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Abstract:
This second edited annual report for publication is a summary of the FASTY project outcomes at the end of the second year of the 3 years project.

Deliverable Numbering:

ID	*Official Deliverable ID (DX.Y)*	
NATURE	*Nature of Deliverable*	
DLEVEL	*Dissemination Level*	
RESPID	*Responsible Partner ID*	
STATUS	*Wn*	*Working document, version n*
	Pn	*PRELIMINARY complete version for discussion, version n*
	Dn	*DRAFT, before peer review*
	F	*FINAL VERSION, after peer review*

*Dissemination:	INT-Project internal, CO-Confidential, RE-Restricted access IST-IST participants, FP5-FP5 participants, PU-Public document
**Nature:	P-Prototype, R-Report, D-Demonstrator, S-Specification, T-Tool, O-Other

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1 Introduction

Communication is a primary need for humanity. While this holds true for mankind in general, the need for communication is even more urgent for disabled people. It is also true that computers play an increasing role as a communication tool. However, in this on-going process disabled people are at a disadvantage. In particular, motor impairments make the use of standard text input devices to the computer difficult and hence slow. For instance, while non-disabled writers have a typing speed of some 200-300 characters a minute, the typing speed of a user operating the keyboard with a mouth stick is not higher than 75-120 characters a minute. Motor impairment often goes together with articulator deficiencies. Thus alternative methods based on speech input will not solve the problem. Providing methods for speeding up keyboard text input is a better way to go. This is the strategy that has been chosen in the FASTY project.

The project is scheduled for the period from January 2001 to December 2003. Below we will give a brief description of the aims of the project and the achievements made during the second project year.

2 Aims

The concrete goal of FASTY is the creation of a system for increasing the text generation rate of disabled persons by so-called predictive typing and dedicated advanced input devices. A prediction system attempts to predict subsequent portions of the text by analysing the text already entered and using frequency data on the vocabulary of the language. Character-by-character text entry is thus enhanced by the possibility of entering whole words and portions of words as they are proposed by the system. The selection of an alternative should be made by means of a single keystroke. Complementary to the presentation of the proposals on the screen, they will be read aloud by means of speech synthesis. The success of a system of this kind can be measured in terms of keystrokes that are saved using the predictions as compared to traditional character-by-character input. FASTY aims at a keystroke saving rate above 50%. Experiences that were made during the first project year indicate that the linguistic quality of the text will also benefit from using the prediction system.

The FASTY text prediction system should apply to four languages: Dutch, French, German and Swedish. The future inclusion of additional languages should also be considered. The multilingual aspect is reflected in the design of the system.

User involvement in the project is strong. It is ensured by means of a user panel. The user needs are analysed subjectively by intensive interaction with the user panel. Additionally an objective User Ability Assessment Tool- (UAAT) -has been developed for user needs investigations. The user panel also plays an important role during verification and validation of the prototype systems. There are two kinds of users in the panel: primary end-users and secondary users such as pedagogues, therapists, carers and family members.

An important aspect of the project is the design and development of a dedicated interface adapted to the needs of the users. The user interface design and the features of the predictor program aim at a wide coverage of primary users (various disabilities) and secondary users (various roles in supporting the disabled person). Self-adapting parameters and flexible configuring should ensure a high degree of usability, user friendliness and accessibility to the system. A user simulation tool will be used in testing the system and adapting it to different users.

Innovative and ergonomic user interfaces for various existing input methods (standard keyboard, on-screen keyboard, scanning) are developed together with the predictor thus minimising time and effort for selecting the desired word from a selection list presented on the screen. In addition, a special pressure sensitive switch/keyboard will be developed and used to improve the user interface- (UI). Strategies for optimal exploitation of residual functions will be implemented.

Dissemination and Exploitation play a central role throughout the project. A Technological Implementation Plan (TIP) has been developed as a preparation for the exploitation plan. After successful finishing of the project the consortium will co-operate in order to come up with a commercial product.

3 Consortium

The FASTY consortium consists of nine partners from four countries: Austria, Belgium, Germany and Sweden.

There are six principal contractors:

- fortec - Research Group for Rehabilitation Technology / Project co-ordinator
- ÖFAI - Österreichisches Forschungsinstitut für Artifical Intelligence
- FTB - Forschungsinstitut Technologie - Behindertenhilfe
- UU - Uppsala University, Department of Linguistics
- MULT - Multitel ASBL
- IGEL Elektronische Kommunikationshilfen GmbH

and three assistant contractors:

- ELI - Seraphisches Liebeswerk, Elisabethinum Axams
- IKuT - Ingenieurbüro für Kunst und Technik II
- FUNDP - Facultés universitaires, Notre-Dame de la Paix

fortec is the project co-ordinator and responsible for managing the project, and for system architecture and internal interfaces. It also develops some of the development tools.

Öfai is responsible for the implementation of the language components and the provider of language resources for German. It also has the responsibility for system integration and prototyping.

FTB is responsible for user involvement including ethics, quality assurance, and user validation. It also has the responsibility for the implementation of the user components.

UU is responsible for dissemination and public relations. It is also the provider of language resources for Swedish and responsible for the grammar based prediction.

MULT is responsible for verification and redesign of the system. It is the provider of language resources for French and Dutch and of speech synthesis solutions for all languages.

IGEL is responsible for the exploitation of the system and for technical implementation. It also contributes to specifications, architecture and user involvement.

ELI's main task is to provide feedback to the developers. It also participates in user related tasks such as prototype testing and assessment of user needs.

IKuT is the developer of new input devices. It has associated with it a local user group.

FUNDP provides an interface between the users and the developers. It participates in the analysis of user capabilities and needs, and assists disabled people in using the product.

In addition, there are a number of sub contractors.

A listing of the project partners with contact information is to be found in the Appendix.

4 Innovative Aspects

There are a number of word predictors on the market. However, they have, typically, been developed for English, which means that they are not well suited for morphologically rich languages such as Dutch, French, German and Swedish. Simply adapting the English programs to these highly inflecting languages by replacing the English dictionaries usually implies a massive reduction of keystroke saving rate. These effects are due to the simplistic language description that is used for predicting English text and that fails to predict the correct inflectional form of a word as required by inflectional languages. The English language description is, as a rule, limited to frequency data on individual words (unigrams) and sequences of words (bigrams, trigrams). Attempts have been made in research systems for Swedish and Spanish to use a more elaborate language description, including n-grams of word classes [1] and syntactic grammars [2]. The experiences made in these projects are taken into account in the FASTY project. They do not, however, present solutions that will ensure a keystroke saving rate of above 50% for the FASTY languages. An additional problem with most of the FASTY languages is the fact that new compounds can be created on the fly, thus making it hopeless to strive for a complete lexicon. Other methods need to be employed for coping with dynamic word formation processes. Being able to cope with compounds, even if they are new, is of great importance, since compounds are usually rather long words and failing to predict them can cause a significant drop of the keystroke saving rate. Since no word prediction system currently available is able to handle new compounds, this aspect of the FASTY system is a true innovation.

