

COTTON TALK: A SPEECH INTERFACE FOR COTTON PLANT MAPPING

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Abstract

A speech interface for one portion of a crop management system was built in this project using the IBM™ Continuous Speech Series (ICSS) speech recognition toolkit. The purpose of the project is to explore the utility of speech input for a time-consuming data entry task, such as cotton plant mapping. Many issues related to usability were considered in the design and implementation of this speech interface, including learnability, efficiency, error prevention and detection, and the user's subjective sense of comfort. The software development procedure used was the 'prototype methodology' process. Many design issues were determined from results using several intermediate prototypes. The long-term goal of this project is to build an interface that allows the user to enter plant mapping data both correctly and conveniently. The most challenging task has been to prevent, detect, and process the occurrence of errors. These errors may come from extraneous noise (i.e., the shutting of a door), the system's erroneous recognition of the user's input, and the user's erroneous input. Many strategies have been employed to cope with these errors without interfering with user convenience. Despite these shortcomings, the system has been tested on both correctness and usability issues and the results have shown that the efficiency of this system will lead to improvements over manual 'window-based' input methods that utilize a keyboard or mouse. Most users who participated in the test were pleased and satisfied the performance of the system despite a few current limitations.

Introduction

COTTON TALK is a speech interface for cotton plant mapping. All information requested by the system are acquired by speech input. Therefore, unlike the plant mapping interface in GOSSYM-COMAX or other software, the use of paper data sheets are no longer necessary because *COTTON TALK* allows you to speak directly to the computer while examining and mapping the plant by voice. Moreover, frequent visual scans of the computer screen are unnecessary because *COTTON TALK* provides appropriate audio responses to help confirm the users' previous input.

The purpose of the present paper is to describe several features (including most of the voice commands and audio responses) and to provide samples of the input and output listings so that potential users can become familiar with the capabilities of the program. The development of *COTTON TALK* is motivated by a desire to improve the efficiency and speed of acquisition of information necessary for optimal cotton crop management.

For now the system only provides features for basic cotton plant mapping. This limitation is intentional. The domain of application was restricted to help control the scope and size of the project. The work reported here is more of a 'proof of concept' than a complete, fully functional product for eventual release to the public. However, enough has been learned to encourage us to continue and broaden the functionality of the program. For example, with a little modification, the program can be used to input insect scouting data obtained from whole plant visual samples, as required for the sampling plan developed by Williams et al. (1995) and described during its development by Willers et al. (1990ab, 1992). The code can also be expanded to adequately map 'crazy cotton'. Such plants in the past have been extremely difficult to map with prepared data forms.

In the long term, we believe that speech interfaces will solve the information acquisition 'bottleneck' that has hampered the wider use of computer-assisted decision support systems. In fact, the field of speech recognition is an active area of research (e.g., Baber et al. 1992; Cole et al. 1995; Jones et al. 1989; Schmandt 1994). Computer assisted decision software systems are data intensive and few users can provide enough time to meet their requirements for timely, reliable information. Someday, we anticipate users will acquire much of these data real-time, using only their voice, as they complete other necessary tasks. *COTTON TALK* is an example of how these capabilities can be achieved within the foreseeable future for those data that still require someone going to 'take a look' at the cotton crop, or are otherwise 'hands busy' tasks (see Chen and Robinson 1990).

Materials and Methods

COTTON TALK is a speaker-independent speech application under the Windows™ 3.1 operating environment. The program is written in Microsoft™ Visual C++™ (ver. 1.0), and calls IBM™ Continuous Speech Series (ICSS) functions to get speech input messages and play audio output messages. The required hardware includes a personal computer with 80486™ DX processor at 33 MHZ or faster, at least 12 MB of free disk storage space, a recommended audio card (i.e., Sound Blaster™ 16), and a dynamic, cardioid, low impedance input microphone (i.e., Electro-Voice™ N/D 857B). Other recommended products and requirements are provided in the toolkit documentation (Anonymous 1993).

