A speech based Menu System for a Navigation device for the blind

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ABSTRACT
The present paper describes a step in the design of a navigation device for the blind. More specifically, the speech interface of a navigational stick is developed, supporting its menu function. The design process is described and the task analysis while interacting with the menu is provided. The steps followed in evaluation and redesign process of the menu are presented, as well as the findings of the respective user tests. Finally a discussion concerning the efficiency and effectiveness of speech interfaces is presented, based on the findings of this study.

Author Keywords
Navigation, blind, speech based menu, visually impaired, GPS

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous. H.5.1.c Audio input/output

INTRODUCTION
The present paper describes a step in development of a study to evaluate navigation modalities for the blind. The study aims to test and compare the major available modalities for non-visual navigation. These modalities include a tactile arrow mounted on a stick which moves in the direction that the user is supposed to go in [1]. Another modality is audio navigation [2] and lastly, a haptic device with vibrators [3] which can be worn as bracelets or belt and which signals the users of the direction using directional vibration. For all of the devices described above, an input system is needed. The most popular ones in this field are Speech and Braille input systems. But, the number of blind people who can read or write Braille is decreasing progressively [4] and thus the present study is focused on speech as the input into the navigation device.

DESIGN PROCESS
An iterative process was used to come up with the design. Since blind users were not available, the literature regarding the blind navigation systems and the participants with normal eye-sight were used to test the system.

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Task Analysis
The menu system offers four basic functions, separated into several sub-menus and accessed by a main menu. There is also an expert mode available, which was designed but not implemented in our prototype, where the user interrupts the system and issues commands. Also due to technical constraints, the barge - in function was disabled while implementing the system and the tests were performed without it. Complete diagrams of the task analysis are presented in Appendix A.

Main Menu
The user is prompted to choose between navigation, bookmarking, browsing routes and changing settings.

Navigation
This function allows the user to input a destination and navigate to that destination with an optional via point, which is a secondary destination imported in the route. The user is prompted to state the requested destination, and if necessary, the system solves ambiguity regarding the destination input by user by asking for clarifications. An example of this would be a case when the user asks to be navigated to the station. Then the system asks whether the participant meant train station or bus station. Of course, the characterization “train station” is still not unique in a real world context, but for the sake of testing, we assumed that it was. In an actual implementation, a unique characterization would be the full address of the requested destination, or in the case of stations, parks and other similar points of interest, the destination would be adequately characterized by a subset of its address, until the point one cannot be any more specific about it. For example, since there is only one Eindhoven Main Bus Station, when such a destination is input by the user, the remaining parts of its address can be omitted.

After solving any ambiguities concerning the main destination, the system proceeds to asking the user whether he or she wishes to be navigated to the main destination, via a secondary destination i.e. a “via point”. This secondary destination is represented uniquely in the system in a manner similar to the main ones, as described above.

After the system has prompted for the use or not of the "via point", it proceeds to the verification of the route. This is done in an implicit way, by stating the beginning of the navigation to the requested destination via the selected "via point", if present. This statement gives time to the user to cancel the action before actually entering the navigation mode.

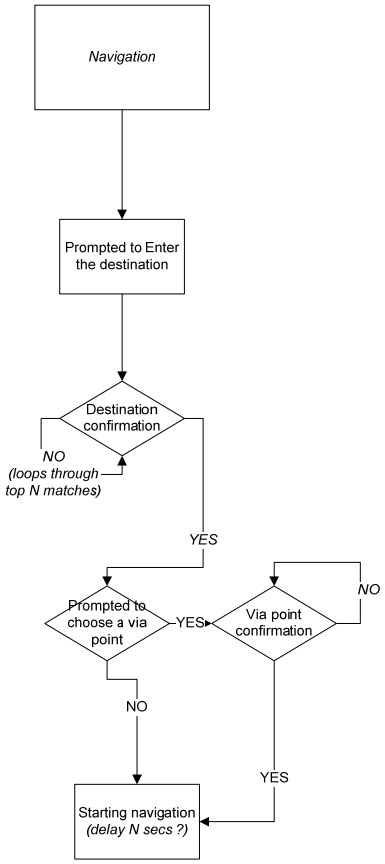

Figure 1. Task analysis flowchart for the function Navigation

On the other hand this function offers verification without the addition of a dedicated dialogue for this purpose. The task analysis flow chart for the Navigation function is presented in Figure 1. Error handling is present at any given point of the menu and will be described in the respective chapter.

Bookmarking

This function allows the user to store a given point of interest that he or she might encounter on way to the destination. This point can be retrieved later using the bookmark retrieval function.