At a general level, the innovative aspects of the FASTY predictor are represented by:

- the predictive power of the prediction engine that is based on a sophisticated language component
- a dedicated, flexible and adaptable user interface that is an integral part of the system
- new input devices

In particular, the innovative nature of the FASTY predictor is reflected in the following features:

- prediction of compounds
- prediction of proper inflectional forms based on the use of parsing
- generic algorithms to ensure cross-language portability
- dictionaries based on general language corpora and on the users' own texts
- adaptation of the dictionaries based on actual use of the predictor

- initially supported languages: Dutch, French, German, Swedish
- user interface that is an integral part of the predictor and
  - adaptable by primary and secondary users
  - capable of using different kinds of input devices
  - automatic adaptation to the performance of the user
- new input device
  - pressure sensitive switch
  - pressure sensitive keyboard

5 The FASTY System

The specification of the FASTY system is based on a market study, a study of available technology and a study of the users' particular needs. Special care has been taken do define an open and flexible architecture that is adaptable to the users' needs. Another focal point has been do define a generic system that is not geared to any specific language. Thus the language components will be independent of the operating system and the prediction strategies will be evaluated with regard to all the FASTY languages. The system should also be portable to platforms other than MS-Windows.

The core components in the architecture of the FASTY word prediction system are:

- **the runtime system**, comprising the User Interface (UI) and the Language Component (LC)
- the **User Adjustment Tool (AT)**
- the **developer tools,** including the User Ability Assessment Tool (UAAT), the Text Collection Tool (TCT), the User Simulation Tool (UST) and the Simple Word Prediction program (SWP)

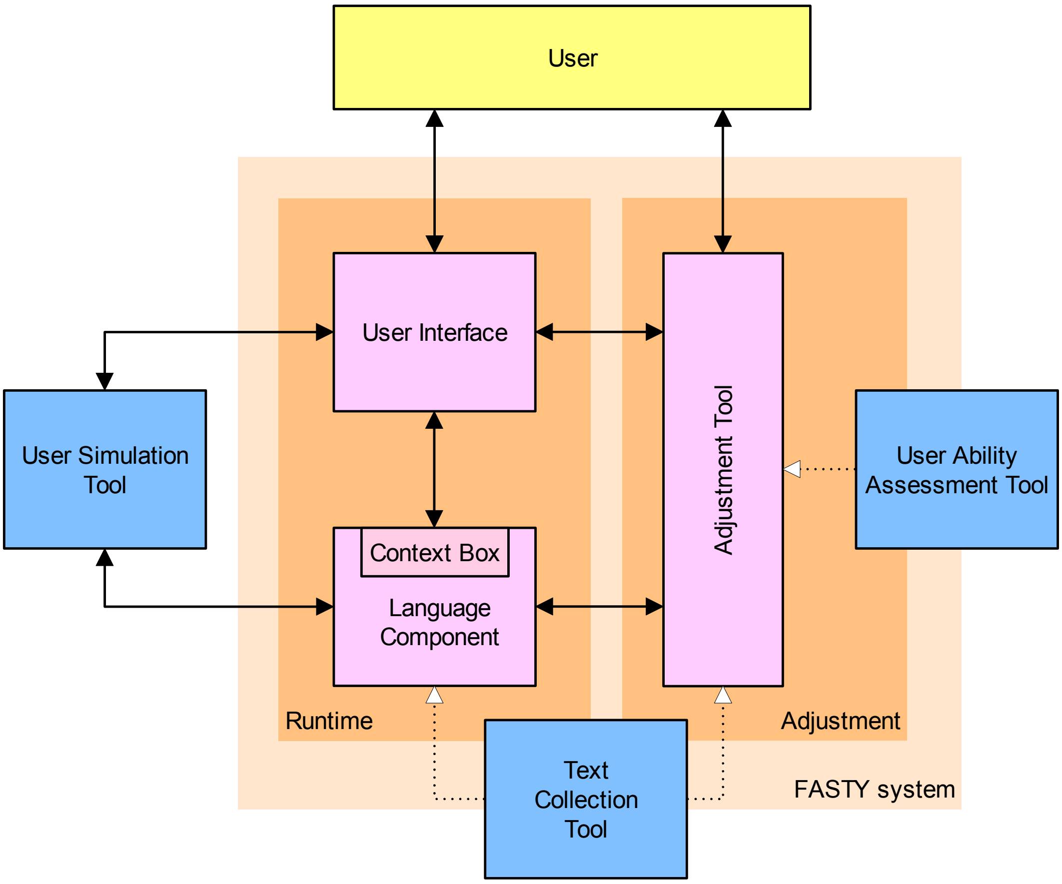

Fig. 1: General System Structure
dotted lines indicate no direct interfaces, but used information and the possibility to use part of the code or methods in later versions of the FASTY system

During the second project year, all the developer tools have been implemented. Further, the different modules of the language component have been implemented and integrated with each other. The integration of the language component with the user interface has been initiated.

Below we give a brief functional description of the different components. For further details, see [3].

5.1 The User Interface

The acceleration of text-input has two main starting points: A good prediction engine and a good input-system in combination with a good user interface. In the second year of the project early versions of the first prototype of the User Interface software (UI) were available as well as the first prototypes of the Pressure Sensitive Keyboard (PSK).

5.1.1 User Interface software

The FASTY system uses standard interfaces like keyboard interface, mouse interface, serial or parallel interfaces that humans use to enter data into a computer. The drivers to operate those interfaces are part of the particular used operating system. In addition to these drivers special purpose FASTY drivers are needed to achieve a consistent data format that serves as input to the FASTY kernel no matter what kind of physical input device is currently connected to the computer.

In general a FASTY driver has to perform mainly three tasks:

- initialisation of the hardware interface on start up
- data transfer
- releasing occupied system resources when the job is done

The FASTY runtime system will use sets of different drivers. An entry of the driver name in the systems initializing file determines, which driver will be loaded during program start up and used during runtime. The Adjustment Tool will be used for selection and setup of the drivers.

All drivers make a consistent set of function available to the FASTY system. They deliver the following information:

Input Driver:

- virtual-key codes
- key states (key up, down or toggled)
- pressure values
- cursor position, cursor move and other adequate data of the pointing device

Output Driver:

- language ID
- prediction list
- part of speech information

Program Driver:

- caret position
- cursor position
- focus change
- active menus
- active dialogs

At the end of the second project year version 1.02.01 of the first prototype of the User Interface software was available.