The program presented here represents the product of several intermediate, smaller projects that were tested on several users before the next phase of development was pursued. Features were added as these smaller prototypes demonstrated their need or functionality. In fact, one could state that the current program is itself an intermediate step toward a larger, more refined software product yet to be developed. The 'prototype methodology' process has served well in the software development of *COTTON TALK* (see Ainsworth and Pratt 1992; Nielsen 1992; and Sommerville 1992).

General Instructions for Speech Input

Guidelines for the use of *COTTON TALK* include the following points. Before starting the program, users should remember or carefully review the following instructions for speech input:

- (1) At each entry, speak clearly, not too softly, and at a conversational pace; do not pause too long between words. Delays between words actually increases the occurrence of errors. The more normal your pace of conversation the better the results.
- (2) After being prompted for input the computer will wait until you begin to speak so you have time to organize your words before speaking.
- (3) Speak only while the screen is not changing and no audio prompts are playing from the computer.
- (4) Always wait for an audio response after each entry.
- (5) Don't include extraneous words like "well, oh, ..."; limit your speech to the context specific words presented below. Do not use excessive words that are not part of the established vocabulary.
- (6) Keep close to the microphone, if it is not a headset (about 2-5 inches), while speaking.
- (7) You can say "WAIT A MINUTE" any time to take a break. When finished with the break you can say "BACK TO PROGRAM" to resume data entry where you previously stopped.
- (8) You can say "GO BACK" to undo, or correct, only the previous entry at any time.

General Instructions for Screen Output

The screen output provides information about the current system state, allowable speech input, and feedback to the user about how the system interpreted the user's input. There are 13 areas (see Figure 1) on the output screen. The information provided by each area are described by number as follows:

- (1) The command line reminds you of the current task.

(2) "QUIT" button allows you to quit the program without saving any data.

(3) "ABOUT" button indicates the current version and author information of this program.

(4) "HELP" button provides you with a brief guide on how to do the current task.

(5) The main-stem (MAIN) and vegetative-branch (VEG) indicators indicate the current active plant map window by highlighting the appropriate word (see MAIN in the example).

(6) The map area displays maps of the main stem and up to three vegetative branches. The data in this area are abbreviated as follows when the corresponding word(s) is(are) spoken:

A : Abscised/Missing
 B : Boll/Open Boll
 F : Flower/Bloom
 G : Green Boll/ Small Green Boll
 T : Terminate.

(7) The field name area displays the field name you entered.

(8) The date area displays the date you entered.

(9) The plant number area displays the numeric label of the plant you are beginning to map from the current sample. A sample is a collection of plants from a specific field on a particular date.

(10) The plant height area displays the plant height you entered in inches.

(11) The site area displays the current node of a branch and the next position to be mapped, by number, on that branch. Up to ten positions can be mapped on a fruiting branch.

(12) The warning area, which appears only when the system detects an input error. When active the background color of this area is yellow. The brief message that appears will tell you why the most recent voice input is invalid.

(13) The echo area, which displays as text the speech input last recognized by the system. In the example screen shown in Fig. 1, the last input recognized was 'Node Thirty One', which results in the error message, 'Excess maximum node number'. In the current version we permit only thirty (30) mainstem nodes to be mapped. The last entry in the example exceeded this limit and so an error message was displayed.

Operation (Mapping) Procedure.

Figure 2 shows the operation procedure of *COTTON TALK*. To start the program, the following steps are used. First, enter the Windows™ 3.1 operating environment, then open the program group "CottonTalk" and next open the program "CottonTalk" (identified by a tree like icon). When the program starts successfully, users are greeted by music and a brief welcome message. Then, wait for about 15 seconds to allow the system to set up the microphone, I/O (audio) card, and the software. If anything goes wrong during this process, check the connection of microphone, adjust the sound card 'mixer' settings, check the audio speaker connection, or the I/O card.

After completing initialization, *COTTON TALK* will ask (prompt) you to supply the following information:

(1) Field Name: <name>.

Example: If the field name is 'Wilbanks', then say... "WILBANKS".

