Program library for DECtalk text-to-speech system

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The DECtalk text-to-speech conversion system offers promise for both basic and applied research. This paper is a report on a program library for the system that utilizes the routines by Edwards (1987). The library contains a number of useful Pascal routines which simplify the basic control of DECtalk. The demonstration program that we have devised should assist users of the system.

In recent years, there has been considerable interest in text-to-speech algorithms and in the use of this technology in the study of computer-mediated reading instruction. The MIT Research Laboratory of Electronics, among others, has led in the development of the MITalk-79 system of text-to-speech conversion (see Allen, Hunnicutt, & Klatt, 1987, for details). The Digital Corporation has also provided a sophisticated DECtalk text-to-speech conversion system.

In general, the transformation of strings of ASCII characters into speech is based on an analysis-by-synthesis procedure. The computer system first analyzes the unrestricted text to extract the underlying phonemic, morphological, and syntactic forms. The system then uses this abstract linguistic representation as the input to the speech-synthesis component, which also entails segmental phonological adjustments such as utterance timing and pitch contour for high-quality speech. The voice output devices utilizing computer speech have been evaluated, and the DECtalk computer system has been shown to produce highly intelligible synthetic speech (Greene, Logan, & Pisoni, 1986).

Several researchers have investigated the use of computer speech in computer-mediated reading. McConkie and Zola (1985) reported on their Computer-Aided Reading System, which displays text and provides instantaneous speech feedback of difficult words when they are "touched" on the screen. Olofsson (1988) discusses some Swedish text-to-speech systems that convert subword units into speech sounds to train disabled readers. Directly pertaining to DECtalk, the system has been used with considerable success by Olson and his colleagues to give speech feedback for word recognition and reading comprehension with reading-disabled children (see Olson,

Foltz, & Wise, 1986; Olson & Wise, 1987). We have also been experimenting with DECtalk to provide immediate on-line and speech feedback to older readers during prose comprehension.

In this paper, we describe a library of Turbo Pascal routines that can control the basic operations of DECtalk on an IBM PC-compatible computer. These routines are compiled with the Turbo Pascal compiler (version 3.01A) on a Digital VAXmate computer, which is fully compatible with the IBM AT. The objectives of the library are twofold. First, it contains a number of useful routines that simplify the technical details of controlling the basic features of DECtalk. Second, it contains a general displaying routine that can present a given text passage in many ways. The listing of the library is shown in Appendix A. A demonstration program is given in Appendix B, in order to illustrate the use of the routines in the library.

Operating Modes of DECtalk

DECtalk has three operating modes: the setup mode, the on-line mode, and the off-line mode (see DECtalk Owner's Manual for detail). In the setup mode, DECtalk allows the user to set various internal parameters such as line speed, data format, trace flags, and the like. In the on-line mode, DECtalk communicates directly with a host computer using escape sequences. The escape sequences are sequences of characters that start with an escape (ESC) character, followed by a string of ASCII characters. They are commands that control the operating characteristics of DECtalk. In the off-line mode, DECtalk acts as a text-to-speech system that accepts commands from the local terminal. In terms of control, the on-line mode is better than the off-line mode, because it provides a more extensive set of commands for the programmer. For example, in measuring the speaking rate of DECtalk, one needs to know exactly when DECtalk finishes speaking: the on-line mode has an escape command that requests DECtalk to send a signal back once the speaking is finished.

Communicating with DECtalk

DECtalk is physically linked with the host computer by a serial cable, through which signals are transmitted

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according to the commonly used RS232 protocol. This protocol defines a mutual agreement between two communicating devices; without it, messages sent from one device will be misinterpreted by the other. In order to facilitate communication between DECTalk and the IBM PC, we must program both of them to transmit data at the same rate and with the same format. We have set DECTalk to transmit data at a rate of 9,600 baud, with no parity checking. This protocol can be specified in the setup mode, with the following commands:

```
SETUP>SET HOST SPEED 9600
SETUP>SET HOST FORMAT NONE
```

The IBM PC is programmed to transmit data with the same protocol. To program the serial port of the IBM PC with Turbo Pascal is quite common for many applications, but it cannot be done with just a few lines of codes. There are many ready-to-use routines commercially available to do such a task. In particular, we have chosen the routines in Edwards (1987), who discusses the programming details of data communication on the IBM PC. The routines that we use are contained in the modules GENERAL.INC, INTER.INC, and DATACOMM.INC. In the remaining part of this paper, we will describe the details of the DECTalk library DECTALK.INC, which is listed in Appendix A.

