submit and defend their masters thesis at either or both of their selected institutions. The masters thesis can be jointly supervised. It is defended in front of a jury with members from the two selected universities.

A detailed description of the study organisation, the modules, and the courses offered by the

	Module	**Topics**	**Credits**
Language Technologies (24 ECTS minimum)	Foundational (LT-M1)	Statistical methods, symbolic methods, cognition, corpus, text and speech, foundations of Linguistics	at least 6
	Computational Syntax and Morphology (LT-M2)	Finite state techniques, probabilistic approaches, formal grammars, tagging, chunking, parsing	at least 9
	Computational Semantics, Pragmatics and Discourse (LT-M3)	Syntax-semantics interface, semantic construction, dialogue, ontologies, formal semantics	at least 9
Computer Science (24 ECTS minimum)	Data Structures, Data Organization and Processing (CS-M1)	Algebraic data-types, relational databases, semi-structured data and XML, information retrieval, digital libraries	at least 6
	Logic, Computability and Complexity (CS-M2)	Logic and inference, automata theory, computability theory, complexity theory, discrete mathematics	at least 9
	Formal Languages and Algorithms (CS-M3)	Formal grammars and languages hierarchy, parsing and compiler design, search techniques and constraint resolution, automated learning	at least 9

Table 1.1: Core Modules

	Module	**Topics**	**Credits**
Language Technologies	Advanced (LT-M4)	Machine translation, information and knowledge representation, information retrieval, question answering, speech recognition and generation, models of human language processing and understanding, psycholinguistics	at least 4
Computer Science	Advanced (CS-M4)	Artificial intelligence, knowledge representation, automated reasoning, semantic web, intelligent and multi-modal interfaces, cognitive modelling, computational psychology, neural networks, machine learning	at least 4

Table 1.2: Advanced Modules

participating universities is available in the rest of this handbook.

Part I

Language Technology Modules

Chapter 2

University of Amsterdam (UvA)

The indicated modules are classified as A, B, C. A means that the module is suitable as a first course in the area (though it may still require basic computational and mathematical skills), B means that it is a second course in the area and C that it is advanced.

2.1 Description of the Foundations of Language Technology Module

The **Foundations of Language Technology** module at *the University of Amsterdam* is covered with courses on:

Language and Speech Processing (6 points, with 2 associated projects of 4 points each) which deals with all basic techniques, including statistical and symbolic methods

2.1.1 Text and Speech

Language and Speech Processing: How to deal with uncertainty and lack of knowledge when building models of human cognitive capacities such as language processing. This includes: -Statistical models for language processing -Language models for speech processing -Models for ambiguity resolution in POS tagging and syntactic parsing -Technological applications. When computational models of language processing are not constructed in a purely linguistic context, but aim at being relevant for psychological theory or for practical applications, they ought to be able to perform tasks like disambiguation and prediction. [**6 ECTS, level A**]

2.2 Description of the Computational Syntax and Morphology Module

The **Computational Syntax and Morphology** module at *the University of Amsterdam* is covered with courses on:

Language and Speech Processing, Computational Syntax, Probabilistic Grammars and Data Oriented Parsing.

2.2.1 Finite State Techniques (FST)

Covered by the course **Language and Speech Processing**.

2.2.2 Probabilistic Approaches

Probabilistic Grammars and Data Oriented Parsing: The course consists of two parts. Part I introduces the use of statistics and probabilities in Natural Language Processing. It focuses on mathematical models and the principles behind them; computational aspects are de-emphasized and left for Part II. The topics to be treated are: syntactic representations, the ambiguity problem, Probability Theory and Statistics, N-gram Models applied to Part-of-Speech tagging, Hidden Markov Models and their relation to Finite State Transducers, Probabilistic Context-Free Grammars and syntactic analysis, limitations of these models.

Part II builds on Part I. It introduces more complex models and discusses their computational properties. The topics are: parsing and ambiguity, the Maximum Likelihood Principle, Probabilistic Context-Free Grammars and Inside-Outside algorithms, problems with PCFG's, Data-Oriented Parsing, Bilexical Dependency Parsing. [**6 ECTS, level B**]

2.2.3 Formal Grammars

Computational Syntax: Knowledge of the main formalisms used in computational descriptions of natural languages, in particular Lexical Functional Grammar, Head driven Phrase Structure Grammar and Optimality Theory. We will start with Wasow and Sag's soft introduction to HPSG, will read some research papers on recent developments, including optimality theoretic approaches. [**10 ECTS, level A**]

2.2.4 Parsing

Covered at undergraduate level

2.3 Description of the Computational Semantics, Pragmatics and Discourse Module

The **Computational Semantics, Pragmatics and Discourse** module at *the University of Amsterdam* is covered with courses on:

Computational Semantics, Dialogue systems, Meaning, Reference, and Modality, Structures for Semantics. The courses cover semantics and pragmatics, syntax-semantic interface and semantic construction.

2.3.1 Syntax-Semantics Interface

Computational Semantics: The course introduces logical methods in natural language semantics and their implementation. [**10 ECTS, level A**]

2.3.2 Semantic Construction

2.3.3 Dialogue

Dialogue systems: Dialogue and man machine dialogue in particular comes with a number of special problems over and above those that one meets in discourse processing. The course will aim to look at a number of problems that are central in current research, such as agreed knowledge, conflict and negotiation, speech act recognition and characterisation of control. [**6 ECTS, level B**]

2.3.4 Formal Semantics

Meaning, Reference and Modality: In this course classical intensional semantics and dynamic semantics are approached from a philosophical-logical perspective. The philosophical backgrounds of the two paradigms are studied as well as their logical formulation. We will study classical texts on intensonality from Frege, Lewis, Stalnaker and Kripke, and zoom in on long-standing issues such as sense and reference; naming, identity and necessity; beliefs de dicto, de re, and de se; speaker's reference and semantic reference; context and context change; modality and discourse. [**6 ECTS, level A**]

Structures for Semantics: Formalization plays an important role in semantics. In this course we will study mathematical techniques that are used in semantics to model natural language phenomena. We will discuss type theory, event structures, and partial semantics. In all cases we will motivate the techniques from a semantic point of view and discuss applications of the tools. [**10 ECTS, level B**]

2.4 Description of the LT Advanced Modules and Applications

The **LT Advanced Modules and Applications** at *the University of Amsterdam* are covered with courses on:

Automated Learning and Adaptive Knowledge Systems, Internet Information, Language Technology Project, Speech Technology Project, Speech Signal Processing, Language Learning, Multimedia Information Retrieval.

2.4.1 Information and Knowledge Representation

Automated Learning and Adaptive Knowledge Systems: This course expands the course

Leren in the Bachelors programme with additional topics from Machine Learning: genetic algorithms, inductive logic programming/relational learning, knowledge-intensive learning clustering, boosting. Applications of Machine Learning for Data Mining and Adaptive Interactive systems will be discussed. Special attention will be given to Machine Learning in the context of text (text mining) and adaptive interactive systems. [**6 ECTS, level B**]

2.4.2 Information Retrieval (IR)

Internet Information: Ever wondered how internet search engines work? Or why you never find what you're looking for? It turns out that many of the fundamental ideas underlying internet search engines go back to algorithms developed in the 1950s. In Information Retrieval we study techniques to locate information in large collections of information, that may contain both structured data (e.g., name, address, telephone number) and unstructured data (e.g., text, images, sounds). These techniques are being evaluated on annual basis as part of a number of international retrieval events. This year, the Internet Information course consists of the following components:

(i) A textbook part, in which we study basis techniques and methods from information retrieval, and in which we put these to work in the setting of web retrieval. (ii) A part in which we discuss recent research in a small number of subareas of web retrieval, including XML retrieval and open domain question answering systems. (iii) A number of practical assignments resulting in the implementation of web retrieval systems and/or extensions. [**10 ECTS, level A**]

2.4.3 Question Answering (QA)

Covered in undergraduate program and often in language technology project.

2.4.4 Speech Recognition and Generation

Spoken Language Generation: While in NLP and Speech the serious difficulties are normally taken to be in the interpretation direction (parsing and speech recognition). Here the question is can one do it all and can one get rid of the limiting factors under which it is possible. Generating text and speech seems comparatively simple. The research questions all center around the notion of quality, which is also the decisive factor in the commercialisation of these techniques. The course gives an overview of the standard approaches in text to speech and text generation and introduces the main research issues. [**6 ECTS, level A**]

2.4.5 Psycholinguistics

Logic and Cognition - from time to tense. We study the relation between the human conceptualization of time and the representation of time in natural language. The course begins with an overview of philosophical thinking about time, and then continues with an examination of current psychological theories. [**10 ECTS, level A**]

2.5 Additions

2.5.1 Language Technology Project:

Changing topics. [**6 ECTS, level B**]

2.5.2 Speech Technology Project:

Changing topics. [**6 ECTS, level B**]

2.5.3 Speech Technology:

In this module the student will acquire insight in the structure, processing and performance of speech technological systems. With this insight one should be able to read and understand most of the literature in this field. One should also be able to extend this information into building one's own applications or into performing one's own research.
At least the following topics will be covered: speech and text corpora; speech segmentation and transcription at various levels; storage and access of (annotated) corpora; speech coding, speech synthesis, speech recognition, and dialogue structures; system evaluation; speech technological applications; overview of interesting research programs and products. [**10 ECTS, level A**]

2.5.4 Speech Signal Processing:

Speech coding and compression – Fourier analysis – band filter analysis – convolution and auto-correlation – relation with automatic speech recognition. [**10 ECTS, level A**]

2.5.5 Language Learning:

We will focus on questions concerning mathematical models of the learning capacity of human beings. The central problem is how people exchange information in a dialogue. This leads to the study of syntactical and semantical learning algorithms. There are various approaches in this area. Historically, the influence of Gold's paradigm, identification in the limit has been very strong. Yet this approach is of limited value, because it leads to negative results and gives us very little clue as to the implementation of language learning algorithms that work in practice. We will present another approach based on categorial grammars, PAC-learning and Kolmogorov complexity. In this context we will introduce the concept of shallowness and will show that under very reasonable circumstances context-free grammars can be learned from text alone. We will explore the possibilities to extend this theory to a general theory of learnable structures. [**6 ECTS, level A**]

For more info see `http://www.studeren.uva.nl/ma-ai/`.

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Chapter 3

Free University of Bozen-Bolzano(FUB)

3.1 Description of the Foundations of Language Technology Module

The **Foundations of Language Technology** module at FUB is covered with courses on:

3.1.1 Text and Speech

Automatic Speech Recognition Introduction to spoken language interfaces; Human speech production and perception systems; Speech signal representation; [**2 ECTS**]

3.1.2 Foundations of Linguistics

Introduction to Linguistics Morphology; Phonetics; Phonology; Syntax; Semantics [**4 ECTS**]

3.2 Description of the Computational Syntax and Morphology Module

The **Computational Syntax and Morphology** module at FUB is covered with courses on:

3.2.1 Finite State Techniques (FST)

See FUB course description in the Computer Science Modules Part.

3.2.2 Formal Grammars

Computational Linguistics Introduction to Formal Grammars: CFG, Feature Structures, CG, TAG. [**2 ECTS**]

3.2.3 Parsing

Text Processing Data and knowledge driven methodologies for text processing; Morpho-syntactic analysis; Content extraction; Part of speech tagging; Shallow parsing; Terminology recognition; Named entities recognition; Word sense disambiguation [**4 ECTS**]

3.3 Description of the Computational Semantics, Pragmatics and Discourse Module

The **Computational Semantics, Pragmatics and Discourse** module at FUB is covered with courses on:

3.3.1 Syntax-Semantics Interface

Computational Linguistics Syntax-Semantics Interface: lambda calculus, introduction to DRT. [**2 ECTS**]

3.3.2 Dialogue

Intelligent Interfaces Multimodal interfaces; Tangible interfaces; Conversational interfaces; Team project [**4 ECTS**]

3.4 Description of the LT Advanced Modules and Applications

The **LT Advanced Modules and Applications** at FUB are covered with courses on:

3.4.1 Machine Translation (MT)

Cross-Language Information Technologies Statistical framework of machine translation; [**1 ECTS**]

3.4.2 Information and Knowledge Representation

See FUB course description in the Computer Science Modules Part.

3.4.3 Information Retrieval (IR)

See FUB course description in the Computer Science Modules Part.

3.4.4 Speech Recognition and Generation

Automatic Speech Recognition Pattern classification; Acoustic modeling; Language modeling; Word hypotheses generation [**2 ECTS**]

3.4.5 Models of Human Language Processing and Understanding

Cross-Language Information Technologies Models and algorithms for various application areas; Document translation; Speech translation; Cross-language information access; Experimental work with available software. [**3 ECTS**]
For more info see `http://www.inf.unibz.it/mcs/lct/`

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Chapter 4

Copenhagen Business School (CBS)

4.1 Description of the Foundations of Language Technology Module

The **Foundations of Language Technology** module at *Copenhagen Business School* is covered with courses on:

symbolic methods, corpus, foundations of Linguistics.

4.1.1 Symbolic Methods

Course in **Logic**, (Comprises the basic concepts of prepositional and predicate logic, model theory and elementary lambda calculus.) [**5 ECTS**]

4.1.2 Corpus Linguistics

[**2 ECTS**] of our course in **Computer-Assisted Terminology** deal with Corpus Linguistics. (The course comprises the use of corpora for terminological and lexicographic tasks.)

4.1.3 Foundations of Linguistics

[**2 ECTS**] of our course in **Linguistic Theories and Formalisms: Syntax** fall under this heading. (The course comprises basic concepts and issue in one or more formal syntactic theories.)

[**2 ECTS**] of our course in **Linguistic Theories and Formalisms: Semantics** fall under this heading. (The course comprises basic concepts and issue in one or more formal semantic theories.)

[**1 ECTS**] of our course in **Computer-Assisted Terminology** fall under this heading. (The course comprises theoretical issues in terminology and lexicography.)

4.2 Description of the Computational Syntax and Morphology Module

The **Computational Syntax and Morphology** module at *the Copenhagen Business School* is covered with courses on:

finite state techniques (FST), formal grammars, parsing.

4.2.1 Finite State Techniques (FST)

[**1 ECTS**] of our general course in **Computer Science** deal with FST.

4.2.2 Formal Grammars

[**4 ECTS**] of our course in **Linguistic Theories and Formalisms: Syntax** deal with Formal Grammars. (The course comprises basic concepts and issue in formal syntax.)

4.2.3 Parsing

Course in **Parsing Strategies**. (The course comprises top-down and bottom-up parsing, left-corner parsing and chart-parsing, and key issues and methods in robust parsing.) [**5 ECTS**]

[**2 ECTS**] of our course in **Linguistic Theories and Formalisms: Syntax** deal with Parsing. (The course comprises methods and techniques for computational implementation of syntactic analysis of Danish sentences.)

[**1 ECTS**] of our course in **Natural-Language Processing** deals with Parsing. (The course comprises problems and methods in natural-language processing.)

4.3 Description of the Computational Semantics, Pragmatics and Discourse Module

The **Computational Semantics, Pragmatics and Discourse** module at *the Copenhagen Business School* is covered with courses on:

dialogue, ontologies, formal semantics.