Current pre-defined selections for this program field are the following names: *Wilbanks, Levee-Cut, Tupelo Number Four, King's Creek, Levingston, Keeler, Racetrack*, or in general, *Field Number <1-5>*. A utility is planned that will increase the latitude of responses that users can select.

(2) Date, by any of the following patterns: <day> <month> <year> or <month> <day> <year> or <today> or <yesterday>.

Example: If the date is '2/21/1995' then you can say... "FEBRUARY TWENTY FIRST NINETEEN NINETY FIVE" or "TWENTY FIRST FEBRUARY NINETEEN NINETY FIVE".

Note the <month> entry has to be the name of the month, not a number like the day or the year. The day can be entered as a cardinal or ordinal number; the year should be entered as a cardinal number. If the words, 'today' or 'yesterday' are spoken *COTTON TALK* will acquire the date information from the computer's internal clock. Using these key words is the quickest and most reliable way to acquire date information.

(3) Plant Number: <number>, state a number between one (1) and twenty (20).

Example: If the plant is item number '2' in a sample from a field on a particular date, then say... "TWO".

(4) Plant Height: <number INCHES> or <number>, state a number between one (1) and eighty (80).

Example: If the height is '51 inches', then say... "FIFTY ONE INCHES" or just say "FIFTY ONE". The program will assume the value is in units of inches.

When asked to input plant mapping data, the mapping location cursor will begin at node 1, position 1. **Node 1 is defined to be the first node above the cotyledonary node.** Several voice commands are used to map a plant and are listed in groups as follows:

(5) The following are the key words to move to a certain location on the plant and to describe the state of the cotton fruiting structures at specific sites:

A) "NODE <number>". Action: Cursor jumps to a certain node on the main-stem or on vegetative branch.

B) "NEXT NODE". Action: Cursor moves to the next node on the main-stem- or vegetative- branch.

C) "POSITION <number>". Action: Cursor jumps to a certain position on a fruiting branch attached to either the main stem, or a vegetative branch. To enter the data at the current position on a fruiting branch say one of the following ...

a) "MISSING" / "ABSCISED" ... if the position is empty, or abscised..

b) "SQUARE" ... if the position has a square.

c) "BLOOM" / "FLOWER" ... if the position has a bloom.

d) "GREEN BOLL" / "SMALL GREEN BOLL" ... if the position has a green boll.

e) "BOLL" ... if the position has an cracked or open boll.

The program will automatically move to the next position on the fruiting branch after each entry is spoken. A tone, or "ding", will sound to advise the user when data for the next position can be spoken. A small shortcut feature has also been programmed. All you have to do is to number and describe the most distal position in a sequence of missing sites on a branch. By default, if you state the position number of the most distal position of a sequence of missing sites the program assumes that all prior sites are also missing. All sites will be set to missing and the cursor will automatically move to the next non-vacant position. For example, if the first five sites are abscised on a branch then simply say, 'Position five is missing'. The system will label positions 1-5 as missing, and be ready for the entry of position 6. When you have described the last position, end the fruiting branch by saying...

D) "TERMINATE" ... if the fruiting branch is abnormally terminated after the last, most distal, position.

E) "END OF BRANCH" ... if the branch ends in normal terminal growth after the last fruiting position.

The program will automatically move to the next node, position 1. The system will inform you of the number of the new node.

The system assumes as a default that a branch at a main stem node is a fruiting branch. The vocabulary to map a vegetative branch attached to a particular mainstem node uses the following command immediately after naming the main stem node:

F) "VEGETATIVE BRANCH" ... Informs *COTTON TALK* to 'tag' the attached branch at current main stem node as a vegetative branch, rather than the default 'tag' of fruiting branch.

Example: Say, 'Node four vegetative branch', or alternately, say 'Node four', and after the system repeats back 'Node four', then respond with 'Vegetative Branch'.