5.1.2 Pressure Sensitive Keyboard

Parts of the FASTY user interface are new devices that enable users to use their motor abilities better for computer input. The idea behind the Pressure Sensitive Keyboard is to evaluate the pressure as additional information in the input process. To press a key or not to press it is one bit of information. By evaluating the pressure it is possible to gain more information from pressing a key. E.g. to press weakly or strongly can be used for different input actions.

This idea was implemented by using Force Sensing Resistor (FSR) technology. It applies a semiconductor-material that changes its resistor value with the pressure on it. So the resistor value can be used to evaluate the pressure on the material.

5.1.2.1 The SensorBox

None of the commercially available interfaces for connecting input devices to PCs are able to analyse the output signal of pressure sensitive sensors. A new hardware interface is therefore being developed within the FASTY project: the SensorBox. The SensorBox measures the resistor values of pressure sensitive elements and converts them into digital data. This data is sent to the PC for further evaluation.

The SensorBox provides up to 8 inputs for sensors. The range of measurement is adapted in such a way that very soft pressure can be used as well as quite hard pressure like in a foot switch.

Fig. 2: SensorBox 2nd prototype

5.1.2.2 The keyboard

The Pressure Sensitive Keyboard (PSK) is a standard PC keyboard with a pressure sensitive element under each key inside the keyboard case. This device allows the evaluation of the pressure on the keys and uses the pressure information for additional functions. At the present time the PSK exists only for a standard PC keyboard. However, this covers most of the potential users. It is planned to build also enlarged PSKs in the future. This would cover the next big group of keyboard users.

Fig. 3: Pressure Sensitive Keyboard prototype

For more details, especially on the technical issues, see [3].

5.2 The Language Component

Below we focus on the functionality of the language component. For further detail, see [4].

5.2.1 Overall Specification

FASTY's core prediction functionality is provided by a statistic language model based on word n-grams and part-of-speech tag n-grams in conjunction. Moreover, the possibility to create user specific dictionaries both during a session and on the basis of previous entered texts, serves as a method for further increasing the prediction accuracy. Further, the use of topic specific lexica will be considered.

The variety of languages to be supported and methods to be integrated into the FASTY system demands a modular architecture. The combination and integration of prediction components needs to be handled in a very flexible way, for a variety of reasons:

- Different languages may put different emphasis on different modules, so it must be possible to arrange these modules in a different way.
- The effects of the different prediction methods are not yet known precisely; experimental adjustments as well as parameter tuning have to be possible.
- Different application scenarios (varying from text writing up to spontaneous dialogs) may require different combination and weighting of components.
- Adaptation to users with different degrees and types of disabilities will also be required.

Thus the backbone of the linguistic prediction component of the FASTY system will be a controller that is flexibly driving the different prediction modules and combining their results. Thus it will be easy to optimise the overall prediction behaviour and also adaptation of FASTY to another language without modifying the whole system will be made possible.

5.2.2 Methods used in existing prediction systems

When one considers methods for saving keystrokes in text typing, one has to differentiate between keystroke-saving methods in the UI and methods involving linguistic or statistical prediction of words, word sequences and phrases. Here we will put our emphasis on the latter. However, for the sake of completeness a short listing of methods belonging to the User Interface side is given below:

- automatically *inserting a space* after every predicted word accepted by the user. This method compensates for the extra keystroke needed for selecting the prediction.
- automatically *removing preceding whitespace* immediately before punctuation characters (and inserting the appropriate amount of spaces afterwards). This method complements the previous one, as the need for the user to backspace the automatically inserted whitespace is alleviated.
- *auto-capitalisation*. This method in fact also needs at least some linguistic knowledge, it is listed here just because of the requirement to be able to change characters the user already has typed. Auto-capitalisation may occur after sentence ending periods, on words recognised as proper names or (in some languages, e.g. German) on nouns in general.

5.2.2.1 String-based statistical methods

All systems on the market that we are aware of use some kind of frequency statistics on words and (sometimes) word combinations. Given a prefix of a word, with a frequency annotated lexicon the most probable continuation(s) of that word can be retrieved easily. Sometimes, not only word-based frequency counts are maintained (unigrams), but also bigrams and even trigrams are used for enhancing prediction accuracy. N-gram language models are widely used in speech recognition systems, and their benefits are also exploited in some predictive typing systems. The key observation behind this kind of models is, that the probability of a word occurring in the text depends on the context.

5.2.2.2 Syntactically motivated statistics

The superiority of n-gram based predictions over simple frequency lexicons stems from the fact, that n-grams are able to capture some of the syntactic and semantic regularities intrinsic to language. However, a severe drawback of word-based n-grams is, that, even with very large training texts, the data still is rather sparse, and thus in many actual cases during prediction no information is available. The usual technique to cope with syntactic regularities uses class-based n-grams (usually n=3), the classes being defined by the part-of-speech information of a tagged corpus. Copestake [5] reports on an improvement in KSR of 2.7 percent points by just taking PoS-bigrams into account. A good description on the integration of PoS trigrams into a statistical word prediction system for Swedish is given in [1].

5.2.2.3 Capturing semantics with statistics

For a human language user it is obvious that in a given context some words are more probable than others just because of their semantic content. Factors influencing word probability due to semantics are (among others):

- the user and the type and topic of the text s/he writes (global factors)
- constraints due to the lexical semantics of words (e.g. subcategorisation requirements); these are local factors that mostly operate on sentence level.

Collocation analysis (in a broader sense, not reduced to idioms only) can reveal some of these dependencies. However, very large corpora are needed. Rosenfeld [6] uses the concept of "trigger pairs" to capture these relationships statistically (basically these are bi-grams of words occurring together in a window of a certain size in a corpus). If a word that has been recently entered occurs in such a trigger pair the probability of the other word of the pair should be increased. Recency, as implemented as a heuristic in some prediction systems, can be seen as a self trigger and is a (rather crude) measure to exploit semantic or topical appropriateness of a word.

5.2.2.4 Rule-based approaches

Several methods of integrating grammar rules into statistics based prediction have been tried, but none of them had made it into a commercially successful product. Such integration, however, is seen as a major challenge in the FASTY system.

5.2.3 Linguistic components and resources for text prediction

Basic to our approach is the modular architecture of our system. In addition to the flexibility such an approach provides for the adaptation to different languages, application scenarios and users – as described in the introduction – it also ensures robustness and graceful degradation in the case one module should be missing or fail. Furthermore, this type of architecture allows for the possibility of exploring various more advanced – and albeit more risky – methods without endangering the successful implementation of the language component in case some of these methods should not prove successful.