4.3.1 Dialogue

[**1 ECTS**] of our course in **Natural-Language Processing** deals with Dialogue. (The course comprises problems and methods in natural-language processing, as they are manifested in e.g. dialogue systems, natural-language interfaces or text summarisation.)

4.3.2 Formal Semantics

[**8 ECTS**] of our course in **Linguistic Theories and Formalisms: Semantics** fall under this heading. (The course comprises basic concepts and issue in one or more formal semantic theories. In addition to this, methods and techniques are presented for computational implementation of semantic analysis of Danish sentences in accordance with the studied theories.)

4.4 Description of the LT Advanced Modules and Applications

The **LT Advanced Modules and Applications** at *the Copenhagen Business School* are covered with courses on:

machine translation, information and knowledge representation, question answering, speech recognition and generation

4.4.1 Machine Translation (MT)

Course in **Machine Translation**. (The course comprises techniques and methods for the development of translation systems.) [**5 ECTS**]

4.4.2 Information and Knowledge Representation

[**5 ECTS**] of our course in **Database Theory and Programming** deal with Knowledge Representation. (The course comprises database theories, the architecture of database systems, and data organisation)

[**5 ECTS**] of our course in **Computer-Assisted Terminology** deal with Knowledge Representation. (The course comprises knowledge structuring and knowledge representation in terminology work.)

4.4.3 Question Answering (QA)

[**2 ECTS**] of our course in **Database Theory and Programming** deal with QA. (The course comprises facilities of database systems.)

[**2 ECTS**] of our course in **Natural-Language Processing** deal with QA. (The course comprises problems and methods in natural-language processing, as they are manifested in e.g. dialogue systems, natural-language interfaces or text summarisation.)

4.4.4 Speech Recognition and Generation

Elective Module in **Speech**. (The course comprises a general introduction to speech technology). [**5 ECTS**]

4.4.5 Additions

Sections of our courses not covered by the preceding headings:

[**4 ECTS**] of our course in **Computer Science**. (General introduction to computer architecture, systems software, networks and application software).

[**3 ECTS**] of our course in **Database Theory and Programming**. (General database theory).

[**2 ECTS**] of our course in **Linguistic Theories and Formalisms: Syntax**. (Specific linguistic issues).

[**2 ECTS**] of our course in **Computer-Assisted Terminoloy**. (Theory and methods in general terminology).

[**1 ECTS**] of our course in **Natural-Language Processing**. (Interaction with knowledge bases when using real-world knowledge in parsing).

Other courses etc.:

An **Elective Module** of [**5 ECTS**].

Project, 15 ECTS. (Assignment typically given by a company or other external partner).

Thesis, 30 ECTS.

For more info see `http://www.id.cbs.dk`

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Chapter 5

University of Malta (UoM)

Under language technology UoM is primarily offering 15 advanced credits + 15 credit project + 30 credit dissertation. In addition there are 9 introductory level credits.

5.1 Description of the Foundations of Language Technology Module

The **Foundations of Language Technology** module at UoM is covered by courses on:

5.1.1 Text and Speech

Fundamentals for Digital Signal Processing This unit teaches the basics and fundamentals underlying DSP as required for speech technologies. Sampling and quantising; Fourier transform; convolution; signal processing operations. Assignments will be carried out on audio, image and weather signals. [**5 ECTS**]

5.1.2 Foundations of Linguistics

Introduction to Computational Linguistics Introductory course including linguistic and computational fundamentals, linguistic categories, tagging, computational morphology, computational syntax, grammar formalisms. [**2 ECTS**]

5.2 Description of the Computational Semantics, Pragmatics and Discourse Module

5.2.1 Syntax-Semantics Interface

Interfacing NL Syntax and Semantics A practical exploration of the interface between syntactic phenomena, (e.g. verbs, simple and complex noun phrases, relative clauses), and their semantic representation using DCGs. Development of a simple NLDB query system. [**2 ECTS**]

5.3 Description of the LT Advanced Modules and Applications

The **LT Advanced Modules and Applications** at UoM are covered with courses on:

5.3.1 Machine Translation (MT)

Machine Translation History, FAMT/HAMT/MAHT, Direct/Transfer/Interlingual Models, Example based MT, Translation Memory, Statistical MT, evaluation of MT systems. [**2 ECTS**]

5.3.2 Speech Recognition and Generation

Speech Technology with Digital Signal Processing Speech technology concepts, speech analysis, speech synthesis, TTS speech corpora, speech recognition, noise, variability, compututational tools, HMMs and neural networks. [**5 ECTS**]

5.3.3 Models of Human Language Processing and Understanding

Natural Language Algorithms This unit presents and examines algorithms used at different levels of NL analysis, notably: words (finite state tools and techniques, stemming), sentences (left corner, earley etc), texts (tokenisation, tagging). [**2 ECTS**]

5.3.4 Additions

Information Extraction The IE problem, overall architecture of IE systems, text representations and tokenisation, named entity recognition, coreference determination, representation of results, text mining. [**2 ECTS**]

Computational Morphology Morphology concepts, morphological analysis and synthesis, finite state techniques, xerox tools, concatenatative and non-concatenative morphology, computational lexicon. [**2 ECTS**]

Natural Language Generation NLG compared to NLU, components of NLG systems, NLG and planning, generation of referring expressions, path planning and description, adaptive generation. [**2 ECTS**]

5.3.5 Project

The project involves the design, implementation, description and presentation of a computational artifact in one of the areas covered in this part of the course. The description of the work to be carried out is fully determined in advance by the lecturer(s) concerned. [**15 ECTS**]

5.3.6 Dissertation - 30 ECTS credits

The disseration involves three main components: identification of a subject area and delimitaion of a topic within that area; a literature survey and seminar; the development of an artifact, and the dissertation.

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Chapter 6

University Henri Poincaré (Nancy 1)

6.1 Description of the Foundations of Language Technology Module

The **Foundations of Language Technology** module at *Nancy 1* is covered with the courses:

- Logic and Statistical Tools for Language Modeling [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Tools and Algorithms for NLP [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Corpus Linguistics [**3 ECTS of a total of 3 ECTS**]. Optional
- Phonetics [**3 ECTS of a total of 3 ECTS**]. Optional

6.1.1 Statistical Methods

Logic and Statistical Tools for Language Modeling. Hidden Markov models, n-grams, perplexity, multi-grams.

6.1.2 Symbolic Methods

Tools and Algorithms for NLP. Finite state techniques. Feature Structures and Unification. Typed Lambda Calculus. Compositionality.

6.1.3 Cognition

Logic and Statistical Tools for Language Modeling. Reasoning Models. Inference.

6.1.4 Corpus Linguistics.

Corpus Linguistics. Techniques and resources for corpus construction. Annotation tools and schemes. Applications.

6.1.5 Text and Speech

Phonetics. Phonetics, phonology, prosody.

6.2 Description of the Computational Syntax and Morphology Module

The **Computational Syntax and Morphology** module at *Nancy 1* is covered with the courses:

- Logic and Statistical Tools for Language Modeling [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Tools and Algorithms of NLP [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Introduction to NLP – Morphology and Syntax [**3 ECTS of a total of 3 ECTS**]. Obligatory
- Grammatical Formalisms [**3 ECTS of a total of 3 ECTS**]. Optional

6.2.1 Finite State Techniques (FST)

Introduction to NLP – Morphology and Syntax. Finite state automata. Tagging.

6.2.2 Probabilistic Approaches

Tools and Algorithms for NLP. Tabulation methods. Polarities and saturation of structures. Syntactic analysis as constraint resolution.

Logic and Statistical Tools for Language Modeling. Hidden Markov models, n-grams, perplexity, multi-grams.

6.2.3 Formal Grammars

Grammatical Formalisms. Head-driven Phrase Structure Grammars. Lexical Functional Grammars. Categorial Grammars. Tree Adjoining Grammars. Metagrammars.

6.2.4 Parsing

Grammatical Formalisms. Parsing Algorithms

6.3 Description of the Computational Semantics, Pragmatics and Discourse Module

The **Computational Semantics, Pragmatics and Discourse** module at *Nancy 1* is covered with the courses:

- NLP Applications [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Introduction to NLP – Semantics and Pragmatics [**3 ECTS of a total of 3 ECTS**]. Obligatory
- Computational Semantics [**3 ECTS of a total of 3 ECTS**]. Optional
- Discourse and Dialogue Representation [**3 ECTS of a total of 3 ECTS**]. Optional

6.3.1 Syntax-Semantics Interface

Introduction to NLP – Semantics and Pragmatics. Semantic Representation.

Computational Semantics. Syntax-semantics interface.

6.3.2 Semantic Construction

Introduction to NLP – Semantics and Pragmatics. Lexical Semantics.

Computational Semantics. Montague Semantics. Compositionality.

6.3.3 Dialogue

NLP Applications. Dialogue systems.

Discourse and Dialogue Representation. Discourse and dialogue models. Anaphora and presupposition resolution. Treatment of the discourse and dialogue history. DRT.

6.4 Description of the LT Advanced Modules and Applications

The **LT Advanced Modules and Applications** at *Nancy 1* are covered with the courses:

- NLP Applications [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Generation [**3 ECTS of a total of 3 ECTS**]. Optional
- Mining of Textual Domains [**3 ECTS of a total of 3 ECTS**]. Optional
- Normalization and Linguistic Resources [**3 ECTS of a total of 3 ECTS**]. Optional
- Lexicology [**3 ECTS of a total of 3 ECTS**]. Optional

6.4.1 Information and Knowledge Representation

NLP Applications. Architectures and techniques for inference in NLP.

6.4.2 Information Retrieval (IR)

Mining of Textual Domains. Symbolic Classification. Numeric Classification. Rule extraction.

Normalization and Linguistic Resources. Introduction to existing lexical, syntactic and semantic resources. The problem of information exchange and information structuring. Marking languages. Normalization.

6.4.3 Question Answering (QA)

NLP Applications. Question answering.

6.4.4 Text and Speech Recognition and Generation

Generation. Basic architecture. Content planing. Micro-planning. Surface Realization.

6.4.5 Models of Human Language Processing and Understanding

NLP Applications. Speech Recognition. Language Understanding. Dialogue Systems.

6.4.6 Additions

Lexicology. Macro- and Micro-structure for dictionaries. Human and electronic dictionaries. Uses of dictionaries in NLP applications.

6.5 Summary

Course	ECTS	Obligatory?	LT M1	LT M2	LT M3	LT M4
Logics and Statistical Tools for Language Modeling	6	Yes	3	3		
NLP Applications	6	Yes			3	3
Tools and Algorithms for NLP	6	Yes	3	3		
Introduction to NLP - Morphology and Syntax	3	Yes		3		
Introduction to NLP - Semantics and Pragmatics	3	Yes			3	
Grammatical Formalisms	3	No		3		
Computational Semantics	3	No			3	
Discourse and Dialogue Representation	3	No			3	
Corpus Linguistics	3	No	3			
Generation	3	No				3
Phonetics	3	No	3			
Mining of Textual Domains	3	No				3
Normalization and Linguistic Resources	3	No				3
Lexicology	3	No				3
Total			12	12	12	15

6.6 Further Information

For more info see `http://tal.loria.fr`. Contact person: Patrick Blackburn. E-mail: `blackbur@loria.fr`

Chapter 7

University Nancy 2

7.1 Description of the Foundations of Language Technology Module

The **Foundations of Language Technology** module at *Nancy 2* is covered with the courses:

- Foundations in Linguistics [**6 ECTS of a total of 6 ECTS**]. Obligatory
- Logic and Statistic Tools for Language Modeling [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Tools and Algorithms for NLP [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Corpus Linguistics [**3 ECTS of a total of 3 ECTS**]. Optional
- Phonetics [**3 ECTS of a total of 3 ECTS**]. Optional

7.1.1 Statistical Methods

Logic and Statistic Tools for Language Modeling. Hidden Markov models, n-grams, perplexity, multi-grams.

7.1.2 Symbolic Methods

Tools and Algorithms for NLP. Finite state techniques. Feature Structures and Unification. Typed Lambda Calculus. Compositionality.

7.1.3 Cognition

Logic and Statistic Tools for Language Modeling. Reasoning Models. Inference.

7.1.4 Corpus Linguistics.

Corpus Linguistics. Techniques and resources for corpus construction. Annotation tools and schemes. Applications.

7.1.5 Text and Speech

Phonetics. Phonetics, phonology, prosody.

7.1.6 Foundations of Linguistics

Foundations in Linguistics. Basic concepts in Linguistics.

7.2 Description of the Computational Syntax and Morphology Module

The **Computational Syntax and Morphology** module at *Nancy 2* is covered with the courses:

- Logic and Statistic Tools for Language Modeling [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Tools and Algorithms for NLP [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Introduction to NLP – Morphology and Syntax [**3 ECTS of a total of 3 ECTS**]. Obligatory
- Grammatical Formalisms [**3 ECTS of a total of 3 ECTS**]. Optional

7.2.1 Finite State Techniques (FST)

Introduction to NLP – Morphology and Syntax. Finite state automata. Tagging.

7.2.2 Probabilistic Approaches

Tools and Algorithms for NLP. Tabulation methods. Polarities and saturation of structures. Syntactic analysis as constraint resolution.

Logic and Statistic Tools for Language Modeling. Hidden Markov models, n-grams, perplexity, multi-grams.

7.2.3 Formal Grammars

Grammatical Formalisms. Head-driven Phrase Structure Grammars. Lexical Functional Grammars. Categorial Grammars. Tree Adjoining Grammars. Metagrammars.

7.2.4 Parsing

Grammatical Formalisms. Parsing Algorithms

7.3 Description of the Computational Semantics, Pragmatics and Discourse Module

The **Computational Semantics, Pragmatics and Discourse** module at *Nancy 2* is covered with the courses:

- NLP Applications [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Introduction to NLP – Semantics and Pragmatics [**3 ECTS of a total of 3 ECTS**]. Obligatory
- Computational Semantics [**3 ECTS of a total of 3 ECTS**]. Optional
- Discourse and Dialogue Representation [**3 ECTS of a total of 3 ECTS**]. Optional

7.3.1 Syntax-Semantics Interface

Introduction to NLP – Semantics and Pragmatics. Semantic Representation.

Computational Semantics. Syntax-semantics interface.

7.3.2 Semantic Construction

Introduction to NLP – Semantics and Pragmatics. Lexical Semantics.

Computational Semantics. Montague Semantics. Compositionality.

7.3.3 Dialogue

NLP Applications. Dialogue systems.

Discourse and Dialogue Representation. Discourse and dialogue models. Anaphora and presupposition resolution. Treatment of the discourse and dialogue history. DRT.

7.4 Description of the LT Advanced Modules and Applications

The **LT Advanced Modules and Applications** at *Nancy 2* are covered with the courses:

- Linguistic Databases [**3 ECTS of a total of 6 ECTS**]. Obligatory.
- NLP Applications [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Generation [**3 ECTS of a total of 3 ECTS**]. Optional
- Mining of Textual Domains [**3 ECTS of a total of 3 ECTS**]. Optional

- Normalization and Linguistic Resources [**3 ECTS of a total of 3 ECTS**]. Optional
- Lexicology [**3 ECTS of a total of 3 ECTS**]. Optional

7.4.1 Information and Knowledge Representation

NLP Applications. Architectures and techniques for inference in NLP.