The system responds by moving control from the 'MAIN' window in Fig. 1 to the 'VEG' window. Users are to map a vegetative branch as if it were a complete plant in its own right. The program adopts the simple convention of mapping the fruiting branches on a vegetative branch in the same manner as fruiting (sympodial) branches directly attached to the main stem. In other words, the main stem is considered to be vegetative branch number zero (0). *COTTON TALK* will number subsequent vegetative branches, (1), (2), or (3), beginning first with the vegetative branch closest to the cotyledonary node (or mainstem node zero (0)).

When the mapping of a vegetative branch has been completed, repeat the next command given below. The highlighted field should change from 'VEG' back to 'MAIN' (see Fig. 1, item 5) and the system will inform you of the current mainstem node number. When you are back once again on the mainstem you can map another vegetative branch or map the first, and subsequent fruiting branches.

6) "BACK TO MAIN STEM" ... to move the 'pointer' back to the main stem, off of the most recently 'tagged' vegetative branch, but one mainstem node above the previous mainstem node number.

To complete, or finish the mapping of the current plant say one of the following commands:

(7) The first of these two commands should only be used at position 1 of the topmost node (i.e., the terminal of the plant) of the main stem:

A) "FINISH PLANT MAPPING", or

B) "END OF BRANCH".

By design, the second command serves a dual function. If it is spoken at position 1 of a fruiting branch the action the system performs is the same as the first command. Otherwise, if the "END OF BRANCH" command is spoken at any position other than the first one, the cursor will move from last position on the fruiting branch to the next higher node on the mainstem. The system will repeat the number of the new mainstem node and be ready at the position 1 site.

Whenever one of the above two commands delineates the apex of the plant being mapped, users can then modify any data record previously entered for the current plant. The modify data commands include:

(8) To modify an entry, say any of the following:

A) "MODIFY DATE" to go back to change the date,

B) "MODIFY FIELD NAME" to go back to change the field name,

C) "MODIFY PLANT NUMBER" to go back to change the plant number,

D) "MODIFY PLANT HEIGHT" to go back to change the plant height,

E) "MODIFY PLANT MAP" to go back to change the plant mapping data at any location on the plant.

If no modifications are necessary or when finished with any corrections to the data using any of the above commands, the program is ready to map the next plant in the current sample, for up to a total of twenty plants. When a sample is finished another sample with the current date from another field can also be mapped, or the program can be closed. After any one the next three commands have been used the data will be written to a permanent file. Before this time in a session no information has yet been written to a permanent data file by the program. The following commands are:

(9) Users can enter plant map data for the next plant from series of plants (i.e., plants from the present field on the same date) by saying... "NEXT PLANT".

(10) Users can enter the plant map data from a different field on the same date as previously supplied by saying ..."NEXT FIELD".

(11) One can end (close) the program and completely close and save the mapping data to a permanent file by saying ..."CLOSE THE PROGRAM". Remember, by manually selected the 'QUIT' (Fig. 1, item 2) you can exit the program without modifying, or saving any data to a file.

At any time during the program, users can always press the "HELP" button on the top left of the screen to get dynamic on-line help. More features to "HELP" will be added as the program is improved.

We used the COMAX-COMAX graphical user interface (GUI) to make comparisons to the performance of *COTTON TALK*. Several subjects of various ages, sex, nationalities, and experience in cotton plant mapping were used. These subjects also differed in occupations; some were cotton producers, others were research scientists or technicians, and others were full-time students working part-time. The use of such a diverse group helped to further, or make major, changes to the software design of the program.

Results

Our discussion will now emphasize the expected results that are obtained when a complete session is performed. First described are several of the audio feedback features of the program followed by a presentation of a sample session. We conclude by discussing the data file naming conventions and provide a listing of a small data file.

Audio feedback of *COTTON TALK*

The audio feedback of *COTTON TALK* provides you with several messages. It will prompt and inform you of the current task that it expects you to complete by voice, for example, "Please enter the date". As control of the program changes to different activities, additional audible prompts are given in response to your voice inputs; for example, it will inform you of the current mainstem node position on the plant by replying "Node one". A speech entry is accepted for positions being mapped on a fruiting branch by having the system respond with a tone, or 'ding'. If a user does not hear this tone while mapping positions on a fruiting branch, he can know immediately that a recognition error has occurred. The system instead responds with an audible error warning message, similar to "Invalid input, please input again."