Using the DECTalk Library

Certain lines of codes must be included in any program that uses the DECTalk library. First, since the DECTalk library DECTALK.INC makes use of the data communication routines in module DATACOMM.INC, which in turn uses routines in modules GENERAL.INC and INTER.INC, the following lines must be included in all programs that use the library:

```
{ $I GENERAL.INC }
{ $I INTER.INC }
{ $I DATACOMM.INC }
{ $I DECTALK.INC }
```

Second, the serial port of the IBM PC must be set up before the program sends any command to DECTalk, and it must be reset after the program finishes the communication with DECTalk. The setting of the serial port on the IBM PC can be accomplished by calling the procedure RS__Initialize() in module DATACOMM.INC. To set the transmission rate at 9,600 baud with no parity bit, the following call is used:

```
RS__Initialize(1,B9600,None,1,8);
```

Similarly, there are a number of DECTalk escape sequences that must be defined before DECTalk is used. An initialization procedure, DECTalk__Initialize(), is written to perform such tasks. This procedure should be called before the program sends any escape sequence to DECTalk:

```
DECTalk__Initialize;
```

To reset the communication port, the RS__Cleanup() procedure in the DATACOMM.INC module is used. This procedure call should be put after the program finishes communicating with DECTalk:

```
RS__Cleanup;
```

The routines in the DECTalk library can be classified into three types: speaking, displaying, and miscellaneous routines. The speaking routines are used to control DECTalk to speak a given text in a variety of ways. The displaying routine, on the other hand, is used to control the screen display of a given text in different ways. The miscellaneous routines control other useful features of DECTalk, such as changing its voice, its speaking rate, and many others.

Speaking Routines in DECTALK.INC

The basic routine of communication is to send a character to DECTalk. The procedure Send() is written to accomplish this task. After the program has initialized the serial port using RS__Initialize(), an 8-bit data can be sent to DECTalk through the procedure Send(), which is a modified version of the procedure RS232__Out() in module DATACOMM.INC.

A sequence of characters, followed by a carriage return, can be sent to DECTalk with the procedure Speak(). This procedure makes use of the previous basic routine Send().

If one wants to know when DECTalk finishes speaking a message, the procedure SyncSpeak() can be used to send the message and detect the end of speaking with Get__SyncSignal(). To synchronize with DECTalk, one first calls SyncSpeak() with the message. While DECTalk is speaking the message, the computer can do other tasks, such as print it. When DECTalk finishes speaking the message, the Boolean function RS232__Avail() will return true, indicating that DECTalk has sent some messages back. The main responsibility of the procedure Get__SyncSignal() is to detect a synchronization signal DT__SYNCSIGNAL. It uses another procedure called Get__Response to get the response from DECTalk. The procedure Get__Response puts the receiving message in a global string variable called Input__String. The program structure for synchronization is as follows:

```
SyncSpeak(Message);
:
{ Do some tasks }
:
Get__SyncSignal;
```

If the computer finishes the tasks earlier than DECTalk finishes speaking the message, it will be held up in the busy-wait loop of Get__SyncSignal(). In any case, DECTalk is synchronized once Get__SyncSignal() returns to the main program.