7.4.2 Information Retrieval (IR)

Mining of Textual Domains. Symbolic Classification. Numeric Classification. Rule extraction.

Normalization and Linguistic Resources. Introduction to existing lexical, syntactic and semantic resources. The problem of information exchange and information structuring. Marking languages. Normalization.

7.4.3 Question Answering (QA)

NLP Applications. Question answering.

7.4.4 Text and Speech Recognition and Generation

Generation. Basic architecture. Content planning. Micro-planning. Surface Realization.

7.4.5 Models of Human Language Processing and Understanding

NLP Applications. Speech Recognition. Language Understanding. Dialogue Systems.

7.4.6 Additions

Lexicology. Macro- and Micro-structure for dictionaries. Human and electronic dictionaries. Uses of dictionaries in NLP applications.

Linguistic Databases. Databases for linguistic applications. Corpus.

7.5 Summary

Course	**ECTS**	**Obligatory?**	**LT M1**	**LT M2**	**LT M3**	**LT M4**
Foundations in Linguistics	6	Yes	6			
Linguistic Databases[1]	6	Yes				3
Logics and Statistics Tools for Language Modeling	6	Yes	3	3		
NLP Applications	6	Yes			3	3
Tools and Algorithms for NLP	6	Yes	3	3		
Introduction to NLP - Morphology and Syntax	3	Yes		3		
Introduction to NLP - Semantics and Pragmatics	3	Yes			3	
Grammatical Formalisms	3	No		3		
Computational Semantics	3	No			3	
Discourse and Dialogue Representation	3	No			3	
Corpus Linguistics	3	No	3			
Generation	3	No				3
Phonetics	3	No	3			
Mining of Textual Domains	3	No				3
Normalization and Linguistic Resources	3	No				3
Lexicology	3	No				3
Total			18	12	12	15
Required			6	9	9	6

7.6 Further Information

For more info see `http://tal.loria.fr`. Contact person: Guy Perrier. E-mail: `perrier@loria.fr`

[1] Other 3 ECTS in CS M3.

Chapter 8

Charles University in Prague

8.1 Description of the Foundations of Language Technology Module

The **Foundations of Language Technology** module at the Charles University in is covered with courses on:

8.1.1 Statistical Methods

Statistical Methods in Natural Language Processing I Introduction to formal linguistics and the fundamentals of statistical natural language processing, including basics of Infromation Theory, Language MOdeling and Markov Models. [**6 ECTS**]

Statistical Methods in Natural Language Processing II Continuation of Statistical Methods in Natural Language Processing I. Introduces the notion of linguistic experiment and its evaluation. The role of corpora in statistical NLP. Standard NLP tasks (tagging, parsing) are explained and methods presented. Short introduction to Statistical Machine Translation. [**6 ECTS**]

8.1.2 Symbolic Methods

Syntax without transformations The course deals with language description tools and options of implementation offered by the theory of Head-Driven Phrase Structure Grammar, a non-transformational linguistic theory, describing linguistic phenomena declaratively, without transformations. Possibilities of the formalism will be illustrated by example solutions to some phenomena (valency, agreement, word order) and their comparison with solutions available in other theories. Interested students will be encouraged to implement and test a toy grammar in a grammar-writing environment. [**3 ECTS**]

Introductory Seminar of Mathematical Linguistics I What is mathematical linguistics; The foundations of the mathematical theory of languages: theory of formal languages

and automata; Immediate-constituent phrase-structure grammars; Introduction to transformational grammars; Introduction to automata theory; Dependency grammars, Categorial grammars; Structural complexity of natural languages from the Chomsky hierarchy perspective; Automatic morphological analysis and disambiguation of natural languages [**3 ECTS**]

Introductory Seminar of Mathematical Linguistics II The seminar follows up with the Introductory seminar of mathematical linguistics I. It deals with the following topics: morphological and syntactic analysis of natural languages; Functional generative description of language (FGD); main features of the formal description of sentence structure; introduction to unification-based formalisms and grammars; prominent grammatical theories of the description of natural language in the West; introduction to corpus linguistics. [**3 ECTS**]

8.1.3 Cognition

Linguistic Aspects of Artifical Intelligence Natural language as a means of human communication is a natural candidate as an input to man-machine communication systems, a basis for knowledge representation and also as an important evidence of an "intelligent" behaviour of dialogue systems. Different aspects of language modules will be discussed, as well as the most recent approaches, systems and trends in man-machine communication domain. [**3 ECTS**]

8.1.4 Corpus Linguistics

Corpus Linguistics I An introduction to the modern branch of computational linguistics which concerns itself with corpora of natural languages. In theory, the following topics are studied: the concept of a corpus; language corpus as a source of knowledge of language; modern computer technologies; corpus typology from various perspectives; representativeness of a text corpus (statistical methods of corpus processing, the text reception and production perspective); administrative markup of texts included in the corpus; structural markup and linguistic annotation of texts (tagging, lemmatization). [**3 ECTS**]

Corpus Linguistics II The seminar focuses on practical issues in corpus linguistics and follows up with the Corpus Linguistics I seminar. The following topics are discussed via essays and seminar papers: corpus design and build-up (methods of language material acquisition, conversion of language data to the unified SGML and XML format; annotation of texts included in the corpus; linguistic (morphological, syntactic, semantic) tagging of corpus texts, lemmatization; linguistic exploitation of corpus material; practical exploitation of the corpus, techniques for language data retrieval in the corpus. [**3 ECTS**]

Language Resources The goal of the seminar is to provide students with the survey of the field of Language Resources. Selected types of linguistic annotations will be described, with emphasis on annotating textual data (morphological categories, constituency and dependency syntactic trees, anaphora, discourse structure, word-sense disambiguation, parallel-text alignment etc.) and lexical data (wordnets, translation dictionaries, valency lexicons etc.). Leading projects for English, Czech, and some other languages will be used for illustration. [**3 ECTS**]

8.1.5 Text and Speech

Basics of speech processing This seminar deals with speech recognition tasks and feature extraction of voice and utterance characteristics. Of particular interest will be topics related to Hidden Markov Models as applied to speech (FFT, n-dimensional clustering, Gaussian mixtures, parameter value extraction from data, phonetic representation, prosodic analysis etc.). Preparation and training of own speech recognition models. [**3 ECTS**]

Text-to-Speech synthesis Speech and its automatic synthesis; writing systems, text analysis and processing; prosody modelling; selected TTS-related language-specific phenomena; approaches and algorithms used in TTS. No prerequisite knowledge assumed. [**3 ECTS**]

Automatic speech recognition Introduction to statistical methods of speech recognition (automatic transcription of speech) and understanding from the founder of the statistical methods in the field. Topics include elementary information theory, hidden Markov Models, efficient hypothesis search methods, statistical decision trees, the estimation-maximization (EM) algorithm, maximum entropy estimation, finite state transducers, context-free grammars, parsing, and the Baum, CYK, and Viterbi algorithms. [**6 ECTS**]

Digital signal processing, speech analysis and synthesis Introduction to the digital signal processing with the focus on speech processing, speech acoustics, speech analysis methods in time and frequency domains, speech coding, synthesis of the speech signal in time and frequency domains. [**3 ECTS**]

8.1.6 Foundations of Linguistics

Introduction to General Linguistics Introduction of the basic linguistic notions with regard to the history and methodology of linguistics. Structural linguistics, its sources and development. Phonology, morphology, lexicon, and syntax. Natural language as a kind of a semiotic system. [**3 ECTS**]

Seminar in General Linguistics Reading and analysis of selected classical structuralist works: F. de Saussure, S. Karcevskij, J. Kuryowicz, V. Mathesius, Vl. Skalicka, B. Trnka and others. [**2 ECTS**]

8.2 Description of the Computational Syntax and Morphology Module

The **Computational Syntax and Morphology** module at the Charles University is covered with courses on:

8.2.1 Finite State Techniques (FST)

Computational Processing of Natural Languages Basic methods and algorithms used for text processing and preprocessing from the point of view of natural language processing in general and Czech processing in particular; besides Czech, the second language of interest is English. The focus is on lower levels of processing but an introduction is given to the complex methods. Fundaments of the Perl language (for text processing). [**3 ECTS**]

8.2.2 Probabilistic Approaches

Statistical Methods in Natural Language Processing I Introduction to formal linguistics and the fundamentals of statistical natural language processing, including basics of Infromation Theory, Language MOdeling and Markov Models. [**6 ECTS**]

Statistical Methods in Natural Language Processing II Continuation of Statistical Methods in Natural Language Processing I. Introduces the notion of linguistic experiment and its evaluation. The role of corpora in statistical NLP. Standard NLP tasks (tagging, parsing) are explained and methods presented. Short introduction to Statistical Machine Translation. [**6 ECTS**]

8.2.3 Formal Grammars

Formal Description of Natural Language Explicit description of language: background, methods, advantages. Transformational generative grammar: its development from its beginnings (N. Chomsky) through the discussions between interpretative and generative semantics (McCawley, Ross, Lakoff) to the theory of government and binding and the minimalist approach. Case Theory (C. Fillmore) and the FrameNet project. Lexical Functional Grammar: grammar and lexicon. Functional Generative Grammar: dependency trees, valency, topic-focus articulation, discourse structure). Speech Act theory (J. Searle), Gricean conversational maxims, Relevance theory Meaning, presupposition and allegation. [**3 ECTS**]

Introductory Seminar of Mathematical Linguistics I What is mathematical linguistics; The foundations of the mathematical theory of languages: theory of formal languages and automata; Immediate-constituent phrase-structure grammars; Introduction to transformational grammars; Introduction to automata theory; Dependency grammars, Categorial grammars; Structural complexity of natural languages from the Chomsky hierarchy perspective; Automatic morphological analysis and disambiguation of natural languages [**3 ECTS**]

Introductory Seminar of Mathematical Linguistics II The seminar follows up with the Introductory seminar of mathematical linguistics I. It deals with the following topics: morphological and syntactic analysis of natural languages; Functional generative description of language (FGD); main features of the formal description of sentence structure; introduction to unification-based formalisms and grammars; prominent grammatical theories of the description of natural language in the West; introduction to corpus linguistics. [**3 ECTS**]

Syntax without transformations The course deals with language description tools and options of implementation offered by the theory of Head-Driven Phrase Structure Grammar, a non-transformational linguistic theory, describing linguistic phenomena declaratively, without transformations. Possibilities of the formalism will be illustrated by example solutions to some phenomena (valency, agreement, word order) and their comparison with solutions available in other theories. Interested students will be encouraged to implement and test a toy grammar in a grammar-writing environment. [**3 ECTS**]

8.2.4 Tagging

Computational Processing of Natural Languages Basic methods and algorithms used for text processing and preprocessing from the point of view of natural language processing in general and Czech processing in particular; besides Czech, the second language of interest is English. The focus is on lower levels of processing but an introduction is given to the complex methods. Fundaments of the Perl language (for text processing). [**3 ECTS**]

8.2.5 Parsing

Statistical Methods in Natural Language Processing II Continuation of Statistical Methods in Natural Language Processing I. Introduces the notion of linguistic experiment and its evaluation. The role of corpora in statistical NLP. Standard NLP tasks (tagging, parsing) are explained and methods presented. Short introduction to Statistical Machine Translation. [**6 ECTS**]

Syntactic parsing of Czech The main goal of this workshop is to provide the students with basic theoretical and practical knowledge of methods used for syntactic parsing of languages with a high degree of word-order freedom. The students have a chance to create a simple grammar covering certain interesting syntactic phenomena of Czech in one of the formalisms or languages available (PATR, Q-systems, Prolog, Lisp etc.) [**3 ECTS**]

8.3 Description of the Computational Semantics, Pragmatics and Discourse Module

The **Computational Semantics, Pragmatics and Discourse** module at the Charles University is covered with courses on:

8.3.1 Syntax-Semantics Interface

From linguistics to logic Formal semantics; history and current directions, fields of study, representative theories (overview). Introduction to alternative set theory. Introduction to Fuzy Logic. Logical inferences and their relation to natural language. Transparent Intensional Logic (TIL), its relation to natural language, constructions in TIL. Tripartite structures and their relation to Functional Generative Description of natural language. Hybrid modal logic. Dynamic representation theory (DRT). [**3 ECTS**]

8.3.2 Semantic Construction

Introduction to theoretical semantics The lecture focuses on theories of formal reconstruction of the semantics of natural language, especially those based on logic. The point of departure is the analysis of the principles and limitations of reconstructing semantics by means of the apparatus of classical (extensional) logic. This then leads to the presentation of the reconstruction by means of intensional logic, and then also by means of further, newer theories, such as the theory of structured meanings, situation semantics, Tich's theory of constructions, discourse representation theory and dynamic logic. [**3 ECTS**]

8.3.3 Dialogue

Linguistic Aspects of Artifical Intelligence Natural language as a means of human communication is a natural candidate as an input to man-machine communication systems, a basis for knowledge representation and also as an important evidence of an "intelligent" behaviour of dialogue systems. Different aspects of language modules will be discussed, as well as the most recent approaches, systems and trends in man-machine communication domain. [**3 ECTS**]

8.3.4 Formal Semantics

Computational Semantics First-order predicate logic and its extensions used for capturing natural language semantics (starting with English, presented methods to be applied to Czech). Topics: predicate logic, proofs, Prolog, lambda calculus, context-free grammars, Discourse Representation Theory, creation of "AI" in Prolog. [**3 ECTS**]

8.4 Description of the LT Advanced Modules and Applications

The **LT Advanced Modules and Applications** at the Charles University are covered with courses on:

8.4.1 Machine Translation (MT)

Tools for human aided machine translation The seminar provides an opportunity to get acquainted with basic tools and methods supporting the automatic translation between natural languages. A special attention is devoted to systems exploiting the concept of the translation memory (Trados, SDLX, IBM Translation Manager) and to MT systems developed at the Charles University (RUSLAN, eslko). [**3 ECTS**]

Statistical Methods in Natural Language Processing II Continuation of Statistical Methods in Natural Language Processing I. Introduces the notion of linguistic experiment and its evaluation. The role of corpora in statistical NLP. Standard NLP tasks (tagging, parsing) are explained and methods presented. Short introduction to Statistical Machine Translation. [**6 ECTS**]

8.4.2 Information and Knowledge Representation

Linguistic Aspects of Artifical Intelligence Natural language as a means of human communication is a natural candidate as an input to man-machine communication systems, a basis for knowledge representation and also as an important evidence of an "intelligent" behaviour of dialogue systems. Different aspects of language modules will be discussed, as well as the most recent approaches, systems and trends in man-machine communication domain. [**3 ECTS**]

8.4.3 Information Retrieval (IR)

Information Retrieval Seminar I The seminar concerns methods of information retrieval in full texts with special emphasise on procedures of natural language processing. In this course, the subject is studied from the theoretical point of view. In the spring term, students are expected to take the seminar Information Retrieval Seminar II. [**3 ECTS**]

Information Retrieval Seminar II The seminar concerns methods of information retrieval in full texts with special emphasis on procedures of natural language processing. In this course, students experimentally implement and test some of the new methods. [**3 ECTS**]