Note that users must always wait for system to supply audio feedback after they have finished speaking. After hearing the audio feedback a user can begin to speak again. Figure 3 shows an example dialogue with *COTTON TALK* and the corresponding audio feedback; however, not all of the possible audio feedback responses provided by the system are illustrated in Fig. 3.

Data files

File naming conventions in *COTTON TALK* are simple. The data file of a plant map session will be stored according to the field name, and is comprised of the first 4 digits of the field name plus a ".map" extension. If a plant to be mapped is the first plant from the field, the program will create a new file using the field name. Thereafter, the plants from the same field on any given sample date will be

saved by appending the mapping data into this pre-existing file whenever a user properly closes the program. The data file is stored in ASCII text form and includes all the data you have entered.

Figure 4 is a sample listing of a fictitious data file. The first line displays the date and format of the sample, the second line displays the counter for which plant was mapped from the sample, and lines three and four display the plant height (in inches) and the name of the field from which the sample was collected. For each additional plant within the sample these four lines would be repeated with the appropriate changes in the counter of line two. Next, the first major section of the file provides information acquired from the main stem. As shown here, there are 15 mainstem nodes, two vegetative branches at nodes four and five, with the first fruiting branch occurring at node six. Position one of this fruiting branch holds a 'boll', positions two-four are 'abscised', and position five holds a 'square'. Additional fruiting branches are similarly listed. The second and third sections of the figure refer to the mapping information from the first and second vegetative branches. For example, 'vegetative branch [1]' has three fruiting branches on nodes four, five and six, on which all sites were 'abscised'. The third section maps the second vegetative branch in similar manner.

If other samples were to be collected for field 'Keeler' on later dates, the pattern shown in Fig. 4 would be repeated, but now the date line would show the date of the next sample and the plant counter would mark the numeric order of plants in that sample. This additional data would be appended to file below the last plant from the sample on the previous date. In its current version, sample data for the same field name during different production seasons should be kept in directories that pertain to each particular year.

Future plans to *COTTON TALK* include the development of utilities that would conform the sample data into file formats compatible with other programs like GOSSYM-COMAX (Baulch et al. 1992) or P-MAP (Landivar et al. 1993).

Discussion

In its current form, field names that currently are not part of the program's dictionary of recognized words have to be added when the complete program is compiled. Many expected users will not desire to go through this exercise. Therefore, a utility is currently being developed to allow any user to enter any field name to the program dictionary at any time a new name is desired to be added. Many of the otherwise necessary programming steps needed to add a new field name to a dictionary will be automatically performed by this utility.

Testing the design and performance of the program revealed somewhat of a blend of good and bad features. However, most results are promising enough to continue development of the concept and necessary software. In fact, the initial performance has exceeded the developers initial expectations. One point of special interest is that during several testing cycles with various users it was found that different accents of users did not affect the test results, as much as other issues. For example, the pace of the user's speech, loudness, and the distance to the microphone when speaking were correlated with many recognition errors. Many users of the program spoke to slowly. Speaking slowly, rather than speaking at a normal conversational pace, is a trait that had to be trained out of many users. The result is that *COTTON TALK* took longer to learn than expected while training several users during testing sessions. By comparison, most users learned in less time how to use the GOSSYM-COMAX GUI, and after only a short demonstration and did not need any additional practice. But, all users needed to practice with at least one plant on their own while learning to use *COTTON TALK*. So, we conclude that lack of adequate training time can have a lot of impact upon the occurrence of errors. But, all test subjects did agree that although it took them longer to learn than first thought, that *COTTON TALK* was still easy to learn.

However, the testing protocol did find that the GUI had an error that did not occur with the speech interface. The GUI error was often encountered during the mapping of the plant to the data sheet because the users' hands were often too busy to count the node numbers and simultaneously record the data. Apparently, *COTTON TALK* allowed for greater freedom and use of the users hands for holding and examining the cotton plant during the data entry process.