When requesting the bookmark function, the user is prompted whether he/she wishes to "create" or "retrieve" a bookmark. If he/she wishes to create one, then the system requires a short name to be recorded which will serve as the identifier of the bookmarked place. Following this, the system provides the user with an option to record an audio message, so that the user is able to associate the bookmark with a representation in the form of sound. The idea behind this specific function is based on the assumption that sound is a means to achieve recollection of natural places, in a context where sight is not available. Recording of message is confirmed explicitly and the time and the location of the place of interest are announced as well. An option to play the message is available here as well. Going back one level, if user wishes to retrieve a bookmark, he/she is prompted for the name previously assigned to it and if there is difficulty in recalling it, a list of the stored bookmark names is available upon request. When a match is achieved, the bookmark is played along with the title, location and time of storage with the optional audio message.

Browsing Route

This function allows the user to listen to a specific stored route in the form of an overview, as if being navigated through it. For this, an origin and a destination are required inputs, which can be already stored destinations or bookmarks. After the user inputs both origin and destination and any related ambiguity is resolved, the system starts describing the route to the user.

A related feature that was neither designed nor implemented, since its value was not unanimously agreed upon, was the possibility of skipping to places of interest, while browsing through the route. For example, the user could skip some steps of the description of the route and hear the directions associated with a specific point of interest or its location. This function though could not be fully developed and described in the given time and the software that was used did not allow its implementation in a simple way, so it was omitted from the design.

Changing Settings

This function allows the user to change the language, increase or decrease the volume and to mute the speaker. This is done by navigating through an initial menu, where the user is prompted to select one the functions above, and by providing feedback when the respective action is performed.

Expert mode & barging in

This mode allows more experienced users to perform actions more efficiently, without having to navigate through all the menus and sub-menus. This is more of an option than a function as the dictionary recognized by the system does not differ in this case, what only changes is that the commands can be issued right after entering the menu and thus actions take less time to be completed. The ability to barge - in is necessary in this function, as the user should be able to interrupt the system and issue a command at any time. For example, an interaction for navigation to a destination in the normal (novice) mode would be as follows:

- *Menu.*

- *Do you want to navigate, bookmark, browse route or change settings?*

- *[I want to] navigate.*

- *Please state you're destination.*

- *[To] station.*

- *Did you mean train station or bus station?*

- *Train station.*

- *To include a "via point" say the name of the point otherwise say "No".*

- *[Via] park.*

- *Starting navigation to train station via park. Estimated time: 10 minutes.*

While the respective interaction for the expert mode would be as follows:

- *Menu, ...*

- *Do you ...*

- *... [I want to] navigate to train station via [the] park.*

-*Starting navigation to train station via park. Estimated time: 10 minutes.*

Square brackets denote optional words that are not evaluated by the speech recognition even if recognized. Triple dots denote interruption of dialogue. An expert mode was not implemented into our prototype.

Error Handling

In order to be able to recover from errors, three error handling commands are designed. These include the repeat command, the cancel command and the menu command. With the repeat command, each audio message can be repeated upon request. With the cancel command, the current action is canceled and data created in the process of the current action are ignored, while the user returns to the previous step of the task analysis. With the menu command, the user is able to return to the menu in any part of the interaction, except for when he/she is prompted to record messages. In the case of the menu command, data created during the interaction are also ignored. The commands menu and repeat were implemented, whereas the command cancel was not.

Additional functions

Three additional functions designed but not implemented in the prototype are, the command "Where am I?", using which the user listens to his/her current location, and the battery function, where the battery status is announced. Lastly, a general function that included help messages spoken to the user in case of difficulty while interacting with the system was designed, but only implemented under Navigation task, specifically while importing "via points".

User Evaluation and Redesign

The first step in the study was testing the interaction flow of the menu with the participants using an adapted "Wizard of Oz" method. It was explained to them that though this menu is being developed for use in a test with blind participants, they should imagine as if they are interacting with the speech menu of a usual GPS navigation system. The flowcharts used for this study are presented in Appendix A. The first iteration of Wizard of Oz was carried out with two participants. One experimenter acted as the "wizard" while the other took down observations. The participants were asked to go through 5 different scenarios which can be found in Appendix C. They were asked to go back to the Menu after completing each scenario. The experimenters had also compiled a list of dictionary words that would be recognized by the system to allow a book-keeping of any new words added to it. The main comment received from the participants was that the welcome message and main menu description was too long. They liked the option to Cancel or go back to the menu at any time during the interaction. Also, some additional words like "right" to confirm an action were added to the dictionary. The complete list of findings can be found in Appendix F.