8.4.4 Speech Recognition and Generation

Basics of speech processing This seminar deals with speech recognition tasks and feature extraction of voice and utterance characteristics. Of particular interest will be topics related to Hidden Markov Models as applied to speech (FFT, n-dimensional clustering, Gaussian mixtures, parameter value extraction from data, phonetic representation, prosodic analysis etc.). Preparation and training of own speech recognition models. [**3 ECTS**]

Text-to-Speech synthesis Speech and its automatic synthesis; writing systems, text analysis and processing; prosody modelling; selected TTS-related language-specific phenomena; approaches and algorithms used in TTS. No prerequisite knowledge assumed. [**3 ECTS**]

Automatic speech recognition Introduction to statistical methods of speech recognition (automatic transcription of speech) and understanding from the founder of the statistical methods in the field. Topics include elementary information theory, hidden Markov Models, efficient hypothesis search methods, statistical decision trees, the estimation-maximization (EM) algorithm, maximum entropy estimation, finite state transducers, context-free grammars, parsing, and the Baum, CYK, and Viterbi algorithms. [**6 ECTS**]

Digital signal processing, speech analysis and synthesis Introduction to the digital signal processing with the focus on speech processing, speech acoustics, speech analysis methods in time and frequency domains, speech coding, synthesis of the speech signal in time and frequency domains. [**3 ECTS**]

8.4.5 Additions

Nonlinear systems and natural languages The main aim of this seminar is to allign together the newest progressive stochastic methods and natural language procesing, from the point of view of chaotic dynamical systems and dimensionality in general. The seminar includes a practical part as well. [**3 ECTS**]

Introduction to Machine Learning (in Computational Linguistics) This one-semester introductory course provides theoretical background of and key algorithms from the field of machine learning (ML) explained independently on a broad spectrum of multidisciplinary applications the ML takes place in. The seminars are application-dependent and they accompany the lecture sessions. The aim of the seminars is an acquisiton of practical experience from application of ML approaches on problems from natural language processing. [**6 ECTS**]

Selected Linguistics Problems I Seminar for students of informatics who are interested in natural language processing. The seminary is mainly focused on the syntax of Czech based on Functional Generative Description. [**3 ECTS**]

Selected Linguistics Problems II Continuation of the seminar Selected Linguistic Problems I. Accent is laid on other aspects of syntax of natural languages with free word order and on the possibility of their formal description. [**3 ECTS**]

For more info see
`http://www.mff.cuni.cz/toUTF8.en/vnitro/is/sis/predmety/garant.php?dat=UFAL`

Contact person: Vladislav Kubon

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Chapter 9

Saarland University (UdS)

9.1 Description of the Foundations of Language Technology Module

The **Foundations of Language Technology** module at UdS is covered with courses on:

9.1.1 Symbolic Methods

Syntactic Theory. Characteristic properties of different grammar models, Phrase Structure Grammars, Lexical Functional Grammar (LFG), Head-Driven Phrase Structure Grammar (HPSG), Categorial Grammar. [**6 ECTS**]

Semantic Theory. This course teaches the prevalent formalisms and methods in natural-language semantics and their applications in natural language understanding systems. The students acquire the background knowledge necessary for an understanding of the current literature, and are acquainted with phenomena and methods in the semantics of words, sentences and texts, together with their formal modelling, as well as with the modelling of the syntax semantics interface and the interface to logic-based inference systems. Topics of this course include: (a)Sentence semantics: Montague-style type-theoretical representations; semantics construction; scope ambiguities; underspecification. (b) Discourse semantics: Anaphora; discourse representation theory (DRT). (c) Lexical semantics: Events; thematic roles; frames; lexical resources. [**6 ECTS**]

9.1.2 Cognition

Computational Psycholinguistics. Computational psycholinguistics is concerned with the development of computational models of how people process natural language. Models are guided by the desire to explain the cognitive architectures and mechanisms that underlie language comprehension, as revealed by evidence from on-line psycholinguistic experiments. This course will begin with an introduction to the aims and central issues in psycholinguistic research, summarising the key empirical observations about human language understanding before considering a range of models which have been proposed. In examining a wide range of computational models

– symbolic, probabilistic, connectionist, and also 'hybrid' computational mechanisms – we consider both how well models explain human behaviour, as well as what they contribute to central theoretical debates concerning the nature of language acquisition and linguistic performance. [**6 ECTS**]

9.1.3 Text and Speech

Language Technology I. Information Management: Classification, IR, Summarisation, IE, Named-entity recognition, Language checking, Question Answering. [**6 ECTS**]

Language Technology II. The goal is to teach concepts and common technologies in the application areas of multilingual information management, machine translation and natural language interaction. Students learn exemplary approaches to building and evaluating such applications and acquire practical experience through designing, implementing and evaluating small systems. Topics covered in the course include concepts in machine translation, multilingual resources, multilingual language technology, computational dialogue modeling and dialogue management, issues in spoken and multimodal dialogue system development and natural language-based computer-assisted learning, user modeling, usability testing and evaluation. [**6 ECTS**]

Speech Science. This course gives an overview of and provides accompanying practical exercises in the three main areas of Speech Science: speech production, the acoustic structure of speech and speech-sound perception. The topics covered include the anatomy and physiology of speech-sound production; articulation and the symbolic representation of speech; theories of speech-production control; the source-filter model of speech production and the acoustic properties of sound classes; the ear and hearing physiology, theories of speech-sound and speech perception. [**6 ECTS**]

Speech Technology. Systems driven by speech technology consist of various components. On of the furthest developed is speech recognition which at its heart is a pattern recognition problem. In this course, we will cover the basic principles of pattern recognition and machine learning and see how they are applied to speech recognition. Specific topics are: classifiers, supervised Learning, unsupervised learning, Hidden Markov Models, Gaussian Mixture Models and Acoustic Modeling, classification and Regression Trees, adaptation, search. [**6 ECTS**]

9.1.4 Foundations of Linguistics

Foundations of Language Science and Technology. Map of Language Science and Technology, why is language/speech difficult and interesting, ambiguity, commication. inference, linguistic phenomena, levels, concepts, phonetics, prosody, morpholoy, syntax ... pragmatics, automata, morphology, CFGs, parsing, corpora and data-intensive linguistics, human parsing: memory limitation and attachment, differences between human and machine processing, logic, ontologies, wordnet, HMMs: grapheme-phoneme-convert, machine learning, spoken dialog systems. [**6 ECTS**]

Phonological Theory. This course provides an overview of and applicational practice in the main phonological theories of the 20th century. Apart from offering knowledge of these theories, one of the main goals is to place present-day approaches into a wider theoretical perspective and avoid a blinkered acceptance of any one school of thought. Topics covered will include Structuralist schools and theories of the Phoneme; feature specification and generative rules in linear generative phonology; the cyclical stress rule; the shift to non-linear phonology and the autosegmental-metrical approach with feature geometry and hierarchical segmental and prosodic representations; phonology and variation - from linear generative rules to Optimality Theory. [**6 ECTS**]

9.2 Description of the Computational Syntax and Morphology Module

The **Computational Syntax and Morphology** module at UdS is covered with courses on:

9.2.1 Probabilistic Approaches

Data-Oriented Parsing and Generation. Data-Oriented Parsing (DOP) models embody the assumption that humans produce and interpret natural language utterances by invoking representations of their concrete past language experience, rather than the rules of a consistent and non-redundance competence grammar. DOP models therefore maintain large corpora of sentences with syntactic structures. They analyze new input-sentences by combining partial structures from the corpus, and employ the occurrence frequencies of these structures to estimate which of the resulting analysis are the most probable one. During this seminar we will have a closer look to the computational and linguistic aspects of DOP. Recently, first Data-Oriented methods for natural language generation have been proposed, which we will discuss at the end of the seminar. [**9 ECTS**]

9.2.2 Formal Grammars

Covered by the course **Syntactic Theory**.

9.2.3 Parsing

Computational Linguistics. The goal of the course is to introduce the students to various standard algorithms in computational linguistics. The focus is on the structure of the algorithms, i.e. their data structures and mechanisms. The course discusses standard algorithms used for various types of linguistic processing in computational linguistics. The algorithms discussed in the course range from shallow methods such as pattern matching algorithms for strings and trees, and finite state methods; to machine learning and statistical techniques such as Hidden Markov Models and decision trees; to various algorithms used in deep linguistic processing. Examples of the latter are memorization techniques, unification, graph algorithms, and inferencing with

ontologies. The algorithms are illustrated with practical applications from computational linguistics. The students will gain hands-on experience with the algorithms either through using existing implementations or by having to implement provided exercises. [**9 ECTS**]

9.3 Description of the Computational Semantics, Pragmatics and Discourse Module

The **Computational Semantics, Pragmatics and Discourse** module at UdS is covered with courses on:

9.3.1 Syntax-Semantics Interface

Morphosyntax-Semantics Interface in Lexicalist Theories. In recent years, there has been an increasing interest in the interface between (morpho-)syntax and word meaning. One of the main reasons for that is that generalizations over word classes have been proven to help linguistic theories - especially the ones developed in the generative tradition - overcome the natural limitations of syntax. In lexicalist theories like Lexical-Functional Grammar (LFG) and Head-Driven Phrase Structure Grammar (HPSG), where the structure of the lexical knowledge plays a central role in the theory, the interest in the interaction between (morpho-)syntax and word meaning has led to the development of linking models like the Lexical Mapping Theory (LMT), the "Optimal Linking" Theory of Butt, Dalrymple and Frank (1997) and the Hierarchical Lexicon models. But although these linking models have as a common starting point the recognition of the importance of word classes for the interface between semantics and syntax, they vary both ontologically and in the range of linguistic phenomena they attempt to explain. The aim of this course is to present and explore approaches on formal, empirical and computational issues related to the Morphosyntax-Semantics Interface in lexicalist theories (mainly LFG and HPSG). It also intends to address inter-framework discussions, since it focuses on both LFG and HPSG. [**9 ECTS**]

9.3.2 Semantic Construction

Covered by the course **Semantic Theory**.

9.3.3 Dialogue

Modeling Grounding Subdialogues in an ISU-Based System. The goal is to gain theoretical knowledge and practical experience in developing dialog systems in the Information-State Update (ISU) framework, with focus on various grounding strategies. Grounding subdialogs, e.g., various degrees of explicit/implicit feedback, verification, clarification or correction, are needed in any dialog system. We will first introduce ISU-based dialog modelling. Then the students will present papers addressing various grounding issues and (optionally) implement ISU-based dialog models. The seminar is related to two research projects at CoLi, DIALOG (tutorial dialogue in mathematics) and TALK (generic methods for flexible, adaptive, multimodal dialogue, with in-car and in-house application scenarios). [**9 ECTS**]

9.3.4 Formal Semantics

Covered by the course **Semantic Theory**.

9.4 Description of the LT Advanced Modules and Applications

The **LT Advanced Modules and Applications** at UdS are covered with courses on:

9.4.1 Machine Translation (MT)

Human and Machine Translation. Examination of the process of translation as done by professional and amateur translators, and existing and proposed machine-translation systems, illuminating what each might learn from the others. [**3 ECTS**]

Empirical Approaches to Machine Translation. This course will focus on the empirical evaluation of recent developments in statistical machine translation (SMT). After the presentation of some essential mathematical background, participants will learn to use open-source software and parallel corpora to build statistical, phrase-based translation models for language pairs of their choice. Available languages include the 11 "old" official EU languages, Chinese, Arabic, Japanese, Inuktitut, and many more languages used in the OPUS project. The quality of the resulting translation systems will be evaluated both by automatic comparison (BLEU score) to reference translations and by inspection and linguistic classification of the errors they make. If applicable, comparative evaluations with commercial or web-based MT systems will also be conducted. [**3 ECTS**]

9.4.2 Information and Knowledge Representation

Language Technology for the Semantic Web: Knowledge Markup and Ontology Learnin.g Establishing the Semantic Web on a large scale implies widespread automatic annotation of web documents with ontology-based semantic metadata (knowledge markup) and dynamic adaptation of corresponding ontologies to evolving applications and domains (ontology learning). Language technology tools will be needed to support this process by providing an automatic analysis of the semantic structure of textual documents. In this way, free text documents will become available as semi-structured documents, from which meaningful units can be extracted automatically (information extraction) and organized through clustering or classification (text mining). The course focuses on the definition and implementation of one or more applications of language technology for the Semantic Web, e.g. ontology-based semantic tagging and information extraction; text mining for ontology development. [**8 ECTS**]

9.4.3 Question Answering (QA)

Question Answering. Question Answering (QA) systems search for answers to a natural language-question a user has asked in a given document collection. The aim of this course

is to improve the already existing QA system QuALiM ("Question Answering with Linguistic Methods"), with which we participated in TREC 2004 and plan to participate in TREC 2005. [**8 ECTS**]

9.4.4 Speech Recognition and Generation

Spoken Language Systems. This course discusses various components of spoken language systems on top of speech recognition. Those components are needed to make complete systems. A particular focus will be language modeling. Specific topics are: Basics in Information Theory, Language Models, Backing-Off, Smoothing, Maximum-Entropy, Speech Understanding, Topics in Spoken Dialogue Systems, Speaker Recognition and Verification. [**6 ECTS**]

Digital Signal Processing. Signal processing is required in various disciplines, speech technology and science among them. On the one hand side hardware and implementation issues will be covered in this course. On the other hand algorithms that extract the essential information of a signal will be considered. Specific topics are: Digital Signal Processors, Real Time Programming, Microcontrollers, Feature Extraction and Feature Transforms, Noise Suppression and Filtering, Wavelets. [**5 ECTS**]

9.4.5 Psycholinguistics

Experimental Methods in Psycholinguistics: Speech comprehension and production. The goal of this course is to enable students to critically evaluate experimental studies in the literature and, more centrally, to run well designed experiments of their own. This seminar will focus on the fundamental concepts and skills necessary to psycholinguistic experimentation, including design, assembly, data collection, analysis and interpretation of results. Following an introduction to various experimental tasks and issues of design and analysis, students are required to conduct an experiment of their own, assembling the materials, collecting and analyzing the data, and finally presenting the results to the class. [**6 ECTS**]

9.4.6 Additions

Introduction to Grammar Engineering using HPSG. The implementation of linguistically-based grammars for natural languages draws on a combination of engineering skills, sound grammatical theory, and software development tools. This course provides a hands-on introduction to the techniques and tools needed for building the precise, extensible grammars required both in research and in applications. Through a combination of lectures and in-class exercises, students will investigate the implementation of constraints in morphology, syntax, and semantics, working within the unification-based lexicalist framework of Head-driven Phrase Structure Grammar. Topics to be addressed in the course include: the use of types and features, lexical rules, constructions, semantic composition, and reversibility of grammars for parsing and generation. The weekly implementation exercises are conducted on the open-source LKB grammar development platform, and will be the basis for evaluation in the course. [**3 ECTS**]

For more info see `http://www.coli.uni-saarland.de/msc/lct/`

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Chapter 10

Utrecht University

10.1 Description of the Foundations of Language Technology Module

The **Foundations of Language Technology** module at *Utrecht University* is covered with courses on:

- Foundations of Language and Speech Technology (subjects covered include: statistical methods versus symbolic methods, Corpus Linguistics, Text to Speech systems) [**4 out of 7.5 ECTS**]
- Foundations of Linguistics (participants acquire an understanding of the grammatical/computational system, as well as its interfaces with the conceptual system and processing systems, and its embedding in human cognition) [**7.5 ECTS**]
- Research Seminar (subjects covered include: Human cognition, issues in acquisition and knowledge representation) [**7.5 ECTS**]

Foundations of Language and Speech Technology Computational linguistics can be studied from a theoretical and from an applied perspective. On the theoretical level, the goal is to model the linguistic knowledge and abilities that enable us to produce and understand language, in its primary spoken manifestation, and in its written forms. On the applied level, we study computer programs that embody aspects of our human linguistic abilitities. Software products with a language component are rapidly becoming standard commodities in our everyday life.