The core of the system will be a module based on the prediction of word forms due to their absolute frequency and the probability of their associated PoS. Such a module is state-of-the-art and guarantees a basic performance. A number of other methods to improve prediction quality will be investigated. All methods will be evaluated with respect to their performance for different target languages and language specific phenomena (e.g., compounding). Those that prove to be successful for one or more of the target languages will be integrated with the core component – either alone or in combination with others.

5.2.3.1 General word n-gram-based Prediction

As stated above, predictions based on frequencies of word sequences are usually more reliable than predictions solely based on simple word frequencies. Frequency tables of word bigrams are thus used as a base in the FASTY language model. As is customary, the bigram model is however supplemented by simple word frequencies. This is due to that no matter how much data is used for extracting bigram frequencies, there will always be a problem of sparse data - most bigrams will have low frequencies and many possible word sequences will not be attested in the training material. A common solution, also implemented in the FASTY language model, is to *interpolate* the probabilities obtained from using larger n-grams (here: bigrams) with the probabilities acquired from smaller n-grams (here: unigrams, i.e. simple word frequencies). The process of interpolation is further described in [7].

During the second project year, software has been developed for easy extraction and compilation of word form uni- and bigrams. By means of this software, frequency lists have been extracted for all FASTY languages from large collections of text (corpora comprised of several millions of words).

5.2.3.2 Part-of-Speech n-gram-based Prediction:

The FASTY language model is further based on part-of-speech frequencies. Since a part-of-speech tag captures a lot of different word forms in one single formula it is possible to represent contextual dependencies in a smaller set of n-grams. One major advantage of making use of part-of-speech frequencies is thus that the problem of sparse data is reduced and a larger context may be taken into consideration. The FASTY language model uses frequencies of part-of-speech tag trigrams, which are supplemented with frequency data of smaller part-of-speech n-grams (uni- and bigrams).

As for the word n-grams, part-of-speech n-grams have been collected for all FASTY languages during the second project year. Special software was designed to extract the relevant data from large corpora and to compile it in a uniform format suitable for integration with the rest of the language components. The corpora used have been tagged, i.e. all word forms have been annotated with part-of-speech information.

5.2.3.3 User- and Topic-specific n-gram-based Prediction:

The FASTY language model is adjustable to the language of specific users in two respects. It applies *short-term learning* whereby the words from the current text are dynamically added to user-specific uni- and bigram frequency lists. During prediction the user-specific frequency lists and the general frequency lists are combined using relative weights. In this way, new words that are repeated (e.g. proper names) can be predicted on their second occurrence. Further, the system will provide for *long-term learning*, by making it possible to permanently save changed user dictionaries from time to time.

Topic-specific words and expressions will be possible to generate from previously written, and electronically readable, texts.

The use of several user- and topic-specific lexicons at the same time will be allowed and all activated lexicons will be searched. Words and expressions with highest probabilities (naturally occurring as in the case of word bigrams, or adjusted as in the case of longer expressions and words coming from user- and topic-specific lexicons) will be offered in a prediction list.

5.2.3.4 Morphological processing and Backup Lexicon:

As stated above, the part-of-speech n-grams provide means to account for larger contexts by representing the distribution of word forms at a generalized level. For this to work though, the language model requires information about the part-of-speech of each word form. Further, the grammar module, described below, bases its analysis on a morpho-syntactic description of the input word forms. Put together, the FASTY language model needs some kind of lexicon, providing all relevant information. Retrieving information from a huge lexicon may be very time-consuming, even though it is done automatically. Special care has therefore been taken to provide a storage format that is easy to search and further, that makes it possible to compress the enormous amount of data to a manageable size. Such an implementation was provided as a prototype at the initiation of the project. During the second project year it has been upgraded and adjusted to suit the FASTY language component. Further, the morphological data required has been gathered for all FASTY languages. This was done with very different tools, whatever was available for each language.

5.2.3.5 Abbreviation Expansion:

Abbreviation expansion is a technique in which a combination of characters, an *abbreviation*, is used to represent a word, a phrase or a command sequence. Whenever the user types a predefined abbreviation, it is expanded to the assigned word, phrase or command sequence. During the second project year the abbreviation module has been integrated in the prototype language component. The integrated version has the following basic functionality:

- given a prefix, all abbreviation codes starting with that prefix are returned
- given an abbreviation, the expansion string is returned
- given an abbreviation and its expansion the system stores that abbreviation in an abbreviation table

Lists of useful abbreviations are to be entered by the user or its care person.

5.2.3.6 Grammar checking as a filter of suggestions:

The FASTY language component is further based on a grammar-checking module. While the n-gram based prediction modules never consider contexts exceeding a limited number of words, the grammar-based module may take an arbitrarily large sentence fragment into consideration. The grammar module does not by itself generate any prediction suggestions, rather it filters the suggestions produced by the n-gram model so that the grammatically correct word forms are presented to the user prior to any ungrammatical ones.

Input to the grammar module is a ranked list of the most probable word forms according to the other language components. The grammar module will assign a value to each word form based on whether the word form is confirmed (grammatical), turned down (ungrammatical) or outside the scope of the grammar description. Based on these three values the word forms are then reranked whereby the grammatical suggestions are ranked the highest and the ungrammatical are ranked the lowest. Since only a subset of the reranked suggestions will be presented to the user, the lowest ranked word forms will not be displayed. This way grammatically impossible suggestions will hopefully not be presented at all, leaving room for possibly intended continuations.

The grammar descriptions are however not complete but cover selected constructions that are identified as crucial from a prediction point of view for the individual languages of the project. Typically, they contain constructions with fairly fixed word order and feature constraints. Examples of such constructions are nominal phrases, prepositional phrases and verbal clusters. Sentence initial position and the placement of the finite verb are further focal points. Grammar rules have been written for all FASTY languages, albeit grammar rules will be further developed during the third project year.

For a system to analyze input texts in relation to a grammar description, special software is required; a *parser.* This was supplied by the Swedish partner at the initiation of the project. A description of the core parsing engine used in the project can be found in [8]. In most applications though, a parser takes whole language structures as input (usually sentences). In the context of word prediction, the parser must allow for language structures that are about to be produced and thereby only are fragmentary. In other words the parsing process must be step-wise and there must be means to dynamically output the analysis made so far. During the second project year, the parser has been adjusted to these conditions and made compatible with the rest of the FASTY system.