After the first iteration, the main menu was split into two steps and this solved the problem of a long welcome message. A beep was added to the system at this point because the participants seemed to be waiting for a prompt to start inputting information. This was also useful in maintaining consistency with the rest of system for example while recording the audio message or the title for the bookmarks, the users waited for a beep. Also, an option to repeat a statement/command was added to the design. In addition to this, some other small changes were made to the dictionary and some statements were re-phrased to make them more understandable. This was followed by second iteration of the "Wizard of Oz" to validate the additions and modifications to the previous design. The users were satisfied with the interaction and made comments that it should be possible to interrupt the system while it was talking, and issue a direct command. This possibility had already been considered in the design but as described above, due to the limitations of CSLU Toolkit and time constraints, it could not be implemented. The dialogue in the system was further refined after the second iteration of Wizard of Oz. All the above observations and recommendations were combined and used to develop a redesign which was implemented in CSLU Toolkit as described below.

Implementation

The tool of choice for the implementation was the CSLU toolkit, where it was possible to incorporate most of the designed features. The transitions between states used both dictionary and grammars, when more than one variable was expected in a voice command. In the beginning of the project, serious difficulties in dealing with the effectiveness of the tool were faced, since speech recognition performance was extremely poor. After overcoming the technical problems, the menu was implemented in a tree-like structure, with a common starting point, which led to

four different choices and the respective sub-menus. The functions implemented were very similar to the ones designed in the task analysis, with the exception of the expert mode, which was not implemented due to time constraints and recognition errors when the barging-in function was activated.

USER TESTING

The system developed above was tested with six subjects - two subjects in first iteration, one in second, two in third and one in the fourth iteration. All the subjects were working as research assistants in a university. Their ages ranged from 23-30. The number of participants was limited and thus no statistical conclusions could be derived but each of the iterations helped to elicit very valuable feedback regarding the design of the interaction. The users were provided with 5 scenarios similar to those in the Wizard of Oz and asked to go through them one by one. After the completion of the scenarios, they were asked for their comments or suggestions. Following this, the users were asked to complete a SASSI questionnaire [5]. During the first iteration the experimenters got an impression that the test participants were rating their interaction with the Speech Recognizer of the CSLU toolkit instead of rating the interaction with our system. This belief was further corroborated by user comments e.g. '…but I think that's the problem with the recognition', 'I am sorry, this doesn't understand me…it is very frustrating'. Also, the scores from the questionnaires did not provide the experimenters with any insights related to design as to why the participants were rating the interaction in a particular way. These observations prompted the experimenters to adapt the questionnaire to include lesser items and combine the questionnaire with an interview to elicit more detailed feedback. Only those items were selected for the questionnaires which were most relevant to quality of interaction and least affected by the quality of the speech recognition system of the toolkit. A compilation of responses collected using the SASSI questionnaire is available in Appendix E. Also, notes made by the experimenters during the interviews are available in Appendix F. The main findings in terms of the overall strengths of the interface and learning points are described below.

The test participants found the interface very easy to learn and they found it clear how to interact with the system. They also found the interaction to be informative but not "pushy". The participants used "help" with the "via points" and although the original design idea included "help" availability at every step, this could not be implemented completely as stated above, because of time constraints.

The results of the user tests were used to make several modifications to the interface at the end of each iteration. One of the participants mentioned that she could not understand "else" as pronounced by the system and confused this word with "and". Since the experimenters had designed the system, the utterances were clear to them, but at times participants could not understand the pronunciation of the speech synthesizer correctly. At this step the word "else" was replaced with "otherwise", to make the utterance clearer and later tests did not detect any remaining problems in this stage. One of the participants commented that she would like to hear a list of bookmarks since she may not remember the title of the bookmark stored by her several days ago. This resulted in addition of a function to retrieve the bookmark list. Further problems were located in the step involving the confirmation of Bookmark i.e. 'The place is bookmarked. To know where is it, say Location. Otherwise say Cancel'. The participants had problems understanding if the 'Cancel' would result in cancellation of the whole bookmarking process. After the first iteration, it was rephrased to make the storage of bookmark clearer but that still was not obvious to the participants. After the third iteration, the statement was rephrased to say the word "Exit" instead of "Cancel" and the participant in the fourth iteration did not have any problems interpreting this.

Furthermore, CSLU speech synthesizer's flat tone affected the interpretation of a question by one of the participants. The system asked 'Do you want to Create or Retrieve a bookmark' and since there was no stress on either Create or Retrieve, the user answered 'Yes', though later she realized it and easily completed the task successfully. This problem was solved by inserting a dot (.) before and after these words so that they may be recognized as separate sentences by the speech synthesizer and the emphasis could become clearer.

Further changes included the splitting of Browsing of a route to input the "Origin" in the first step and "Destination" in the next step because one of the participants had a problem phrasing the origin and destination in one step. This also confirmed to the consistent and clear step-by-step approach of the interface. There were several other minute details that helped in fine-tuning of the interface to accommodate various participants' needs. By the end of the last iteration, one major comment by users was that the system was useful and easy to learn, and that they would really like to interrupt the system.