The purpose of this course is to give a broad overview of the methods and techniques that are currently used in language and speech technology, and to offer the participants hands-on experience with these techniques in the context of existing language engineering environments.

The course covers the full linguistic spectrum, from sound to meaning and reasoning.

At one end of the spectrum, knowledge of speech acoustics, and models of speech production, is required for the design of speech synthesis systems. We present model-driven systems, discuss systems using diphone building blocks, and look into the limitations of methods for speech unit selection. Successful systems are based on statistical methods and the use of large (speech) corpora. Key technology is Hidden Markov Modelling, first used in speech recognition systems,

but later applied to other application areas in linguistics. The course presents the foundations of HMM technology. For hands-on experience we use the Hidden Markov Toolkit, and apply this to the Corpus Spoken Dutch, a 10 million word corpus of natural, spoken language.

At the other end of the spectrum, we study computational methods for language processing at different levels of analysis. Topics covered include finite state techniques, part-of-speech tagging and supertagging, shallow and deep parsing, up to the assembly of full meaning representations, and reasoning with them. A fundamental problem in computational semantics is the pervasive ambiguity of natural language. We discuss techniques of underspecification to deal with this problem in an efficient way. [**7.5 ECTS**]

Foundations of Linguistics Participants acquire an understanding of the various modules of the grammatical system and theta theory and the way they interrelate, more in-depth on A-bar movement, basics of LF and relations between syntax and processing (Pritchett). It will stimulate active ability in syntactic argumentations. Issues dealt with include: Syntactic processing (The garden path phenomenon: parsing theories before Pritchett; Pritchett: theta-attachment, TRC, OLLC.); A vs. a-bar movement (Islands (Ross), Subjacency, CED (Huang), Conditions on movement); LF: quantifier raising, unselective binding: indefinites, wh-phrases vs. adverbial wh, Multiple wh-questions, Superiority (the attract account) [**7.5 ECTS**]

Research seminar The goal of this seminar is to stimulate the participating students to enhance and integrate insights from different fields in linguistics

This weekly seminar is intended to provide a common background for all students on each of the subdisciplines that students may choose as MaS. It will include suitable presentations from research seminars that take place at UiL OTS (e.g. the Trans seminar on Syntax and Semantics (TSSS), the Experimental Linguistics meetings (ELITU), the Computational Linguistics meetings), lectures from workshops and conferences and individual presentations by researchers of UiL OTS (by PhD students, postdoc's and staff). In many cases, the actual presentations will be preceded by a special introduction provided for the students by either the speaker or a staff member, so as to make sure the intention of providing common ground does not get lost in the details of the immediate research question at hand. For full credit students are required to attend at least 24 such sessions. [**7.5 ECTS**]

10.2 Description of the Computational Syntax and Morphology Module

The **Computational Syntax and Morphology** module at *Utrecht University* is covered with courses on:

- Foundations of Language and Speech Technology (subjects covered include: Finite State Techniques, Part-of-speech tagging) [**3.5 out of 7.5 ECTS**]
- Logic-based approaches in Natural Language Processing (Formal grammars, type logic, proof nets, natural language processing) [**3.5 out of 7.5 ECTS**]

Foundations of Language and Speech Technology See above. [**7.5 ECTS**]

Logic-based approaches in Natural Language Processing Computational grammar formalisms for the analysis of syntax and semantics can be modelled as specialized logics. This deductive perspective makes it possible to import powerful methods from algorithmic proof theory into the study of parsing and natural language processing.

The course has three parts.

We first present deductive parsing for context-free grammars and their generalizations, and discuss the proof search procedures that correspond to the familiar parsing algorithms (top-down recursive descent, bottom-up shift reduce and mixed Earley-style parsing).

In the second part of the course, we study type-logical grammars and related formalisms (e.g. pregroup grammars, deductive minimalism). In type-logical grammar, categories themselves are modelled as logical formulas. This makes it possible to eliminate rewriting rules, and formulate deduction directly in terms of the connectives that build complex categories. Algorithmic proof theory for these formalisms makes use of proof nets, a kind of connection graphs capturing the resource-sensitivity of grammatical deduction. Proof nets form a natural interface to the Curry-Howard view on meaning assembly familiar from functional programming.

In the third part of the course, we analyse performance aspects of human language processing in terms of proof search strategies. We show that proof nets faithfully reflect the finite computational resources of the human processor, and we analyse the preferences of the processor in terms of proof search strategies. [**7.5 ECTS**]

10.3 Description of the Computational Semantics, Pragmatics and Discourse Module

The **Computational Semantics, Pragmatics and Discourse** module at *Utrecht University* is covered with courses on:

- Generalized quantifiers (formal semantics) [**7.5 ECTS**]
- Logical Form (syntax-semantics interface) [**7.5 ECTS**]
- Logic-based approaches in Natural Language Processing (semantic construction) [**4 out of 7.5 ECTS**]
- Dynamic Semantics (formal semantics, semantic construction) [**7.5 ECTS**]
- Semantic web (explicit semantic connections, ontology, data bases, efficient searching) [**7.5 ECTS**]
- Conceptual semantics (formal semantics: meanings as relations involving expressions of language, objects in the world, and the mental states of speaker/hearer) [**7.5 ECTS**]

Generalized quantifiers This course gives an introduction to the theory of Generalized Quantifiers and related areas. The theory came out of the work of Richard Montague and was later developed into a general semantic theory of quantifiers like every, some, most. The course has three parts. We will first study the principles of the theory, primarily from Gamut 2, par. 7.2. In the second stage we will read articles that elaborate on some theoretical and empirical aspects (like the behaviour of negative polarity items like in Nobody lifted a finger). Then we are going to look into semantic studies of nominal, temporal and spatial expressions that attempt, like the theory of Generalized Quantifiers, to formulate general algebraic properties of denotations. [**7.5 ECTS**]

Logical form In this course, we look at semantic motivation for representations at the level of Logical Form (LF). Issues addressed are pronouns as bound variables, scope ambiguities, interaction between quantifiers and question words. [**7.5 ECTS**]

Logic-based approaches in Natural Language Processing See above. [**7.5 ECTS**]

Dynamic Semantics In the first half of the course, we treat the classical systems of dynamic semantics Dynamic Predicate Logic (DPL) and Discourse Representation Theory (DRT). The exposition covers linguistic data, philosophical considerations and logico-technical details. In the second half we present an algebraic treatment of presupposition, mainly for the case of propositional logic. This part includes a brief introduction to Boole algebras. [**7.5 ECTS**]

Conceptual semantics People hold different views on the relation between language, states of mind and the outside world. A conceptual approach to meaning claims that words primarily stand for ideas (concepts, images, thoughts, ...). This is an attractive view, for nobody will deny that we have mental representations and concepts, and that we reason with them. Language is in the brain, and for that reason linguistics is a branch of cognitive science, on a par with psychology and neuroscience. But it is not easy to build a psychologically realistic theory of meaning. One of the problems for the conceptual approach is that it does not give us a clear view of the relation between words, concepts and the outside world. People have a quite solid intuition about that relation, and this intuition of the external relevance of natural language is something we want a semantic theory to capture. Researchers who take the aboutness of language as a core property have developed so-called referential approaches to meaning. Note that there is no implication that the representations in a referential theory of meaning as such have psychological import. Ideally, we would want to build a theory which combines insights from both the conceptual and the referential theory and analyzes meanings as relations involving three things: expressions of language, objects in the world, and mental states of the speaker and hearer.

In view of the above, it is currently virtually impossible to develop a linguistic theory of lexical semantics without also incorporating insights from related disciplines such as psychology, cognitive science, logic, philosophy of language, etc. Correspondingly, the present course will focus on a critical analysis of various theories of meaning, in which representatives of the so-called componential analysis, also known as the classical theory, will be studied, as well as representatives of what is known as prototype theory, an approach that has emanated from the field of language psychology.

Along the way, a picture is likely to emerge of a struggle between two competing theories. However, there have also been attempts to view the classical theory as a theory of discrete symbolic information which is essential for the language system, whereas prototype theory is taken to be about what has become known as subsymbolic informatiotion. The mental lexicon can be seen as the locus where both types of information are (or must be) integrated. [**7.5 ECTS**]

10.4 Description of the LT Advanced Modules and Applications

The **LT Advanced Modules and Applications** at *Utrecht University* are covered with courses on:

- Data bases and Language typology [**7.5 ECTS**]
- Language and Speech resources [**7.5 ECTS**]
- Neurocognition of Language I and II [**15 ECTS**]
- Speech perception and Psychophysics [**7.5 ECTS**]
- Semantic Structures [**7.5 EC**]
- Evaluation of Language and Speech Technology systems [**7.5 EC**]

Data bases and Language typology Students are introduced to the aims, core concepts and methodology of typological research, and examine in some detail a number of non-Western languages. They gain hands-on experience in the use of descriptive grammars and native speakers of unfamiliar languages, and in the theory and practice of using databases for language typology.The course consists of a component on typological theory, and a component on linguistic databases. Students must pass both components.

Language typology is the systematic study of the similarities and differences between the world's more than 5000 natural languages. It searches for universal properties or systematic patterns of variation in morphological, syntactic or syntactic aspects of languages, and to classify variation along genetic, areal or structural lines. Because of the methodological emphasis on broad cross-linguistic patterns, typologists rely on electronic databases to manage, structure, and examine their data. The course includes an introduction to the theory and practice of designing a database, with emphasis on typological databases. [**7.5 ECTS**]

Language and Speech Resources Aim of the course is to provide an introduction to repositories of linguistic data, by focussing on two of them: annotated corpora (i.e., written and spoken) and linguistic databases.

Corpora represent a collection of texts which are usually annotated with part of speech and morphological information. They often encode syntactic and phonological information. Linguistic databases are usually oriented towards the description of specific phenomena either by means of examples with glosses or by means of variables.

Particular attention will be dedicated to the techniques and to the standards which should be adopted in order to develop them. In addition, issues concerning the archiving of linguistic resources on the web, including metadata standards (serving as finding aids) will be addressed and current initiatives will be presented. Furthermore, issues related to the digital encoding of language data will be discussed including standards such as SGML and XML.

The course will also focus on possible uses of these two resources among which: linguistic research, development of new human language technologies and as teaching aids. [**7.5 ECTS**]

Neurocognition of language I, II PART ONE Acquiring in-depth knowledge of (1) state of the art in the study of the linguistic system; (2) acquiring insight in the significance of results of linguistic theory for neurocognive research.

This course deals with natural language grammar as a computational system defining a mapping between form and interpretation. Special attention will be given to providing insight in the type of computations the brain must be able to carry out in order to be able to process natural language. We will study and critically discuss recent research literature addressing the question of how the components of this system can be characterized and how they interact. Specific topics will include: basic operations of the syntactic system, economy conditions, approaches to island phenomena, interpretive dependencies, the relation between the conceptual and lexical systems, memory systems, language, impairments, processing.

PART TWO Acquiring in-depth knowledge of (1) state of the art in the study of brain-language relations; (2) acuiring insight in how linguistic theory can be applied to neurocognive research.

This course deals with language processing (i.e., perception and production) from a neurocognitive perspective. We will study and critically discuss recent research literature addressing the question of how the brain implements language. Studies of intact as well as brain/language-impaired persons will be scrutinized. In doing so, we will acquire insight in how (psycho)linguistic theory can be a tool in neurocognitive research, and how neurocognitive insights can constrain linguistic theory. Specific topics will include: sentence processing, the autonomy of syntax, semantic processing, interactions between parsing and discourse interpretation, modularity in language production, agrammatism, the debate between 'loss of knowledge' and 'processing resources' views of language impairment, similarities and differences between language breakdown and language acquisition. [**15 ECTS**]

Speech perception and Psychophysics An insight into the basic properties of human hearing (psychoacoustics), into the processes involved in speech perception, and into the relationships between the two.

Every sound we perceive reaches our brain via our hearing organs, where it is processed in a number of different ways. A fair amount is known about these auditory (psychoacoustic) processes, at least with respect to simple laboratory signals; a good survey is provided in Brian Moore's book, which serves as the basis of this course. A great deal less is known about the processing of more complex signals, let alone about the relevance of it all for the perception of speech, even though speech is the signal that our hearing has to deal with most of the time. It is the aim of this course to explore the links between the functionality of human hearing and the perception of speech. There are a number of more or less explicit theories about speech perception, none of which have so far been definitely rejected. What characterizes most theories

is that they take a clear position with respect to the psychophysics of hearing: some claim that speech perception cannot usefully be studied independently from pschychoacoustics, but others assert that knowledge of human hearing contributes nothing of value to knowledge of speech perception. [**7.5 ECTS**]

Semantic Structures This research seminar offers an orientation on the field of semantics, an interdisciplinary collaboration of logicians and linguists who investigate aspecs of meaning in natural language. The purpose of this course is to become familiar with semantic methods by closely reading and discussing a selection of articles, and working on specific research questions. This year's theme is Optimality theoretic semantics, a recent development in linguistic theory that grew out of connectionist theories of cognition and neutral networks. [**7.5 ECTS**]

Evaluation of Language and Speech Technology systems In this course, several systems that use language and speech technology will be introduced. We will have a look at multimodal dialogue systems for information retrieval, speech synthesis systems, systems for audio look-up, and machine translation systems. We will analyse several of these systems from the view point of the user. For this, we need to discuss and understand the methodological basis of such assessments. Based on our observations, we will identify the system's weak points and will learn in what direction solutions should be found. In addition, students will develop themselves a simple spoken dialogue system, in which attention needs to be given to speech synthesis, linguistic analysis, speech recognition, dialogue structure, error repair, and so on. The focus of the course is on high level understanding of processes, while detailed technologies will be presented in the subsequent course on Fundamentals of Language and Speech Technology. [**7.5 ECTS**]

For more info see:

CAI Master: `http://www.phil.uu.nl/en/education/students/CAI/`;
Linguistics Master: `http://www-uilots.let.uu.nl/MA_PhD_Prog/MA_Program/MA.htm`

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Part II

Computer Science Modules

Chapter 11

University of Amsterdam (UvA)

The indicated modules are classified as A, B, C. A means that the module is suitable as a first course in the area (though it may still require basic computational and mathematical skills), B means that it is a second course in the area and C that it is advanced.

11.1 Description of the Logic, Computability and Complexity Module

The **Logic, Computability and Complexity** module at *the University of Amsterdam* is covered with courses on:

Basic Logic, Core Logic, Model Theory, Introduction to Modal Logic, Advanced Modal Logic, Information Theory, Game Theory for Information Sciences.