5.2.3.7 Compound prediction:

In three of the FASTY languages: German, Dutch and Swedish, compounds constitute a group of words that is particularly hard to predict within a word prediction system. In these languages compounds can be productively formed to fill a contextual need. It is of course impossible to predict such a word formation by means of traditional n-gram frequency counts. On the other hand, compounds tend to be long words, which means that successful prediction would save a great deal of keystrokes. Within the FASTY language model, compounds have hence been given a special treatment. Since compound prediction is a true innovation in word prediction systems, the way how to infer new compounds from the input evidence, has been subject to research. The solution has been not to predict a productively formed compound as a whole, but to predict its parts separately. More specifically, the current implementation supports the prediction of right-headed nominal compounds, since these, according to a corpus study of German corpus data, are by far most common.

The split compound model provides two quite different mechanisms for predicting the respective parts of a compound, i.e. modifier (the left hand side of a compound) prediction and head prediction (the right hand side of a compound). Below we will give a simplified description of how the model functions. Since the system has no means of knowing when a user wants to initiate a compound, the prediction of modifiers is integrated with the prediction of ordinary words. If the user selects a noun that has higher probability of being a compound modifier, the system assumes this use was intended and starts the prediction of the head part instead of inserting the default white space after the selected noun. The head of a compound determines the syntactic behaviour, and the basic meaning of the compound as a whole. Hence, we may expect a productively formed compound to appear in the same type of contexts as the head does when it functions as an independent word. When predicting the head, the system therefore makes use of the word preceding the modifier, as if the modifier wasn't there. Assume the user has written *en god äppel (a tasty apple),* and intends to write *en god äppelpaj (a tasty apple pie).* When searching for possible compound continuations, the system will then search for bigrams with the first position held by *god,* and if the training corpora contained instances enough of the sequence *god paj, paj* is suggested as a possible head of the compound. Further, the head prediction model gives precedence to words that, in the training material, functioned as heads in many compounds. According to studies of German and Swedish compounds, some words occur much more often in compounds as heads, than other words. A secondary feature that has been explored, is the semantic relation between the modifier and the head. If the semantic class of the modifier is known (for instance *apple* above may be assigned to a class containing fruits and berries), this information may be used to search for probable heads (following the given example these may be words belonging to classes of baked and cooked things).

During the second project year this approach has been settled and specified, software has been implemented to extract the statistical material and the statistical data has been gathered for German, Dutch and Swedish. The semantic classes have been approximated by automatically extracting information on how words co-occur in corpora, and the probabilities of semantic classes to join in compounds have been estimated on the bases of how they co-occur in attested compounds. The semantic classes have, so far, only been obtained for German and Swedish, but a tool for automatically deriving these statistics has been implemented.

5.2.4 Interaction of components and control structure

The operation of the Language Component (LC) is driven by the User Interface (UI). Depending on the request type, the LC returns one or more values as a response to the UI (e.g. the *n* most likely predictions).

A central part of the interaction between LC and UI is the *Context Box*. The role of the context box is to provide a repository for the context data needed by the prediction component. The context box contains textual data that may be manipulated by the UI via interface functions and LC-internal data structures that are not visible to the outside. The size of the context box is limited, it is only big enough to store the context needed by the predictor. It is not intended to be a cache of the whole file the user is editing. (If such caches are needed for some reason they should be handled separately by the user interface).

To manipulate the content of the context box, interface functions are provided to:

- extend the context box by a character (or a string)
- remove the last n characters from the context box. Note that for syntactic constraints on prediction the current sentence is sufficient as context.
- clear the context box
- replace the whole context by a string
- insert an accepted prediction into the context box. This amounts to removing the prefix and inserting the selected string.

At any time the content of the context box changes, the relevant portion of it's text buffer is (re)tokenized.

The *Controller* receives requests from the User Interface and is responsible for:

- Extracting the input data required for the different prediction components from the Context Box
- Selecting which prediction components to use (depending on the current parameter settings)
- Feeding the different prediction components with the appropriate input
- Possibly enriching the Context Box with data returned from some components (e.g. part-of-speech information)

The *Prediction Generator* receives the predictions made by the different components, together with their probabilities, and combines them to a prediction list which is delivered to the User Interface. How the Prediction Generator comes up with the combined prediction list depends on:

- Parameter settings, which may be user and language specific. E.g. compound prediction may not be useful in French and every user may want to use his or her own abbreviation table.
- Interpolation weights that have to be determined empirically.

Each of the components relies on language specific resources, where some are shared between different components. Also the possibility exists, that a component uses the results of other components, e.g. grammar-based prediction uses compound analysis and morphological processing.

See further [3].

5.2.5 Speech Synthesis

For users with dyslexia or other language impairments, it may be hard to recognize an intended word form among the prediction suggestions, since there may be problems distinguishing similar words from each other. The same may hold for users with bad eyesight. Therefore most of the current word prediction systems on the market make use of a speech synthesizer, providing an audible presentation of the suggested word forms.

The speech synthesizer used in the FASTY system is a concatenation of a grapheme to phoneme converter (a program translating letters to a phonemic representation) and a phonetiser that converts phonemes into sound.

The conversion from letters to phonemes, is based on a so-called decision tree; a machine-learning algorithm stemming from the field of Information Theory. By means of this technique, rules stating how letters should be mapped to phonemes may be inferred automatically from a training dictionary in which word forms are listed along with their phonemic descriptions.

The award winning MBROLA phonetiser, made available through the Multitel partner, performs the second conversion, from phonemes to actual sound. MBROLA bases its speech synthesis on diphones, which means that it takes into account how the pronunciation of a phoneme is influenced by the preceding and succeeding phonemes. More information on MBROLA synthesizer may be found at http://tcts.fpms.ac.be/synthesis/mbrola.

5.3 User Adjustment Tool

Before a user starts working with the FASTY system, it has to be adjusted to his/her specific needs and situation. The adjustment consists in the setting of a large number of parameters and options. This is not a trivial task, and it will be carried out in co-operation between the primary user and the carer. The Adjustment Tool (AT) will offer support in this process. It provides two modes, a simple one for beginners, and a more sophisticated one for advanced users.

The Adjustment Tool will contain some functionality based on functions of the User Ability Assessment Tool, but it will also contain extended features. The user runs a set of tests and answers some questions, which are intended to provide a picture of her abilities. The results are used to make settings in a first run. Those settings can be fine-tuned manually with increasing practice and experience. The user-presentation of the parameters will be divided into some user-modes like easy, medium and expert. This model ensures that all parameters may be changed. At the same time, inexperienced users will not be bothered by them.