Another item of interest is the time required to map a single plant. Obviously, this time is related to the size and number of occupied positions on the plants fruiting branches. But, for plants having heights between 20 to 28 inches and having one to three vegetative branches, the average time used to map one plant was about 5 minutes. For a single user, this time is longer than the time to map plants by the GUI from pre-recorded data sheets, but is less than the combined time to first map a plant to a data sheet and then enter the data using a GUI. But, we are working to improve the speed at which a plant can be entered by voice. We find the time of five minutes to be somewhat slow ourselves. We are developing additional features that should dramatically reduce the time required to map a complete plant of any size.

The slowness of the current system, however, is not necessarily a drawback. For example, another application of this type of input system could be the description of insect damage or the presence of different species of insects at each fruiting site. The data entry pace of the current system is faster than most people's search time while

examining a plant for insects. The current structure is flexible enough, due to the use of C programming features (e.g., 'pointers') in the creation of the data files, to add other descriptions of fruit status to the dictionary. These additions could be as descriptive as 'worm damaged square', 'boll weevil puncture', or 'plant bug nymph present'. The program is already on a good start toward developing features for, say, entomological needs. In fact system accuracy in recognition is better with phrases than with single words. And, the processing time by ICSS to recognize a phrase or a single sentence does not necessarily increase over that needed for individual words.

Also, *COTTON TALK* can reduce the number of personnel for mapping plants. In commercial use this could provide considerable savings in labor costs, for once acquired, costs in software and hardware can be amortized in a single season for farms with large acreages. A common practice for plant mapping is to use two people, one to examine the plants and for another to record the data that the first person has called out loud. One of these individuals, or yet a third person, would still be needed to enter the data for computer use. With *COTTON TALK* one worker can perform the complete process without the need for a companion to record the data while he 'calls' it out, or to later take the time to key in the data for later analysis.

Overall, we have to admit that for now, most users make more errors using *COTTON TALK* than using a comparative GUI interface like that found in the GOSSYM-COMAX GUI. But, one fact of immense potential, is that most errors were easy to correct by the users of *COTTON TALK*. This fact suggests that many errors can be resolved by additional programming, including the transfer of the ICSS version of the code into an upgraded development toolkit, VoiceType Application Factory for Windows™ (ver. 1.1), and use of better hardware, like a headset microphone. Furthermore, recent discussion with the developers of ICSS have also indicated that the current form of some of *COTTON TALK*'s logic could be responsible for some of these errors. We are in process of investigating their suggestions to learn if improvements in performance are possible by making these changes.

Conclusion

Cotton plant mapping is a hand/eye busy task for which it is inconvenient to use a keyboard or mouse as an input tool. This project's goal has been the design a speech interface, *COTTON TALK*, to simplify the plant mapping task. *COTTON TALK* is a user-independent continuous speech interface which was developed on a personal computer under the Windows™ operating system. Many design issues in regard to usability were considered in *COTTON TALK*, including language design, feedback strategy, error reduction and error handling. The system was tested to improve the efficiency of the cotton plant mapping task and most test users strongly agreed that it was very easy to

learn. Although most errors in the system test were easy to correct, the higher error rate than desired is still a problem for *COTTON TALK*. Improvements in hardware and software are being explored to correct recognition errors.

Disclaimer

Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the USDA and does not imply the exclusion of other available products.

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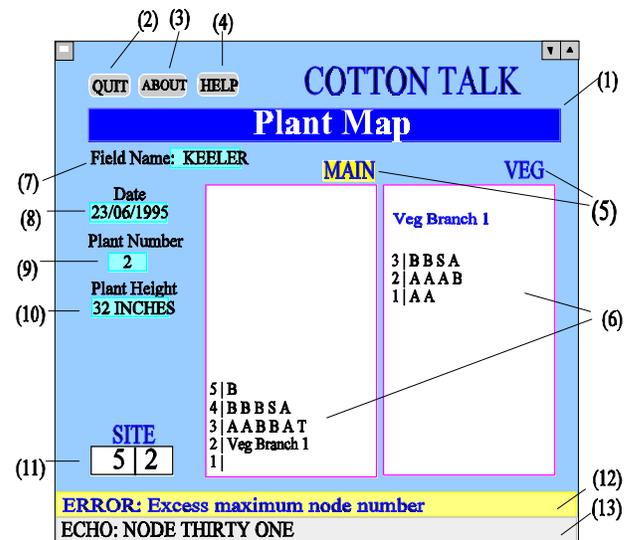


Figure 1. Sample screen display of *COTTON TALK*.