11.1.1 Logic and Inference

Basic Logic: basic knowledge of syntax and semantics of propositional and first order logic. Use of proof systems. Acquaintance with completeness proof of first order logic. [**3 ECTS, level A**]

Core Logic: The first part of the course will cover the history of logic from Aristotle to the nineteenth century. In the second part, we will cover important areas of modern logic, in particular applications of modal logic, and logical methods in linguistics, philosophy and mathematics. [**6 ECTS, level B**]

Model Theory: The basics of model theory (definitions, products etc.). Quantifier elimination. Algebraic notions in Model Theory: isomorphisms, automorphisms. Elementary equivalence. Applications of Compactness of first order logic (nonstandard models). Ultrafilters, ultraproducts, ultrapowers. Omitting types. Other topics (if time permits). [**6 ECTS, level B**]

Introduction to Modal Logic and **Advanced Modal Logic**: Overview of the most important methods and techniques in modal logic. Modal languages are often used as simple but flexible

languages for the description of relational structures. Thus modal logic finds application in various areas like computer science, mathematics, linguistics and economy. Notwithstanding this enormous diversity in occurrence and application we can still speak about 'modal logic' as such owing to the unifying force of the theory of modal logic. This course builds on the 'introduction to modal logic' course of the first trimester. It will address a number of questions regarding expressivity, decidability, complexity and algebraic aspects. [**3 ECTS, level B**] and [**6 ECTS, level C**] respectively.

11.1.2 Computability Theory

Information Theory: Information is a core concept in computer science, Information technology, but also in sciences like physics, mathematics and logic. The mathematical theory for this concept was developed around 1950, starting with the work by Shannon. The theory is related to probability theory but has a quite distinct flavour. The course covers topics like entropy, data compression, channel capacity, and Kolmogorov Complexity. [**6 ECTS, level A**]

11.1.3 Complexity Theory

Game Theory for Information Sciences: Over the course of a single decade Games have been transformed from a subject studied in recreational Mathematics, a specialism in Economics and a feircely competetive but taken to be less serious field in artificial Intelligence into a well respected fundable branch in computer science and information technology. At the same time an earlier research program on the relation between logic and computer science has been resumed with new endeavour and substantial emphasis. The course contents covers two aspects of this connection between Games theory and computer science. In the first place the course offers a basic introduction in game theory as developed since 1945 primarily within Economy. In the second place the course shows the use of game based models in computer science, in particular in computation and complexity theory. [**6 ECTS, level B**]

11.2 Description of the Formal Languages and Algorithms Module

The **Formal Languages and Algorithms** module at *the Unversity of Amsterdam* is covered with courses on:

Constraint programming, Automated Learning and Adaptive Knowledge Systems, Language Learning, Probabilistic Grammars.

11.2.1 Search Techniques and Constraint Resolution

Constraint programming : Constraint programming is an alternative approach to computing in which the programming process is limited to a generation of requirements (constraints) and to solving them by general methods and domain dependent methods. The aim of this course is to discuss the basic aspects of constraint programming. Students will learn problem modeling

by means of constraints and the main techniques used to solve such systems of constraints. The course will focus on the fundamental notions of constraint satisfaction problems, local consistency, constraint propagation, complete and incomplete constraint solvers, and various search methods. To illustrate these principles, the constraint programming language Eclipse will be used. [**6 ECTS, level B**]

11.2.2 Automated Learning

Automated Learning and Adaptive Knowledge Systems: This course expands the course Leren in the Bachelors programme with additional topics from Machine Learning: genetic algorithms, inductive logic programming/relational learning, knowledge-intensive learning clustering, boosting. Applications of Machine Learning for Data Mining and Adaptive Interactive systems will be discussed. Special attention will be given to Machine Learning in the context of text (text mining) and adaptive interactive systems. [**6 ECTS, level B**]

Language Learning: The course will focus on questions concerning mathematical models of the learning capacity of human beings. The central problem is how people exchange information in a dialogue. This leads to the study of syntactical and semantical learning algorithms. There are various approaches in this area. Historically, the influence of Gold's paradigm, identification in the limit has been very strong. Yet this approach is of limited value, because it leads to negative results and gives us very little clue as to the implementation of language learning algorithms that work in practice. We will present another approach based on categorial grammars, PAC-learning and Kolmogorov complexity. In this context we will introduce the concept of shallowness and will show that under very reasonable circumstances context-free grammars can be learned from text alone. We will explore the possibilities to extend this theory to a general theory of learnable structures. [**6 ECTS, level A**]

11.2.3 Probabilistic Grammars

Probabilistic Grammars: The goals of the course are: (1) Understanding the mathematical and linguistic ideas behind the use of probabilities and statistics in Natural Language Processing, especially parsing; (2) Understanding the probabilistic/statistical view on learning, its properties and algorithms; (3) Understanding the computational properties of the most important algorithms in this approach.

Probabilistic grammars start where formal language theory stops. Ambiguity resolution, robustness, efficiency, learning/adaption and estimation from data is the starting point for probabilistic grammars. The subject matter for these mathematical models is Natural Language Processing (as oppose to Formal Language Processing - e.g. compilation). The course concentrates on syntactic parsing with ambiguity resolution as the core subject for probabilistic grammars. We will look mainly at the following subjects for Probabilistic Context-Free Grammars (PCFGs): Mathematical aspects of probabilistic grammars, Estimation Theory for supervised and unsupervised learning, Algorithms for estimation of PCFGs, Efficient parsing under PCFGs. Then we will consider aspects of Data Oriented Parsing and how it resembles/deviates from PCFGs: parameter estimation, efficiency and linguistic issues. [**10 ECTS, level B**]

11.3 Description of the Data Structures, Data Organisation and Processing Module

The **Data Structures, Data Organisation and Processing** module at *the University of Amsterdam* is covered with courses on:

Advanced Database Techniques, Internet Information, Multimedia Information Retrieval, Design and Organisation of Autonomous Systems, Knowledge Communication.

11.3.1 Semi-Structured Data and XML

Advanced Database Techniques: In this course, we study developments to enhance traditional relational database technology to provide data management for non-administrative applications.Topics included are XML and Xquery for web-based applications; temporal models to support applications involving time; spatial extensions to support e.g. Geographical information systems; association rule discover over databases to support data mining; and support for querying streaming data such as they appear in sensor networks. [**6 ECTS, level B**]

11.3.2 Information Retrieval (IR)

Internet Information: Ever wondered how internet search engines work? Or why you never find what you're looking for? It turns out that many of the fundamental ideas underlying internet search engines go back to algorithms developed in the 1950s. In Information Retrieval we study techniques to locate information in large collections of information, that may contain both structured data (e.g., name, address, telephone number) and unstructured data (e.g., text, images, sounds). These techniques are being evaluated on annual basis as part of a number of international retrieval events. This year, the Internet Information course consists of the following components:

(i) A textbook part, in which we study basis techniques and methods from information retrieval, and in which we put these to work in the setting of web retrieval. (ii) A part in which we discuss recent research in a small number of subareas of web retrieval, including XML retrieval and open domain question answering systems. (iii) A number of practical assignments resulting in the implementation of web retrieval systems and/or extensions. [**10 ECTS, level A**]

Multimedia Information Retrieval: With the growth of the Internet and developments in imaging technology, very large digital image and video archives have been created and used in numerous applications. Together with the increase in the number of pictorial archives, demands are also growing for methodologies and techniques to store and retrieve pictorial entities from large image archives. In this course a broad range of techniques are studied to access multimedia information including multimedia features (synonyms for text, color and shape invariants for images), multimedia information space modeling (logic model, vector space model, statistical model), indexing (kd-trees, inverted file), learning and classification (nearest neighbor, neural network), user interaction (active learning), visualization and presentation techniques. [**6 ECTS, level B**]

11.3.3 Autonomous Systems

Design and Organisation of Autonomous Systems: The goal of the course is understanding of design and organization of autonomous systems.

This course will focus on the integration aspects when dealing with autonomous systems. Topics which will be presented are: architectures for autonomous systems, models for hiearchical decomposition, internal representations and models, sensor data fusion, reactive behaviour, coolaborating agents. [**6 ECTS, level A**]

11.3.4 Knowledge Systems

Knowledge Communication: Knowledge of the most important theoretical concepts concerning knowledge communication, as well as of the specific research questions relevant to this area of research within Artificial Intelligence (AI). Skills in designing and implementing such systems with a team of fellow students.

This course discusses the notion of knowledge communication between intelligent agents (such as humans) and how that ability can be automated using computers. Traditionally the internal organisation of a knowledge system is highly determined by the intended use of the system. To overcome this limitation knowledge systems should be augmented with means that allow them to autonomously determine what and how (and possibly with whom) to communicate. Important applications of knowledge communication systems are Intelligent Tutoring Systems and Interactive Learning Environments. These educational systems are therefore mostly used as examples during the course. [**6 ECTS, level A**]

11.4 Description of the CS Advanced Modules and Applications

The **CS Advanced Modules and Applications** at *the University of Amsterdam* are covered with courses on:

Automated Reasoning, Multi-agent Sytems and Distributed AI, Neural Nets and Symbolic Reasoning, Machine Learning - Pattern Recognition, Automated Learning and Adaptive Knowledge Systems, Multimedia Content Analysis.

11.4.1 Automated Reasoning

Automated Reasoning: The course begins with an introduction to automated reasoning and the various goals and methods in the area; examples: program verification, model checking, natural language retrieval, knowledge representation, planning, mathematics. After this a treatment follows of the most important reasoning tasks, such as satisfiability in propositional logic and theorem proving in first order logic. We examine resolution, tableaux, unification, and normal forms, with extensions and refinements; reasoning with identity; theorem proving in other logics, such as modal logic and higher order logic. In addition other reasoning tasks and automatizing

them are discussed, such as interactive theorem proving, inductive theorem proving en model checking. [**6 ECTS, level A**]

11.4.2 Intelligent and Multi-Modal Interfaces

Multi-agent Sytems and Distributed AI: The concept of "intelligent agent" is fundamental in Artificial Intelligence, meaning anything that can perceive the environment and act upon it in order to achieve some goal. In "distributed AI" the focus is no longer on single agents but on "multiagent". [**6 ECTS, level B**]

11.4.3 Neural Networks

Neural Nets and Symbolic Reasoning: Parallel distributed processing is transforming the field of cognitive science. In this course, basic insides of connectionism (neural networks) and classical cognitivism (symbol manipulation) are compared, both from a practical perspective and from the point of view of modern philosophy of mind. Discussing the proper treatment of connectionism, the course debates common misunderstandings, and it claims that the controversy between connectionism and symbolism can be resolved by a unified theory of cognition; one that assigns the proper roles to symbolic computation and numerical neural computation. [**6 ECTS, level A**]

11.4.4 Machine Learning

Machine Learning - Pattern Recognition: Understanding of novel methods and algorithms for statistical pattern recognition. Introduction: what are the basic issues in Statistical Pattern Recognition? - Density Estimation, Expectation Maximization - Linear discriminant analysis - Kernel methods, support vector machine - System performance, combining classifiers - Feature selection. [**6 ECTS, level A**]

Automated Learning and Adaptive Knowledge Systems: Understanding the main principles and methods of Machine Learning systems. Presentation and discussion skills. This course expands the course Leren in the Bachelors programme with additional topics from Machine Learning: genetic algorithms, inductive logic programming/relational learning, knowledge-intensive learning clustering, boosting. Applications of Machine Learning for Data Mining and Adaptive Interactive systems will be discussed. Special attention will be given to Machine Learning in the context of text (text mining) and adaptive interactive systems. [**6 ECTS, level B**]

11.5 Additions

11.5.1 Multimedia

Multimedia Content Analysis: Understanding of structure, components, and performance of systems for multimedia retrieval. The explosion of multimedia content in databases, broadcasts, streaming media, etc. has generated new requirements for more effective access to these global information repositories. Content extraction, indexing, and retrieval of multimedia data

continues to be one of the most challenging and fastest-growing research areas. A consequence of the growing consumer demand for multimedia information is that sophisticated technology is needed for representing, modeling, indexing, and retrieving multimedia data. In particular, we need new scalable browsing algorithms allowing access to very large multimedia databases, and semantic visual interfaces integrating the above components into unified multimedia browsing and retrieval systems. This course focuses on the current issues in Multimedia Systems. We will cover the main problems and challenges in video analysis, including shot-break detection, video summarization and browsing, higher-level semantic analysis, cognitive issues, visual-audio fusion, the use of computer graphics techniques in video production, human-computer interaction, and learning strategies. [**6 ECTS, level B**]

For more info see `http://www.studeren.uva.nl/ma-ai/`.
Contact person (international students): Ms. Joke Hendriks
E-mail: `lstudex@science.uva.nl` (international bureau)
Contact person: Lucia Creveld
E-mail: `lucia@science.uva.nl` (study advisor)

Chapter 12

Free University of Bozen-Bolzano(FUB)

12.1 Description of the Logic, Computability and Complexity Module

The **Logic, Computability and Complexity** module at FUB is covered with courses on:

12.1.1 Logic and Inference

Logic Agents that Reason Logically; Motivating the course; Propositional Logic; Foundations of Propositional Logic; Deduction in Propositional Logic; First Order Logic; Foundations of First Order Logic; Using First Order Logic; Representation, Reasoning, and Logic; Conceptual Modelling and Logic; Entity Relationship diagrams; UML class diagrams. [**4 ECTS**]

Non Classical Logics Modal logics; Non-monotonic logics; Process logics

Formal Methods Propositional and First Order Logic. Modeling Systems as Transition Systems. Temporal Logics: 1. Linear Temporal Logic (LTL) 2. Computation Tree Logic (CTL and CTL*) Model Checking CTL formulas. Ordered Binary Decision Diagrams (OBDD's). CTL Symbolic Model Checking. [**4 ECTS**]

12.1.2 Automata Theory

Formal Languages Finite state machines and applications. Theory of finite automata and regular languages. [**2 ECTS: obligatory**]

12.1.3 Computability Theory

Advanced Algorithms Introduction and overview. Computational geometry. Graph algorithms and network optimization. Algorithm analysis techniques. Numerical algorithms. Linear programming. Approximation algorithms. Randomized algorithms. Online algorithms and competitive analysis. [**4 ECTS: obligatory**]

Theory of Computing Models of computation, Turing Machines, decidability [**4 ECTS: obligatory**]

12.1.4 Complexity Theory

Theory of Computing computational complexity, NP-completeness, polynomial time reductions, polynomial hierarchy [**4 ECTS: obligatory**]

12.1.5 Discrete Mathematics

Advanced Statistics Tests of hypothesis about a population mean and about a population portion; Comparing two population means and determining the sample size. Testing the assumption of equal population variances; Comparing two population proportions and determining the sample size. Multinomial experiments and contingency table analysis; Simple linear regression: the least square approach, the coefficients of correlation and determination, using the model for prediction; Quality, processes and systems. Statistical control and control charts, charts for monitoring the mean and the variation. [**4 ECTS: obligatory**]

12.2 Description of the Formal Languages and Algorithms Module

The **Formal Languages and Algorithms** module at FUB is covered with courses on:

12.2.1 Formal Grammars and Languages Hierarchy

Formal Languages Formal Grammars, Context-free grammars and languages. [**2 ECTS**]