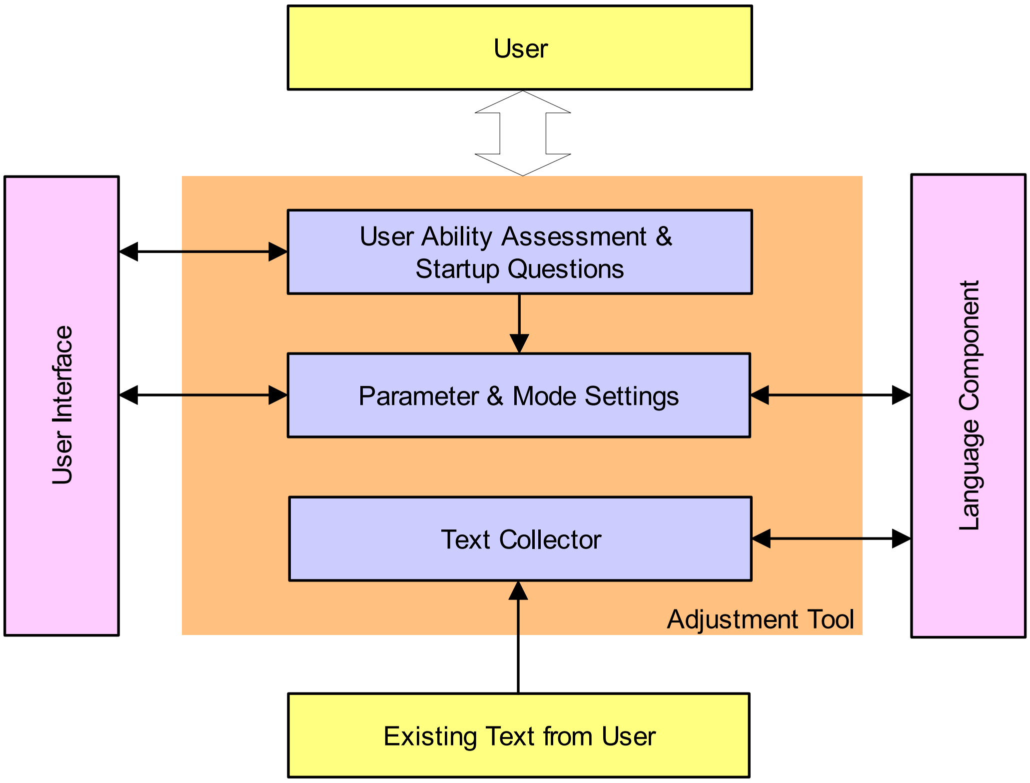

Fig. 4: General Structure of the Adjustment Tool

5.4 Developer tools

As mentioned above, the FASTY system comprises four developer tools, i.e.

- a user ability assessment tool, UAAT
- a text collection tool, TCT
- a user simulation tool, UST
- a simple word prediction tool, SWP, for the developers of the language component

5.4.1 User Ability Assessment Tool (UAAT)

A User Ability Assessment Tool (UAAT) was developed to collect data about basic user performance, such as typing speed, or reaction time. The program supports standard input devices as well as special input devices connected via serial port and some prototypes of pressure sensitive input devices developed by IKuT. The collected information is used to determine the applicability of further tests to the situation of the user. It is also used to get an impression of the user's current hardware and software status and the way text input is written.

The results from the questionnaires and the User Ability Assessment Tool do not show a uniform picture of the potential users. There is a wide variety of abilities and demands. Although FASTY will not contain communication assistance, the desire for an appropriate support was expressed.

5.4.2 Text Collection Tool (TCT)

During the second project year, the collection of texts produced by potential users was completed. The objective has been to create a linguistic resource reflecting the language used by the target users - a resource that has been used to supplement the standard project corpora in the compilation of linguistic resources. The texts have primarily been collected from members of the user panel by means of the Text Collection Tool (TCT) that was developed during the first project year. The TCT eases the collection process by automatically retrieving relevant textual material from the hard drives of target computers. In order to protect the privacy of the participating users, the TCT replaces personal data, such as names and addresses, with neutral tags. Apart from texts retrieved from the members of the user panel, texts have been collected from the Internet, which has been searched for websites maintained by motor impaired persons. The resulting text collection comprises more than nine hundred text samples in German, French and Swedish. Throughout the collection process special care has been taken to fulfil the ethical guidelines.

5.4.3 User Simulation Tool (UST)

A user simulation tool will help the user interface and language component developers to evaluate different algorithms and settings. Later commercial versions may help carers to find the best settings for the primary users in an iterative way without burdening the primary user herself with the testing of all possible settings and options.

The UST is composed of both hardware and software parts. The hardware part is used to simulate input from special input devices connected to a serial port. Below is a picture of the hardware part.

Fig. 5: UST Hardware with removed cover

5.4.4 Word Prediction Tool for Developers (SWP)

As should be clear from the description of the language component, the FASTY system bases its predictions on several linguistic sources, out of which word form frequencies are only one. During the development of the language component it has therefore been vital to have a test bed for experimenting with the effect of the different language models. Along with the progress made in compiling the linguistic data and the implementation of the different language models, a development tool has continuously been updated. This (dynamically changing) tool, labeled A Simple Word Predictor (SWP), has been in daily use at the three language development sites (ÖFAI - German, MULT- Dutch and French, UU-Swedish). By means of SWP, baselines for the core functionality for the four languages have been set in terms of keystroke savings for different parameter settings of the program.