DISCUSSION

A major factor affecting the design process was the choice of the speech recognition and synthesis software i.e. CSLU Toolkit. Although the toolkit is very easy to learn and use, these advantages are shadowed by its instability and poor resilience of the speech recognizer in noisy environments or with non-native American accents. Also, the speech synthesizer does not have a very clear pronunciation. The factors mentioned here affected the accuracy of the interaction which in turn affected the users' experience with the interaction. Thus, the experimenters had to choose accuracy over freedom and flexibility and this was commented upon by the users who wanted to interrupt the system and execute expert commands. Also, when asked if they would like to use this system, all subjects commented

that they find this system very useful and would use it, but only if the speech recognition is accurate and robust. Another trade-off that the experimenters found themselves making was regarding depth of the menu vs the efficiency and for the sake of clarity, at times, the number of steps had to be increased in order to allow for a clear interaction even if it takes a few seconds more. This appears to be a rational trade-off when the interface is to be used by novices but may not hold for expert users and thus again points to the need for an expert mode.

In particular, in context of the navigation device for the blind, while using a speech based menu is useful, it may at the same time raise some privacy related issues. For example, a person standing in a public place and talking and listening to a "stick" may attract attention that he/she does not appreciate and this may be stigmatizing [6]. An alternative could be, wearing a microphone to input speech commands but this requires wearing of an additional device. Wearing earphones is also not advisable for audio output as it interferes with the sense of orientation of the blind [7]. These issues require further exploration which is planned in future studies.

A robust speech interface is highly appreciated, although an expert mode is quite often sought for. This expert mode, although not put to the test, is assumed to be useful only when using the same dictionary as the non expert mode. The experimenters feel that such an expert mode should only differ from a non expert mode in the possibility for simultaneous input of several commands, rather than a step by step approach of inputting variables.

The experimenters felt that the iterative design process was very valuable in helping the design process of the speech interface, even though the iterations were in very small steps and with very limited number of users. This was supported by the view that once the steps are well understood and formulated, they can be later expanded in terms of time spent to design them and the number of users that were tested during them. Another point that emerged over the course of the study was that questionnaires with quantitative responses may not be as useful if there is no available baseline interface to compare against. Such questionnaires although can be very useful as guides for interviews with users in the initial stages of the design. Another finding that further illustrates the importance of user testing was that at times, the participants could not recognize the pronunciation of the words by the speech synthesizer in CSLU while it was very clear to the designers since they were used to it. This is not a revolutionary finding in any sense but such findings can act as argument-settlers in situations where the importance of user centered design needs to be demonstrated.

CONCLUSIONS AND FUTURE WORK

In conclusion, further developments are needed in the field of speech recognition before it becomes an accepted form of interaction with the interfaces. This can only be accomplished by development of robust systems and a seamless integration with other modes of interaction.

As a future work the addition of the aforementioned features which have not been implemented as yet, is suggested, in order to perform a user testing with the complete application and draw significant conclusions. This user testing should be performed in a larger time frame and with a larger number of subjects, so as to achieve higher confidence in the results. Additionally, the use of more advanced speech recognition technology is suggested, since the recognition rate of the CSLU toolkit is relatively poor and there is no training function provided other than the audio calibration. As stated in the scope of this study, a general goal of the researchers is to embed this speech interface into the prototype of a navigational walking stick for the blind. This iteration in the device's design cannot be performed unless some additional results are acquired and the technological issues faced in this case are solved.

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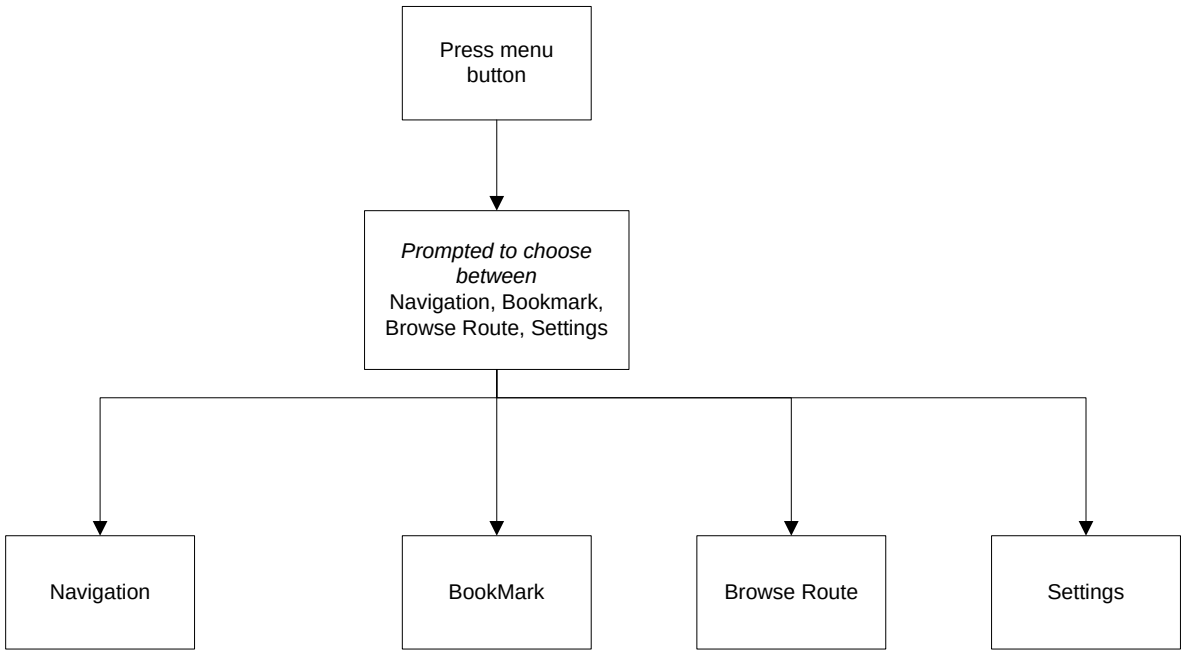
APPENDIX A