12.2.2 Parsing and Compiler Design

Compilers Introduction to the Notion of Compiler. Lexical Analyzer. Syntax Analysis and Parser construction: 1. Top-Down Parser 2. Bottom-Up Parser 3. Operator-Precedence Parsing 4. LR Parser. Syntax-Directed Translation to Translate Programming Language Constructs. Semantic Analysis: Type Checking. Code Generation and Principles of Code Optimization. [**4 ECTS**]

12.2.3 Search Techniques and Constraint Resolution

Programming Languages The role of programming languages. Imperative Programming. Data representation. Procedure activation. Object Oriented Programming. Logic Programming Paradigm: Propositional Logic, Programming, First Order Logic Programming: Prolog, Prolog techniques and advanced techniques, Constraint logic programming. Functional Programming, Typed Functional Programming: Lisp, Scheme. Concurrent Programming. Languages for hardware description: VHDL [**ECTS 4: obligatory**]

Computational Logic Computational Logic: motivation and importance of the field. Propositional and First Order Logic: deduction, proof theory, automated theorem proving. Higher Order Logic. Induction and Abduction. Constraint (Logic) Programming. Non-monotonic reasoning. [**4 ECTS**]

12.2.4 Automated Learning

Machine Learning Algorithms and Applications; Bayes' rule, maximum likelihood; Generalization, penalization, model selection; Statistical learning theory; Sata reduction and dimensionality reduction; Regression, classification and density estimation [**4 ECTS**]

12.3 Description of the Data Structures, Data Organisation and Processing Module

The **Data Structures, Data Organisation and Processing** module at FUB is covered with courses on:

12.3.1 Algebraic Data Types

Data Warehousing and Data Mining Visual data mining. Statistical primer: parameter estimation, quality metrics of parameter estimation, hypothesis testing, Bayes theorem, histograms, scatter plots, regression. Classification algorithms. Clustering algorithms. Association rules. Web mining. Spatial mining. Temporal mining. Data Warehousing. OLAP. The multidimensional join. Data integration. Data quality [**8 ECTS: obligatory**]

12.3.2 Relational Databases

Database management system Storage and File Structure; Indexing and Hashing; Query Processing; Query Optimization; Transactions; Concurrency Control; Recovery System [**4 ECTS**]

Foundations of Databases Relational query languages, conjunctive queries, relational calculus, query processing and optimization, datalog and recursion, datalog evaluation, negation in datalog, complexity and expressiveness of query languages, incomplete information, disjunctive databases. [**4 ECTS**]

Database Programming Design and architecture of large scale information systems; multitier architectures, applications servers, web applications, middleware; database programming: store procedures, triggers, cursors; ODBC, JDBC, CORBA [**4 ECTS**]

12.3.3 Semi-Structured Data and XML

XML and Semistructured Databases Semistructured data models, XML, DTD, XMLSchema, XPath, XQuery, expressive power of XML query languages, storage of XML in RDBMS, tools for querying XML data. [**4 ECTS**]

12.3.4 Information Retrieval (IR)

Multimedia Retrieval Organization of large multimedia documents; Searching text, picture, music, voice, and video documents; Feature extraction; Indexing [**4 ECTS**]

12.3.5 Digital Libraries

Digital Libraries Digitization, storage, and interchange; Digital objects, composites, and packages; Metadata, cataloging, author submission; Naming, repositories, archives; Spaces (conceptual, geographical, 2/3D, VR); Architectures (agents, buses, wrappers/mediators), interoperability; Services (searching, linking, browsing, and so forth); Intellectual property rights management, privacy, protection (watermarking); Archiving and preservation, integrity Enterprise Application Integration; Design and architecture of large information systems; Commercial web sites, scientific servers, data clusters; Middleware, databases, programming languages and distributed systems; Web data [**4 ECTS**]

12.4 Description of the CS Advanced Modules and Applications

The **CS Advanced Modules and Applications** at FUB are covered with courses on:

12.4.1 Artificial Intelligence (AI)

Artificial Intelligence Introduction to AI, Intelligent Agents. Problem solving and search techniques. Constraint satisfaction problems. Introduction to games. Introduction to planning. [**4 ECTS**]

12.4.2 Knowledge Representation (KR)

Knowledge Representation A review of computational logic. Knowledge Representation. Structural description logics. Propositional description logics. Knowledge bases. Modal logics. Logics and databases [**4 ECTS**]

Knowledge Bases and Databases Languages for conceptual data modeling and ontology design; Intelligent information access; Query processing in knowledge based systems; Knowledge base integration; Distributed knowledge based systems [**4 ECTS**]

12.4.3 Semantic Web

Semantic Web Technologies Semantic Markup; Resource Description Framework (RDF); Languages for the Semantic Web (OWL); Ontologies; Tools for Ontology Construction; Reasoning Engines; Semantic Web-enabled Agents; Applications [**4 ECTS**]

12.4.4 Intelligent and Multi-Modal Interfaces

Human Computer Interaction Introduction to Human Computer Interaction. ACM model for HCI: human, computer, use and context, development process. Human and computers' characteristics. User modeling: cultural and cognitive aspects. The design process. Experiencing building applications through various methods and systems. Techniques for prototyping and implementing graphical user interfaces. Evaluating interface quality to apply the training in industry. Guidelines for building applications for different appliances: PDA, cellphones, industrial devices, computers etc. [**4 ECTS: obligatory**]

12.4.5 Neural Networks

Intelligent Systems Search and constraint satisfaction; Knowledge representation and reasoning systems; Machine learning; Neural networks; AI Planning Systems [**4 ECTS**]

12.4.6 Machine Learning

Advanced Topics in Machine Learning Density estimation; Linear discriminants; Reinforcement learning; Hidden markov models; Computational learning theory (support vector machines) [**4 ECTS**]

12.4.7 Additions

Technical Scientific Communication Organizational patterns and outlining. Audience analysis. Correspondence, sales letters. Short reports, summaries, abstracts. Technical descriptions, manuals. Oral presentations. Analytical reports. [**4 ECTS: obligatory**]

Internet Technologies Web applications design; Tools and languages to develop web applications; Mobile applications design; Tools and languages to develop mobile applications [**4 ECTS**]
For more info see `http://www.inf.unibz.it/mcs/lct/`

Contact person: Raffaella Bernardi

E-mail: `bernardi@inf.unibz.it`

Chapter 13

University of Malta (UoM)

13.1 Description of the Logic, Computability and Complexity Module

The **Logic, Computability and Complexity** module at the UoM is covered with courses on:

13.1.1 Computability Theory

Computability and Complexity Chomsky's language hierarchy, Pumping lemmata to prove limits of each of Chomsky's language classes, Turing Machines and the limits of computing, Intractability, and NP-completeness. [**2 ECTS**]

13.1.2 Discrete Mathematics

Mathematics of Discrete Structures The course is primarily aimed to introduce the basic mathematical tools that are required for the formal and rigorous treatment of the various aspects of computing. Topics include Set theory, Relations and Functions, Natural Numbers and cardinality, Group theory, Graph theory. This unit is also intended to introduce the concept of logic as a tool for studying the validity of arguments. Topics include an introduction to: Predicate and propositional logic, Logical equivalence and satisfiability The syntax of First Order Logic, Axioms and inference rules, Proof systems and techniques, Set theory. [**4 ECTS**]

13.1.3 Algorithms

Algorithmics Theory and use of algorithms. Programming language concepts including Turing Machines and Turing powerful languages, programming constructs, and the theory of algorithms; imperative, object-oriented and declarative programming. Concepts of algorithms and data structures, highlighting the relation that exits between the two. Correctness and efficiency will be emphasized as theSorting, searching, graph and tree processing, and hashing techniques. Abstract data types (ADTs) will be formally defined and illustrated with case studies for list, stack, queue, priority queues, and MAX heaps. Cousework includes a small software project. [**6 ECTS**]

13.2 Description of the Formal Languages and Algorithms Module

The **Formal Languages and Algorithms** module at the UoM is covered with courses on:

13.2.1 Formal Grammars and Languages Hierarchy

Formal Languages and Automata This module deals with the formal treatment of languages and automata (or machines) to recognise languages. The aims are not only at instilling the basic notions of languages, grammars and automata using formal mathematical notation but also provides a practical perspective, by applying the mathematical results to design parsers.

Syllabus includes Formal languages and grammars; Regular languages; Context-free languages; Closure properties of regular and context-free languages; Normal forms for grammars; Recognition algorithms for grammars. [**3 ECTS**]

13.2.2 Parsing and Compiler Design

Compiling Techniques This unit discusses the basic concepts of compilers for computer programming languages and compiling techniques. It includes a presentation of the theory of formal languages and presents the concepts and texhniques behind: Lexical Analysis; Syntax Analysis and Code Generation. [**4 ECTS**]

13.2.3 Search Techniques and Constraint Resolution

Techniques in AI This module aims to familiarize students with the nature of AI problems and related practical solution techniques. Topics include: Problem Solving; Searching - Graphs; Agenda/Means-End Analysis/Constraint Satisfaction; Game Playing; Knowledge Representation; Expert Systems; Planning - Blocks World. The second half of the course is oriented towards Search and Optimization problems; Function Approximation problems (i.e. Function Learning and Synthesis); ANNs (theory, architecture, design, and implementation); Genetic and Evolutionary Algorithms (background, design, and implementation); Montecarlo Techniques applied to Search and Optimization problems; Artificial Life; WISARD neural network for scene analysis; Feature extraction and the Hough Transform. [**3 ECTS**]

13.3 Description of the Data Structures, Data Organisation and Processing Module

The **Data Structures, Data Organisation and Processing** module at the UoM is covered with courses on:

13.3.1 Information Retrieval (IR)

Adaptive Hypertext Systems Adaptive Hypertext Systems must be able to discover, represent, and manipulate user interests and requirements as users navigate and search through a

hyperspace, and then adapt the organisation of and the presentation of information accordingly. This study-unit introduces essential components of Adaptive Hypertext Systems: information storage and retrieval, hypertext reference models, cognitive modelling, and adaptation techniques. [**6 ECTS**]

13.4 Description of the CS Advanced Modules and Applications

The **CS Advanced Modules and Applications** at the UoM are covered with courses on:

13.4.1 Semantic Web

Agent Technology The course deals with the theory and practice of intelligent agents including basics (history, subject matter), software architecture, properties and models of agents, agent inter connectors and agent systems, aspect models, mobility, co-ordination and security, architecture types for agent-based application systems, commercial agent application, standardization efforts, web services, ontologies, mark-up languages, semantic web and future directions. [**6 ECTS**]

13.4.2 Machine Learning

Machine Learning, Expert Systems and Fuzzy Logic Part (I): Machine Learning includes Principles of learning machines, Gold's Theorem; Concepts and Categories in Cognitive Science; Computational learning theory (COLT); PAC-learning; Grammatical inference; Concept learning; Find-S, Candidate Elimination, and the ID-3 learning algorithms.

Part (II): Pattern Recognition includes Clustering techniques; Linear discriminant analysis; Pattern Feature Extraction; Pattern Understanding; Advanced Neural Networks (Hopfield, Kohonen networks); Support Vector Machines. [**6 ECTS**]

13.4.3 Additions

Formal Methods When designing safety-critical systems, it is not sufficient to test the software / hardware written, but it may be necessary to mathematically verify that the system works correctly. This course explores different topics in this research area, including mathematical tools (such as logics, and property languages), formal modeling of computer languages and systems, and techniques used for automatic model checking of such systems.

Syllabus: Temporal Logic, process calculi; Synchronous programming, circuit semantics; Model Checking of software and hardware. [**4 ECTS**]

Contact person: Michael Rosner

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Chapter 14

University Henri Poincaré (Nancy 1)

14.1 Description of the Logic, Computability and Complexity Module

The **Logic, Computability and Complexity** module at *Nancy 1* is covered with the courses:

- Algorithms and Complexity [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Logics and Models of Calculus [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Models of Perception and Reasoning [**6 ECTS of a total of 6 ECTS**]. Obligatory

14.1.1 Logic and Inference

Logics and Models of Calculus. Fundamental concepts in classical and intuitionistic logics. Model theory and proof theory. Proof methods: natural deduction, sequent calculus, tableaux, resolution, etc.

Models of Perception and Reasoning. Basic concepts used in artificial intelligence for the modeling of human perception, reasoning and cognitive faculties.

14.1.2 Automata Theory

Logics and Models of Calculus. Turing Machines.

14.1.3 Computability Theory

Logics and Models of Calculus. Fundamental concepts in computability: recursive functions.

14.1.4 Complexity Theory

Logics and Models of Calculus. Complexity measures in terms of space and time.

Algorithms and Complexity. Complexity Classes, NP-completeness, polynomial reduction, NP complete problems.

14.2 Description of the Formal Languages and Algorithms Module

The **Formal Languages and Algorithms** module at *Nancy 1* is covered with the courses:

- Program Semantics and Compilers [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Distributed Systems [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Logics and Models of Calculus [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Constraints [**3 ECTS of a total of 3 ECTS**]. Optional

14.2.1 Formal Grammars and Languages Hierarchy

Program Semantics and Compilers. Regular expressions. Context free languages. Lexers and parsers.

14.2.2 Parsing and Compiler Design

Program Semantics and Compilers. Code parsing and compiler design.

Distributed Systems. Automatic compilation of distributed programs.

14.2.3 Search Techniques and Constraint Resolution

Algorithms and Complexity. Search algorithms.

Logics and Models of Calculus. Proof Search.

Constraints. Constraint programming, constraint enumeration and propagation.

14.3 Description of the Data Structures, Data Organization and Processing Module

The **Data Structures, Data Organization and Processing** module at *Nancy 1* is covered with the courses:

- Algorithms and Complexity [**3 ECTS of a total of 6 ECTS**]. Obligatory

- Program Semantics and Compilers [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Software Analysis and Design [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Rewriting Techniques and Transformations [**3 ECTS of a total of 3 ECTS**]. Optional

14.3.1 Algebraic Data Types

Algorithm and Complexity. Basic data structures. Advanced data structures.

Program Semantics and Compilers. Algebraic data structures. Abstract machines. Functional Languages. Data structures for compilation.

14.3.2 Relational Databases

Software Analysis and Design. Databases: design, functional dependencies, normalization, logic schemes, security, coherence, concurrent access, interfaces.

14.3.3 Semi-Structured Data and XML

Rewriting Techniques and Transformations. Rewriting algorithms and transformation of XML documents.

14.4 Description of the CS Advanced Modules and Applications

The **CS Advanced Modules and Applications** at *Nancy 1* are covered with the courses:

- Information Networks [**6 ECTS of a total of 6 ECTS**]. Obligatory
- Software Analysis and Design [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Distributed Systems [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Introduction to Research [**6 ECTS of a total of 6 ECTS**]. Obligatory

14.4.1 Additions

Information Networks. Networks (models, topologies, architectures). Communication Protocols.

Software Analysis and Design. Information system design. UML modeling. Design patterns and architectural patterns.

Distributed Systems. Fundamental concepts in distributed systems (architectures, synchronic/asynchronic models), distributed algorithms (communication protocols, mutual exclusion, election, consensus, etc.)

Introduction to Research. A small project of research under the supervision of a lecturer, taking a period of 10 weeks, with a dedication of one day per week.