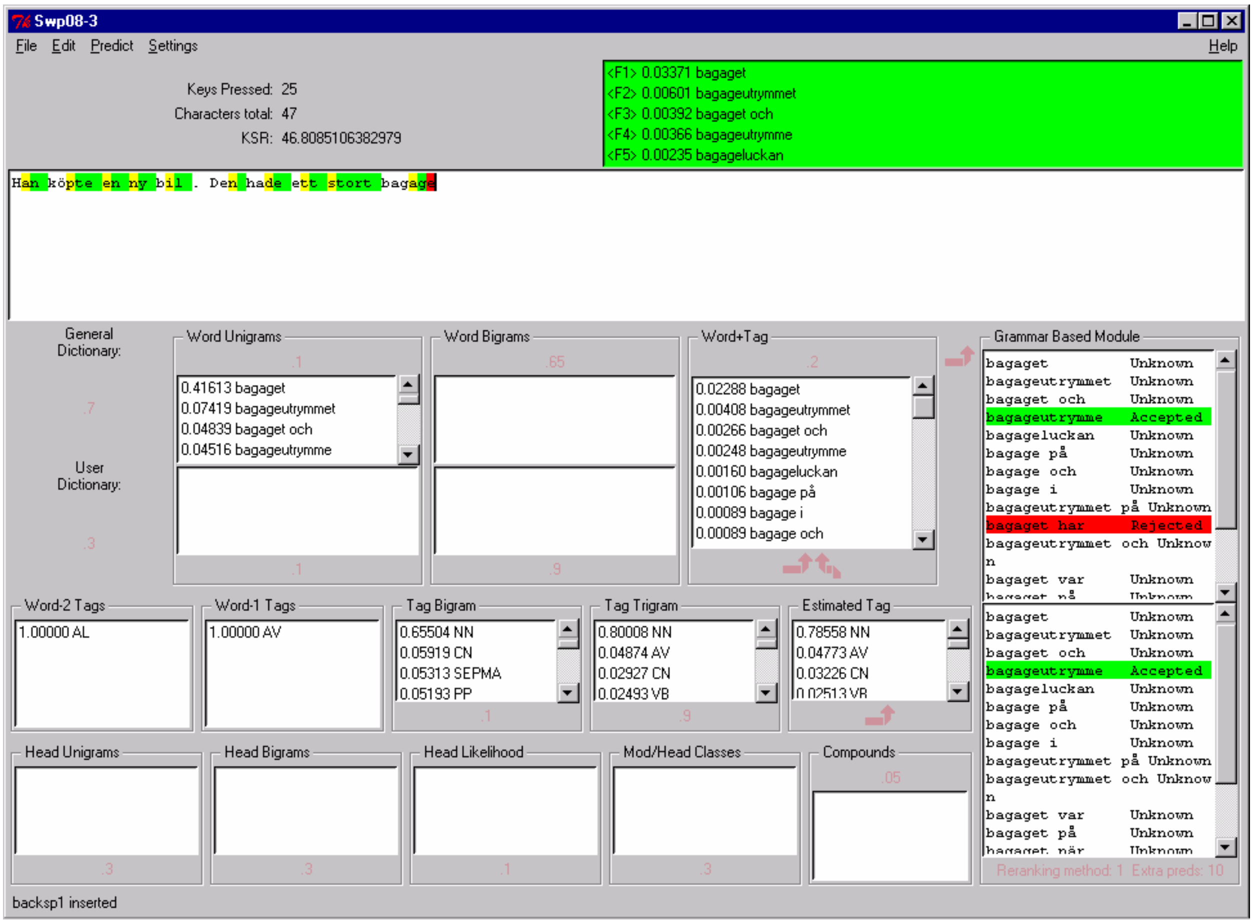

Fig. 6: Screenshot of the SWP

In its final state SWP provides for

- word n-gram based prediction
- part-of-speech n-gram based prediction
- a morphological backup lexicon
- compound prediction
- combination of a (dynamically learning) user dictionary
- grammar checking as a filter of predictions
- a parameter configuration file
- a user dictionary

The effect of the different language models may be viewed in the different windows at the lower part of the graphical interface as letters are entered via the keyboard. Furthermore, prediction parameters can be easily changed and a prediction simulation facility allows for examining the effects of different parameter settings on large batch files.

6 User involvement

6.1 User abilities, preferences and needs

The aim of the report on “User Abilities, Preferences and Needs“ [9] is an in-depth analysis of the abilities, needs and preferences of potential users. In particular to investigate the potential user's knowledge and needs with respect to word prediction and related tasks were important information when defining the functional specification of the FASTY system.

In the beginning of the project a potential user pool consisting of 58 primary and secondary users was set up by the partners FTB, ELI, IKuT, FUNDP, IGEL, MULT and FORTEC.

Two questionnaires were developed; a **User Description Sheet** (UDS) to be able to choose appropriate participants for this investigation and an extensive **User Questionnaire** with regards to the preferences and user needs in view of word prediction. The User Questionnaire also includes sections about the handicap, the software and hardware used, PC usage and typing, and the readiness to be involved and to support FASTY.

The results of the questionnaires are summarized below

- Nearly 75% of the primary users have mobility problems, where some have extreme difficulties in PC operations. Half of the users have difficulties in communication.
- More than a third of the users do not use a standard mouse or a standard keyboard. Nearly half of the users do not operate the keyboard with both hands.
- Nearly all users will use the word prediction with MS Word or another word processing software. One third will use it also for Internet applications.
- Approximately one third of the users are still working with Windows 95. The remaining group is working with Windows 98 or higher. The primary users are working with older and slower hardware than the secondary users.
- 70-80% of the users are ready to be involved in or to support FASTY. Only half of the users are willing to supply private or office text for text collection and text collecting tools.
- About half of the primary users know word prediction programs even if they do not use them. Only a few users have some concrete ideas about word prediction.
- The majority of the users think that a program with word prediction should be useful for them. They expect to type faster and to write correct sentences.
- Users want the insertion of predicted words to be as automatical as possible. It is important that the predictor inserts not only the chosen word, but also for example a space after a predicted word and after punctuations. Abbreviation expansion as well as automatic capitalization after punctuations is also desirable.
- The users want to choose a prediction using the function keys or the input device. The selection list should contain at least 1 or 5 predictions but no more than 10. The number of words in a prediction string should be adjustable.
- Grammar checking is desirable for a great majority of the users.
- One third of the users want opportunities of audible feedback.
- It is important to the users that new words are added automatically to the dictionary which should be editable.

6.2 Ethical Aspects

The Report on Ethical Aspects [10] describes the actions and efforts that have been and will be taken to assure an appropriate ethical standard in the FASTY project and will serve as a guideline. The Community Directive on the protection of individuals with regard to the processing of personal data and on the free movement of such data (Directive 95/46/EC) together with the opinions of the European Committee of Ethic (ECE) have been the basis for this report.

The variety of subjects includes the behaviour towards the other partners involved in the project as well as the handling of collected data such as user questionnaires, user ability assessment data, and text samples. Since sensitive and confidential data is involved special care has to be taken in protection of the privacy of the participating persons. Particularly persons suffering from any kind of communication disorder, which is one of the target groups in the FASTY project, deserve in general a high degree of protection.

All data should be transformed and kept in a form, which avoids a trace back to a specific user or permits identification of a specific user for no longer than is necessary. This was a guideline in the development of the Text Collection Tool that was mentioned above.

7 Technological Implementation

7.1 Technological implementation plan

The Technological Implementation Plan summarises the results that have and will be achieved in the project. A midterm draft plan for FASTY is available.

By the middle of the second year of the three-year plan, the following was achieved:

- The prototype of a User Ability Assessment Tool (UAAT) has been developed for testing purposes.
- The prospective users have been contacted and the user panel has been founded.
- A first rapid prototype has been developed, in order to give the potential users a view of the ideas.
- A FASTY web-site has been created (available in English, German, French, Dutch and Swedish) and can be accessed under http://www.fortec.tuwien.ac.at/ fasty
- A FASTY folder has been created (available in English, German, French, Dutch and Swedish).
- The first edited annual report was published and is additionally available online.
- A prototype of a pressure sensitive keyboard (FASTY Box) and pressure sensitive single sensors are available for testing and gaining first data.
- The internal structure of the FASTY system was developed together with the interfaces between the modules and their basic functionality.
- The first version of a user simulation tool is available.
- A Text Collection Tool has been developed which helped to collect and anonymize user text.