TASK ANALYSIS OF THE SPEECH INTERFACE

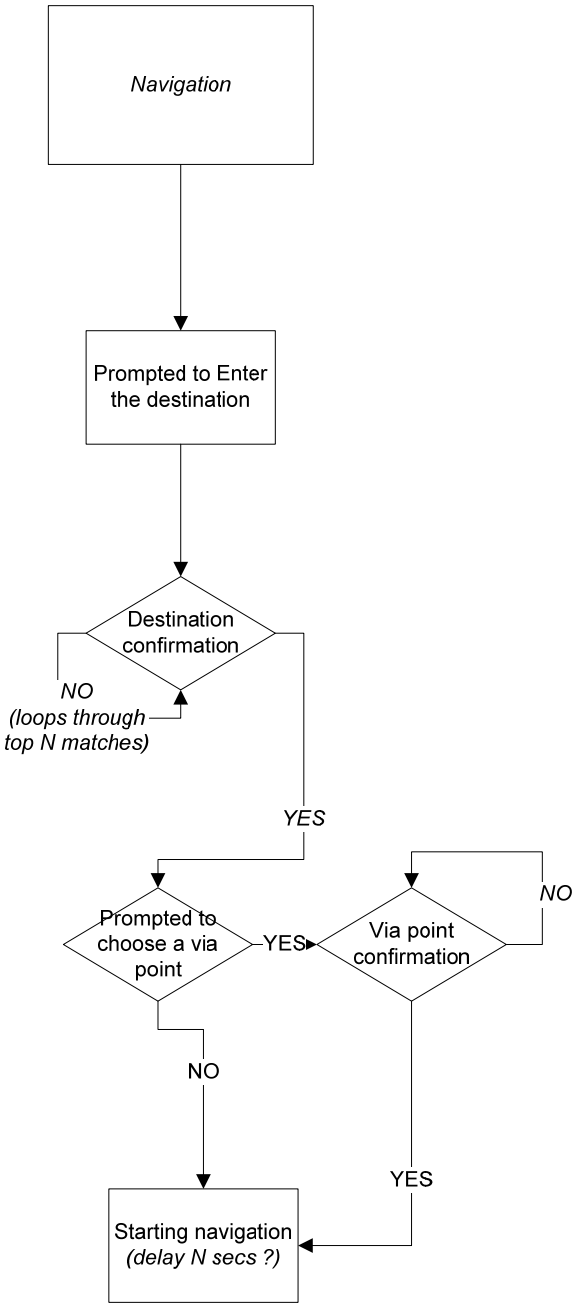
A(i) Main Menu



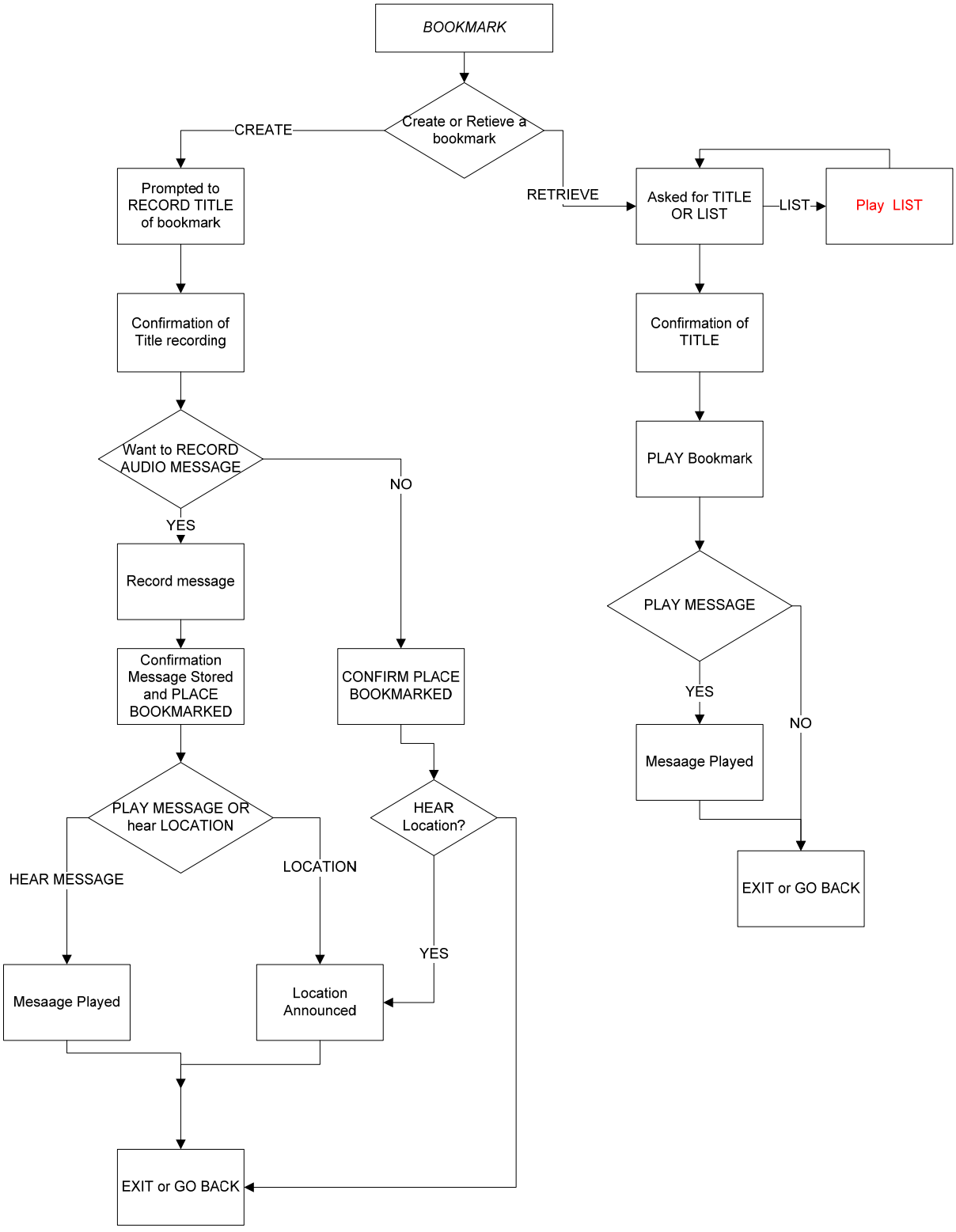
At any time the user can go back to main menu and ask

- **Where am I/Present Location** : to know his location (if applicable, w.r.t. to his current destination)
- **Battery** : To know battery status