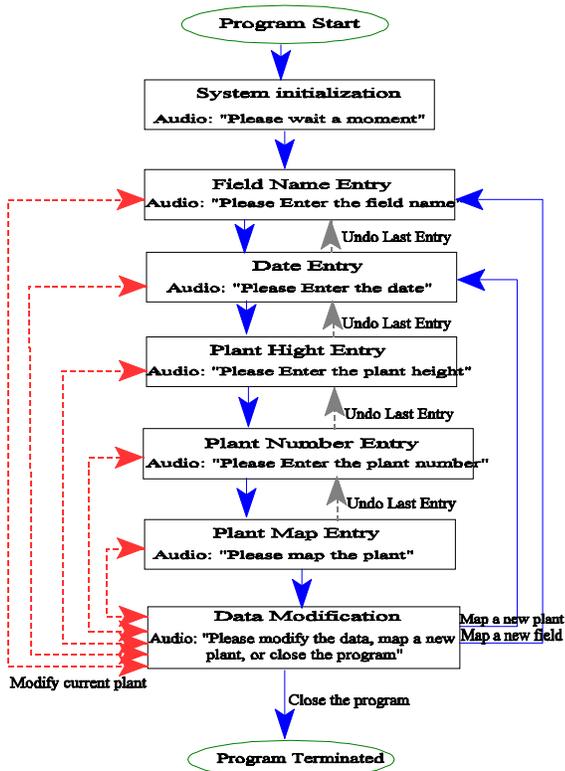


Figure 2. System Operation of COTTON TALK.

System: Please enter the field name.
 User : King's Creek.
 System: Please enter the date.
 User : August twenty-first nineteen ninety five.
 System: Please enter the plant number.
 User : Three.
 System: Please enter the plant height.
 User : Twenty one inches.
 System: Plant mapping begin.
 System: Node one.
 User : Node five.
 System: Node five.
 User : Missing.
 System: "ding"
 User : Boll.
 System: "ding"
 User : Next node.
 System: Node six.
 User : Boll.
 System: "ding"

Figure 3. A sample dialogue of COTTON TALK.

DATE: 16/8/1995 (dd/mm/yy)
 Plant No: 1
 Plant Height: 25 INCHES
 Field Name : KEELER

Plant map ==> MainStem:
 Node[1] Site:
 Node[2] Site:
 Node[3] Site:
 Node[4] Site: Vegetative Branch [1]
 Node[5] Site: Vegetative Branch [2]
 Node[6] Site: B A A A S
 Node[7] Site: B A A S S
 Node[8] Site: B A A S S
 Node[9] Site: A A A S
 Node[10] Site: A A A A
 Node[11] Site: A A A A
 Node[12] Site: A A A
 Node[13] Site: A A A
 Node[14] Site: A A A
 Node[15] Site: A A

Plant map ==> Vegetative Branches [1]:
 Node[1] Site:
 Node[2] Site:
 Node[3] Site:
 Node[4] Site: A A
 Node[5] Site: A A
 Node[6] Site: A

Plant map ==> Vegetative Branches [2]:
 Node[1] Site:
 Node[2] Site:
 Node[3] Site: B A A A
 Node[4] Site: B A A A
 Node[5] Site: A A S
 Node[6] Site: A A S
 Node[7] Site: A S
 Node[8] Site: A A
 Node[9] Site: A
 Node[10] Site: A

Figure 4. Sample Print out of a Data File named "keel.map" (from Field "KEELER") showing only the first plant of the sample for August 16, 1995.