- A huge amount of user text (from disabled users) and general text has been collected for linguistic analysis.
- A detailed definition of the Language Component was developed.
- A prototype of the language components has been developed and language resources for all supported languages have been created.
- A SAPI Interface for speech output has been developed.

8 Dissemination and PR Activities

During the second project year, the FASTY partners have continued to carry out several activities for the dissemination of the expected results of the project and the benefits of the future use of its results.

8.1 Project presentation on the web

There is a presentation of the FASTY project on the web at the following site:

http://www.fortec.tuwien.ac.at/fasty

The presentation is available in English and further, for all FASTY languages. During the course of the project some minor changes have continuously been done and during the second project year a major upgrade has been undertaken. Fig. 7 shows a screenshot of the current English version.

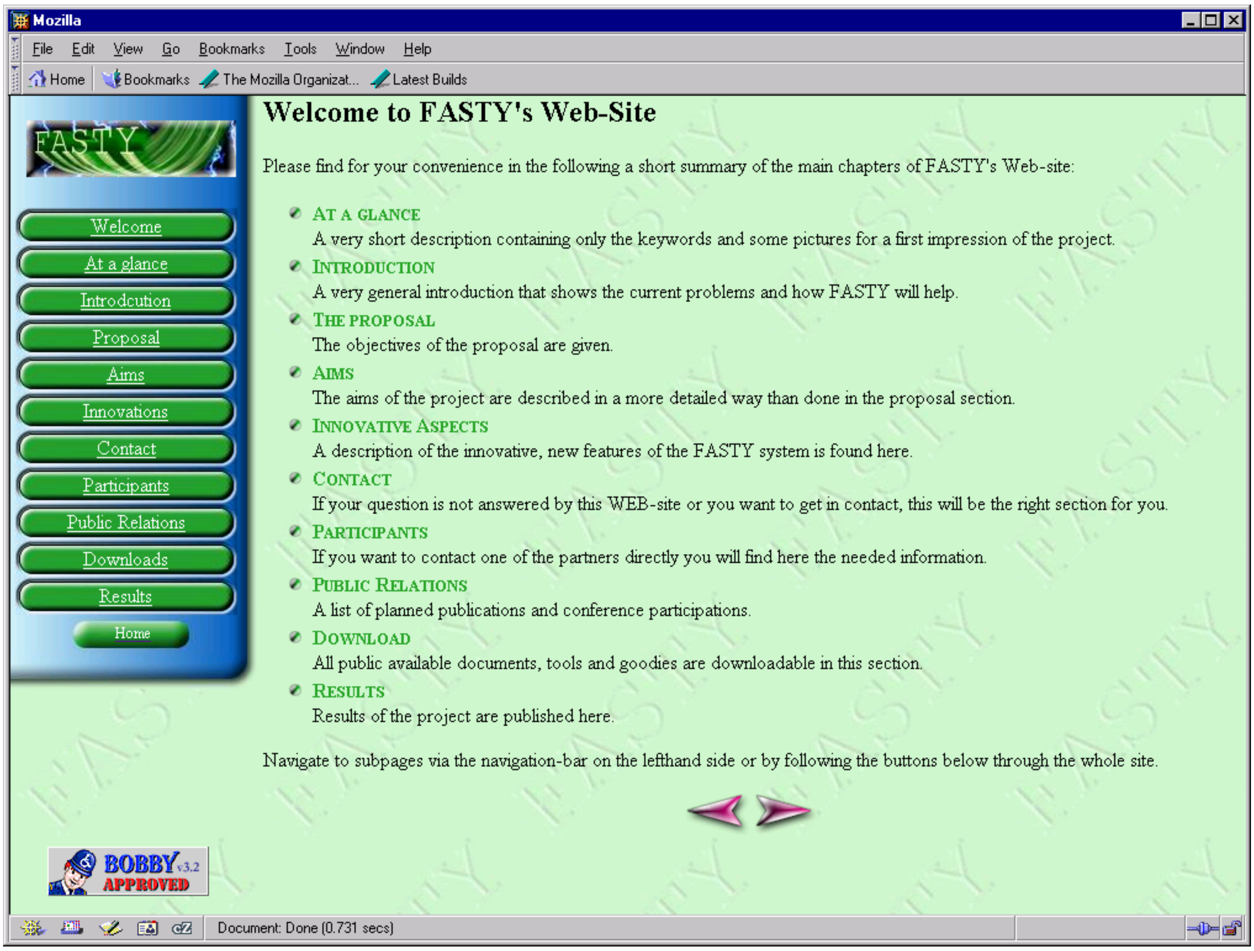

Fig. 7: Screenshot of the current English start-page of the FASTY website

8.2 Project Folder

A colourful Project Folder, with an overview of the objectives and features of the project, has been issued in English as well as in the FASTY languages and distributed at meetings, conferences and workshops. It is available for download at the FASTY web site (http://www.fortec.tuwien.ac.at/fasty). During the second project year it has been revised to better mirror the current state of the project.

8.3 Project presentations

During the second project year the FASTY partners have participated in several conferences and other events, as detailed below:

- Workshop with user trials at FTB, 11 April 2002
- Workshop at Modem , 24 April 2002
- Presentation of KeyboardBox to Creth, 6 June 2002
- ScienceWeek@Austria, 14-16 June 2002
- Presentation at the Special School of Saives, Belgium, 2 July 2002
- ICCHP, Linz, Austria, 15-20 July 2002
- ECAI, Lyon, France, 21-27 July 2002
- ISAAC, Odense, Denmark, 10-15 August 2002
- COLING, Taipei, Taiwan, 26-30 August 2002
- Presentation at service of help center for integration of disabled children, Mons, Belgium, 13 September 2002
- Presentation to occupational therapist, Namur, Belgium, 19 September 2002
- Workshop with the team of Creth concerning input devices, 26 September 2002
- Integra, Altenhof, Austria, 25-27 September 2002

And the following articles about FASTY have been accepted and presented at conferences:

- "Wordform- and class-based prediction of the components of German Nominal compounds in an AAC system", ICCHP 2002 and COLING 2002
- "Predicting the Components of German Nominal Compounds", ECAI 2002
- Overview of the FASTY project in the ELSNews issue 11.2 (2002)

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[9] D4.2 User Abilities, Preferences and Needs – FASTY 2001

[10] D4.3 Report on Ethical Aspects – FASTY 2001

APPENDIX

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