A(ii) Navigation sub-menu

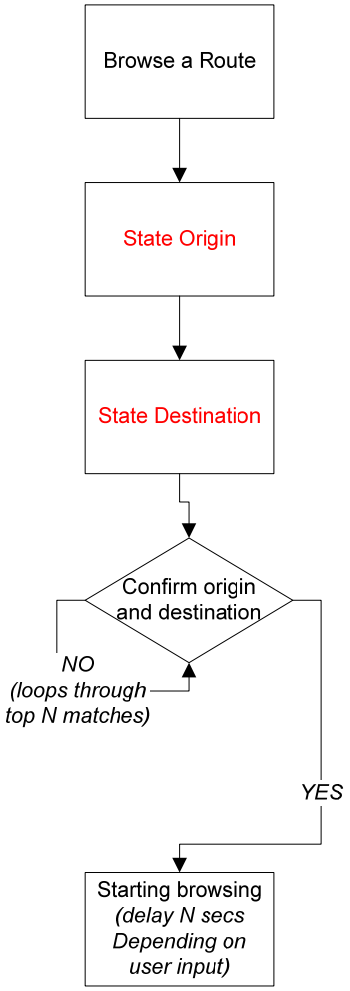


A(iii) Bookmark SubMenu



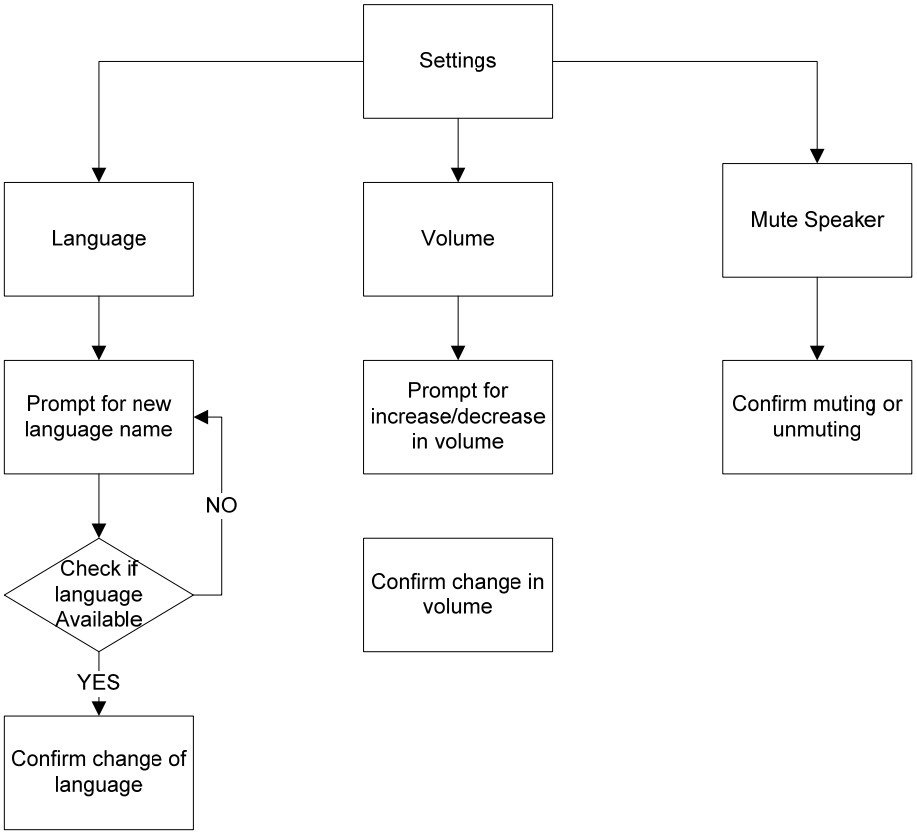
(The blocks in red text were later additions to the original design)

A(iv) Browse SubMenu



(The blocks in red text were later additions to the original design)

A(v) Settings submenu



APPENDIX B
Dictionary

- General
  - ✓ Yes
    - o Yup
    - o Yeah
    - o Ya
    - o Ok
    - o Uh huh
    - o Mhm
    - o Right
    - o That’s right
  - ✓ Ok
    - o Yup
    - o Yeah
    - o Ya
    - o Yup ok
    - o Yeah ok
    - o Uh huh
    - o Mhm
    - o Right
    - o That’s right
  - ✓ Continue
    - o Go on
    - o Yes continue
  - ✓ No
    - o Nope
    - o What? No!
    - o Uh uh
    - o M-m
    - o Nah
  - ✓ Cancel (spoken in any submenu – leads you one level up)
    - o Wait
    - o Wait no
    - o No
    - o Nope
    - o What? No!
  - ✓ Repeat
    - o Please repeat
    - o Come again
    - o What?
    - o Sorry
    - o Pardon
  - ✓ I don’t understand
    - o Don’t understand
    - o Sorry
    - o Pardon
    - o Please repeat

        - Come again
        - What?
    - ✓ Exit (spoken in submenus - leads you to the menu)
    - ✓ Exit menu
- [...] Menu [...]
    - ✓ [please/can you/would you/...]Take me to A/B/C (via B) [please/if you may/...].
        - A: Street [street/alley/boulevard/...] [number] Number [zip/zip code/...] Zip Code, City ((Google maps))
        - A': Street AND Street
        - B: Hot Spot (Hospital, Station, Pharmacy, Museum, Super market, Theatre)
        - C: Bookmark
    - ✓ [Make/Do] Bookmark [please/...]
        - *Listen/ Hear/... (?)*
        - *Where is it/this/that?*
    - ✓ Hear/Retrieve/Repeat/Play bookmark
    - ✓ [please/can you/would you/...] Browse A/B/C [please/if you may/...].
        - Forth/Forward/Next
        - Back/Backwards
    - ✓ Settings
        - Language D
        - Volume Up/Up/Loud/Louder/High/Higher
        - Volume Down/Down/Low/Lower/Low/Lower
        - Mute/Unmute
    - ✓ Current Location
        - Where am I?
        - What is here?
        - Present location?

APPENDIX C
Scenarios used for testing

Scenario 1

You want to navigate to **Down Town**, without a via point.

Scenario 2

You want to navigate to a destination but with a via point in between. So you want to go to **Canteen** and the via point is **Station**.