14.5 Summary

Course	ECTS	Obligatory?	CS M1	CS M2	CS M3	CS M4
Algorithms and Complexity	6	Yes	3		3	
Program Semantics and Compilers	6	Yes		3	3	
Logic and Models of Calculus	6	Yes	3	3		
Information Networks	6	Yes				6
Software Analysis and Design	6	Yes			3	3
Models of Perception and Reasoning	6	Yes	6			
Distributed Systems	6	Yes		3		3
Introduction to Research	6	Yes				6
Rewriting Techniques and Transformations	3	No			3	
Constraints	3	No		3		
Total			12	12	12	18

14.6 Further Information

For more info see `http://tal.loria.fr`. Contact person: Patrick Blackburn. E-mail: `blackbur@loria.fr`

Chapter 15

University Nancy 2

15.1 Description of the Logic, Computability and Complexity Module

The **Logic, Computability and Complexity** module at *Nancy 2* is covered with the courses:

- Foundations in Mathematics [**6 ECTS of a total of 6 ECTS**]. Obligatory
- Knowledge Representation and Inference [**3 ECTS of a total of 6 ECTS**]. Obligatory

15.1.1 Logic and Inference

Knowledge Representation and Inference. Classical Logic. Proof Theory. Model Theory. Knowledge Representation.

15.1.2 Computability Theory

Foundations in Mathematics. Recursive functions. Decidability and undecidability.

15.1.3 Complexity Theory

Knowledge Representation and Inference. Complexity Classes in terms of space and time.

15.2 Description of the Formal Languages and Algorithms Module

The **Formal Languages and Algorithms** module at *Nancy 2* is covered with the courses:

- Advanced Algorithms and OOP [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Scripting Languages for NLP [**6 ECTS of a total of 6 ECTS**]. Optional

15.2.1 Formal Grammars and Languages Hierarchy

Scripting Languages for NLP. Regular Expressions. Context Free Languages.

15.2.2 Parsing and Compiler Design

Scripting Languages for NLP. Parsing algorithms.

15.2.3 Search Techniques and Constraint Resolution

Advanced Algorithms and OOP. Search and sorting algorithms.

15.3 Description of the Data Structures, Data Organization and Processing Module

The **Data Structures, Data Organization and Processing** module at *Nancy 2* is covered with the courses:

- Advanced Algorithms and OOP [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Coding and Normalization of Information Repositories [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Linguistic Databases [**3 ECTS of a total of 6 ECTS**]. Optional

15.3.1 Algebraic Data Types

Advanced Algorithms and OOP. Basic and Advanced Data Types. Data specification. Object Oriented Programming.

15.3.2 Relational Databases

Linguistic Databases. Relational Databases. Normalization. Tools for access and exploration of corpus databases.

15.3.3 Semi-Structured Data and XML

Coding and Normalization of Information Repositories. Markup languages. Normalization. The problem of information exchange and information structuring.

15.4 Description of the CS Advanced Modules and Applications

The **CS Advanced Modules and Applications** at *Nancy 2* are covered with the courses:

- Coding and Normalization of Information Repositories [**3 ECTS of a total of 6 ECTS**]. Obligatory
- Knowledge Representation and Inference [**3 ECTS of a total of 6 ECTS**]. Obligatory

15.4.1 Automated Reasoning

Knowledge Representation and Inference. Automated Theorem Proving. Reasoning methods (tableaux, resolution, etc.). Testing.

15.4.2 Additions

Coding and Normalization of Information Repositories. Advanced topics in Normalization. Efficient access to large repositories. XML theory and practice.

15.5 Summary

Course	ECTS	Obligatory?	CS M1	CS M2	CS M3	CS M4
Foundations in Mathematics	6	Yes	6			
Advanced Algorithms and OOP	6	Yes		3	3	
Coding and Normalization of Information Repositories	6	Yes			3	3
Knowledge Representation and Inference	6	Yes	3			3
Scripting Languages for NLP	6	No		6		
Linguistic Databases[1]	6	No			3	
Total			9	9	9	6
Required			9	9	6	4

15.6 Further Information

For more info see `http://tal.loria.fr`. Contact person: Guy Perrier. E-mail: `perrier@loria.fr`

[1] Other 3 ECTS in LT M3

Chapter 16

Roskilde University

16.1 Description of the Logic, Computability and Complexity Module

The **Logic, Computability and Complexity** module at *Roskilde University* is covered with courses on:

- Advanced topics in databases (ADB)
- Artificial Intelligence and Intelligent Systems (KIS)
- Design of algorithms with Internet applications (ADMI)
- Discrete mathematics and logic (MATE)
- Language Engineering with Java and XML (LE)
- Tools and Concepts in Programming (BRP)

16.1.1 Logic and Inference

Advanced topics in databases (ADB). Deductive DB model. Integrity constraints. [**3 ECTS**]
Artificial Intelligence and Intelligent Systems (KIS). Logic and inference. Logical agents. [**3 ECTS**]
Discrete mathematics and logic (MATE). Formal logic. [**4 ECTS**]

16.1.2 Automata Theory

Language Engineering with Java and XML (LE). Abstract machines. Automata Theory. [**1.5 ECTS**]

16.1.3 Complexity Theory

Design of algorithms with Internet applications (ADMI). Algorithms and Complexity. [**1.5 ECTS**]
Tools and Concepts in Programming (BRP). Elementary Complexity. [**2 ECTS**]

16.1.4 Discrete Mathematics

Discrete mathematics and logic (MATE). Discrete mathematics. [**3.5 ECTS**]

16.2 Description of the Formal Languages and Algorithms Module

The **Formal Languages and Algorithms** module at *Roskilde University* is covered with courses on:

- Design of algorithms with Internet applications (ADMI)
- Language Engineering with Java and XML (LE)
- Paradigms of programmering (PIP)
- Tools and Concepts in Programming (BRP)

16.2.1 Formal Grammars and Languages Hierarchy

Language Engineering with Java and XML (LE). Regular and context-free languages. [**2 ECTS**]
Tools and Concepts in Programming (BRP). Grammars and EBNF. [**2 ECTS**]

16.2.2 Parsing and Compiler Design

Language Engineering with Java and XML (LE). Basic parsing techniques (syntactic analysis). Parser generators. Compiler Design. [**3 ECTS**]
Paradigms of programmering (PIP). Parsing. [**1 ECTS**]

16.2.3 Search Techniques and Constraint Resolution

Design of algorithms with Internet applications (ADMI). Search Techniques. [**4 ECTS**]
Tools and Concepts in Programming (BRP). Searching. [**2 ECTS**]

16.3 Description of the Data Structures, Data Organisation and Processing Module

The **Data Structures, Data Organisation and Processing** module at *Roskilde University* is covered with courses on:

- Advanced topics in databases (ADB)
- Databases (DB)
- Design of algorithms with Internet applications (ADMI)
- Language Engineering with Java and XML (LE)
- Paradigms of programmering (PIP)

16.3.1 Algebraic Data Types

Paradigms of programmering (PIP). Algebraic Data Types. [**2 ECTS**]

16.3.2 Relational Databases

Advanced topics in databases (ADB). Indexing. Optimization. [**3 ECTS**]
Databases (DB). Relational Databases. [**3 ECTS**]

16.3.3 Semi-Structured Data and XML

Databases (DB). XML Databases. [**1 ECTS**]
Language Engineering with Java and XML (LE). Semi-Structured Data and XML. [**1 ECTS**]

16.3.4 Information Retrieval (IR)

Databases (DB). Information Retrieval. [**2 ECTS**]
Design of algorithms with Internet applications (ADMI). Retrieval techniques. [**2 ECTS**]

16.4 Description of the CS Advanced Modules and Applications

The **CS Advanced Modules and Applications** at *Roskilde University* are covered with courses on:

- Advanced topics in databases (ADB)
- Animation and simulation (ANS)

- Artificial Intelligence and Intelligent Systems (KIS)
- Human Computer Interaction (HCI)
- WWW Technology - a practical view (WT)

16.4.1 Artificial Intelligence (AI)

Artificial Intelligence and Intelligent Systems (KIS). Artificial Intelligence. [**2.5 ECTS**]

16.4.2 Knowledge Representation (KR)

Advanced topics in databases (ADB). Knowledge Representation. [**1.5 ECTS**]
Artificial Intelligence and Intelligent Systems (KIS). Knowledge Representation. Rule- and frame-based systems. [**1 ECTS**]

16.4.3 Semantic Web

WWW Technology - a practical view (WT). Markup languages. [**2 ECTS**]

16.4.4 Intelligent and Multi-Modal Interfaces

Animation and simulation (ANS). Animated interfaces. Domain-specific models. [**2 ECTS**]
Human Computer Interaction (HCI). Interaction. [**3 ECTS**]

16.4.5 Machine Learning

Artificial Intelligence and Intelligent Systems (KIS). Machine Learning. [**1 ECTS**]

16.4.6 Additions

Animation and simulation (ANS). [**3 ECTS**]

16.5 Summary

Course	ECTS	M1	M2	M3	M4	Total
Advanced topics in databases (ADB)	7.5	3		3	1.5	7.5
Animation and simulation (ANS)	7.5				5	5
Artificial Intelligence and Intelligent Systems (KIS)	7.5	3			4.5	7.5
Databases (DB)	7.5			6		6
Design of algorithms with Internet applications (ADMI)	7.5	1.5	4	2		7.5
Discrete mathematics and logic (MATE)	7.5	7.5				7.5
Human Computer Interaction (HCI)	7.5				3	3
Language Engineering with Java and XML (LE)	7.5	1.5	5	1		7.5
Paradigms of programmering (PIP)	7.5		1	2		3
Tools and Concepts in Programming (BRP)	7.5	2	4			6
WWW Technology - a practical view (WT)	7.5				2	2
Total		18.5	14	14	16	

For more info see `http://www.ruc.dk/dat\textunderscoreen/International_students/`.

Contact person: Troels Andreasen

E-mail: `troels@ruc.dk`

Chapter 17

Utrecht University

17.1 Description of the Logic, Computability and Complexity Module

The **Logic, Computability and Complexity** module at *Utrecht University* is covered with courses on:

17.1.1 Type theory

Type theory is introduced via the Curry-Howard isomorphism. We start by presenting the genesis of type theory as an answer to the Russell-paradox. Then, simpel types are introduced. Subsequently, we introduce the simply typed lambda calculus as a calculus to construct inhabitants of types, using the basic operations of abstraction and application. We show that lambda calculus also makes sense without types, as a calculus of functions and we study some metatheoretical theorems both for the untyped and for the typed lambda calculus w.r.t. expressive power. The next step is that we exhibit the Curry-Howard isomorphism: simply typed lambda calculus is isomorphic, in a technical sense, with natural deduction for intuitionistic propositional logic. We illustrate the difference between this logic and classical propositional logic. Finally, we discuss extensions of simply typed lambda calculi. In the practicum simple deductions in intuitionistic and classical propositional logic are executed on the computer.

Course aims: Understanding type theory and its place in linguistics, computer science and logic. The ability to perform simple re- and deductions in simply typed and related lambda calculi. The ability to use soundness and completeness of both Heyting algebra's and Kripke frames for intuitionistic logic. Knowledge of the meta theory (termination, confluence, subject-reduction, expressiveness) of simply typed and related lambda calculi. The ability to apply the Curry-Howard isomorphism. [**7.5 ECTS**]

17.1.2 Commonsense reasoning

Artificial Intelligence often uses logical models of reasoning. Logic investigates the validity of patterns of reasoning. Standard logic confines itself to the study of fully reliable inferences. Although this is adequate for fields like mathematics, for many other applications standard logic

is too restricted. In other scientific areas, as well as in commonsense reasoning, people are often faced with incomplete, uncertain or even inconsistent information. To deal with this, they use reasoning patterns where it can be rational to accept a conclusion even if its truth is not guaranteed by the available information.

This course focuses on logics that systematise validity criteria for such 'defeasible' reasoning patterns. Logics of this kind are often called 'nonmonotonic logics', since new information may invalidate previously drawn conclusions. This course covers some of the best-known nonmonotonic logics, in particular default logic, circumscription and argumentation systems, as well as formal theories of abductive reasoning. Upon completion of this course, the student will have obtained insight in and mastery of the main logical techniques for formalising defeasible commonsense reasoning patterns, and will be able to apply these techniques to basic examples of such reasoning. [**7.5 ECTS**]

17.2 Description of the Data Structures, Data Organisation and Processing Module

The **Data Structures, Data Organisation and Processing** module at *Utrecht University* is covered with courses on:

- Language and speech resources (description: see above) [**7.5 ECTS**]

17.3 Description of the CS Advanced Modules and Applications

The **CS Advanced Modules and Applications** at *Utrecht University* are covered with courses on:

- Philosophy of AI [**7.5 ECTS**]
- Semantic Web [**7,5 ECTS**]
- Intelligent Agents [**7,5 ECTS**]
- Multi-agent systems [**7,5 ECTS**]

17.3.1 Semantic Web

The World Wide Web has the potential to become the primary source for storing and accessing data. However, its content is marked up in such a way that it is accessible only to humans.

Current Web search engines have serious difficulties in processing search queries. Even though they return impressive results, their level of precision and recall clearly shows their limitations.

An interesting alternative is the creation of a Semantic Web in which meaning is made explicit, allowing machines to process and integrate Web resources intelligently. This technology might

allow for quick and accurate web search and facilitate communication among heterogeneous web-accesible devices.

The aim of the course is to examine this area of research by reading and discussing papers. We will also extend the techniques developed within the Semantic Web to deal with the integration of heterogeneous linguistic data encoded in various language resources such as corpora and databases. This will be achieved through the creation of an ontology of linguistic concepts which will formalize linguistic knowledge and will allow us to reason about it. [**7.5 ECTS**]

17.3.2 Intelligent Agents

This course is about the theory and realisation of so-called intelligent agents, pieces of software that display some degree of autonomy, realised by incorporating 'high-level cognitive / mental attitudes' into both modelling and implementation of this kind of software. As such, the subject of intelligent agents is at the cross-roads of the fields of artificial intelligence and mainstream computer science, in particular software engineering. These mental attitudes comprise 'informational' and 'motivational' ones and are often of the so-called BDI kind, dealing with 'beliefs', 'desires' and 'intentions' of agents. The agent concept calls for an integration of several topics in artificial intelligence, such as knowledge representation and reasoning (in particular reasoning about action and change) and planning. Agent technology, as the field is generally called, has a great potential of applications, ranging from intelligent personal assistants to e-commerce and robotics (where in the latter case often the term 'cognitive robotics' is used).

In the course we will devote much time to the philosophical and theoretical (mostly logical) foundations of the area of intelligent agents, and then go on with describing ways of realising them by special architectures and so-called agent-oriented programming languages in which one can program the 'mental states' of agents. This course presents the introductory theory for the agent-directed courses in the Master programme and is required for courses such as MAS and MAP. [**7.5 ECTS**]

17.3.3 Multi-agent systems

This course builds on the Intelligent Agents course. In the intelligent agents course, various notions related to single agents are studied. In this course we study the multiagent systems and related topics. In particular, we study: 3APL: a programming language to implement multiagent systems, the interaction between agents communication, co-ordination, co-operation, negotiation, the methodologies for designing and developing multiagent systems, multiagent applications and their characterizations. [**7.5 ECTS**]

For more info see

CAI Master: `http://www.phil.uu.nl/en/education/students/CAI/`

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