Scenario 3

On your way to your destination you come across an Orchestra in front of Bijenkorf. You want to create a bookmark titled '**Orchestra**' and record an associated message here.

Scenario 4

You want to retrieve the bookmark named '**Orchestra**'.

Scenario 5

You want to browse the route from "**station**" to "**restaurant**".

Scenario 6

You want to **mute** the speaker.

APPENDIX D
Adapted SASSI questionnaire

1. A high level of concentration is required when using the system

   Strongly Disagree *Disagree* *Slightly disagree* *Neutral* *Slightly Agree* *Agree* *Strongly Agree*

2. I enjoyed using the system

   Strongly Disagree *Disagree* *Slightly disagree* *Neutral* *Slightly Agree* *Agree* *Strongly Agree*

3. I felt in control of the interaction with the system

   Strongly Disagree *Disagree* *Slightly disagree* *Neutral* *Slightly Agree* *Agree* *Strongly Agree*

4. I was able to recover easily from errors

   Strongly Disagree *Disagree* *Slightly disagree* *Neutral* *Slightly Agree* *Agree* *Strongly Agree*

5. I would use this system

   Strongly Disagree *Disagree* *Slightly disagree* *Neutral* *Slightly Agree* *Agree* *Strongly Agree*

6. It is clear how to speak to the system

   Strongly Disagree *Disagree* *Slightly disagree* *Neutral* *Slightly Agree* *Agree* *Strongly Agree*

7. It is easy to learn to use the system

   Strongly Disagree *Disagree* *Slightly disagree* *Neutral* *Slightly Agree* *Agree* *Strongly Agree*

8. It is easy to lose track of where you are in an interaction with the system

   Strongly Disagree *Disagree* *Slightly disagree* *Neutral* *Slightly Agree* *Agree* *Strongly Agree*

9. The system didn’t always do what I expected

   Strongly Disagree *Disagree* *Slightly disagree* *Neutral* *Slightly Agree* *Agree* *Strongly Agree*

10. The system is easy to use

    Strongly Disagree *Disagree* *Slightly disagree* *Neutral* *Slightly Agree* *Agree* *Strongly Agree*

APPENDIX E
Item responses to the SASSI questionnaire (adapted)

	Round I	Round II	Round III	Round IV
Concentration	**1**	**2**	**6**	**6**
Enjoyed using the system	**2.5**	**6**	**6**	**5**
Felt in control of interaction	3	6	6.5	2.5
Easy Recovery from errors	**3.5**	**1**	**5**	**6**
Would use this system	3	1	6	4
Clear how to speak to the system	6	2	6.5	7
Easy to learn	5	6	6.5	6
Easy to lose track	**6**	**1**	**2.5**	**2**
Performed as expected	**2**	**6**	**4.5**	**6**
Easy to Use	5.5	6	6.5	7

- *The individual numbers are nor as useful as the trend in the numbers*
- *Round I & III : Scores are average of the two participants*
- *Round II & IV: Scores are from 1 participant*

APPENDIX F

NOTES FROM INTERVIEWS & OBSERVATIONS

F(i) Wizard of Oz

Round I

Subject 1:

- Stop intro everytime
- Does it Cancel my bookmark when I say cancel at the end of bookmarking?
- Switch the menu on/off

Subject 2:

- Include a beep tone
- Include Time/Distance update when confirming navigation
- Include location with directions while browsing
- Repeat Menu
- Where am I should also have a time/distance update

Round II

Subject 3:

- Wasn't sure about bookmarking but clearer once she got into the menu.
- Used the ' via point' help

Subject 4:

- Used the 'via point help'
- Some commands sounded long to her but were clear also

Subject 5:

- Include current destination/here as origin point
- Cancel at every step

APPENDIX F(ii)

System Testing

Round I

Subject 1:

- Easy to understand what to say
- But, the system recognition made it very frustrating for the participant to continue

Subject 2:

- She heard ‘else’ as ‘and’ in the step described below
  ‘To include a via point, state the name of the point else say continue’
- System did not recognize ‘Navigate’ very well
- Since the intonation of audio synthesizer is flat in the CSLU, the user answered yes to ‘Do you want to ‘Create’ or ‘Retrieve’ a bookmark’. Later, though she realized it and corrected herself.

Round II

Subject 3:

- She didn’t understand how to state the origin and destination of the bookmark
- Liked the ease of use
- She didn’t understand if Cancel cancels the whole bookmarking process
- It would be helpful to have a list of the bookmarks

Round III

Subject 4:

- Wanted to skip commands
- Expert mode?
- Liked the explicit commands in the system
- Would use it himself

Subject 5:

- Not sure if cancel cancels the whole bookmarking process
- Very clear menu
- Didn’t know about bookmarks but was clear once entered the menu

Round IV

Subject 6:

- Easy to use
- Clear menu structure
- Constrained