Displaying Routines in DECTALK.INC

One simple way to interface on-line and speech output is to use the standard `WriteLn()` function to print the passage, but this may not be acceptable because the text presentation rate is so fast. An alternative is to delay the displaying of characters by using the `Delay()` function. The advantage of this approach is that characters are displayed on the screen very smoothly. There are other presentation methods, such as delaying between words, delaying between phrases, and delaying between sentences. In the procedure `Display()`, all of these different presentation methods are included. There are five parameters in this procedure. The first is the text message (maximum 255 characters) that is to be displayed on the screen. The second parameter specifies the delay time (in milliseconds, approximately) between characters. Similarly, the third, the fourth, and the fifth parameters specify the delay time between words, phrases, and sentences, respectively. The procedure considers each character one by one and determines which delay time to use according to the nature of the character. If the character is a period, an exclamation mark, or a question mark, then the procedure delays the processing by means of the fifth parameter. If the character is a comma, a semicolon, or a colon, then it treats the punctuation as a phrase delimiter. It will then use the delay time specified by the fourth parameter. These definitions of delimiters are declared at the beginning of the DECTalk library. Although this general displaying routine is general enough to allow different delays between linguistic frames of different units, it is not intelligent enough to recognize some of the special forms in English such as abbreviations. More work remains to be done to improve this procedure. However, the procedure in its current implementation can be used for a wide variety of tasks.

Miscellaneous Routines in DECTALK.INC

Many other DECTalk features, such as the speaking rate and voice are also programmable. The default speaking rate is approximately 180 wpm, but one can vary the rate from 120 to 250 wpm with the procedure `Speaking_Rate()`. To set DECTalk to speak at 200 wpm, one calls `Speaking_Rate(200)`. The default pauses of 160 msec after commas and 640 msec between sentences can be lengthened with the procedures `Comma_Pause()` and `Period_Pause()`. Both procedures accept one argument, which sets the additional delay after the comma and period. To set the delay after a comma at 200 msec, one calls `Comma_Pause(40)`. Similarly, if one wants the delay between sentences to be 740 msec, one calls `Period_Pause(100)`. However, when one uses these procedures to lengthen the pauses after commas or periods, the speaking rate of DECTalk will be affected.

Another interesting feature is to change the voice of DECTalk. DECTalk has seven built-in voices: a standard male voice, a standard female voice, a deep male voice,

an older male voice, a child's voice, a deep female voice, and a light female voice. The procedure `Change_Voice()` selects the voice. The default voice is the standard male "Perfect Paul." For DECTalk to speak in a light female voice, one calls `Change_Voice(7)`.

The pronunciations produced by DECTalk have high fidelity in most cases, but they are not perfect. Because there are so many exceptions to the rules of English pronunciation, the built-in dictionary of DECTalk contains only the most common exceptions. DECTalk has another user dictionary that can be maintained in order to modify the pronunciations of certain words. The best way to do this is to try out the pronunciation via the off-line mode, with the local terminal. If a desirable pronunciation can be found, the function `Update_Dictionary()` can be used to update the user's dictionary. This function accepts the word to be changed as the first argument and the new pronunciation as the second argument. It will then return a character sent back from DECTalk, indicating whether the update is successful or not. A "0" character indicates that DECTalk has accepted the word successfully. If the returned character is "1," then it means that DECTalk has no room to store the given word. If a "2" character is returned, the entry is too long (i.e., longer than 256 characters).

Demonstration Program

This demonstration program was devised to (1) illustrate the program structure for using the DECTalk library DECTALK.INC, and (2) demonstrate the selection of different parameters in the displaying routine. The program defines a passage of text at the beginning and controls DECTalk to speak each line of the passage with different voices. The displaying speed of each line also varies from fast to slow, and the synchronization structure is used to coordinate the computer with DECTalk. This demonstration will show that the computer displays the first few lines faster than DECTalk. However, as the delay times between linguistic frames of different sizes increase, DECTalk will speak faster than the text display in the last few lines. Synchrony for on-line display and speech output is achieved at the end of each line.

Conclusion

The DECTalk text-to-speech computer system offers promise for basic research on the mechanisms of speech feedback of unrestricted text, and for applied research on component analysis and remediation of reading.

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APPENDIX A

```

(**=====**
**                               DECTalk Library                               **
**=====**
**
** Purpose: to provide a number of routines to ease the                      **
**           technical details of controlling DECTalk.                        **
**
** Usage: used as an included file in any Pascal program                     **
**         compiled with Turbo Pascal 3.01A.                                **
**
** Requirements: GENERAL.INC, INTER.INC, and DATACOMM.INC by                 **
**               C. Edwards (1987) in his book "Advanced                     **
**               Techniques in Turbo Pascal". San Fransico:                   **
**               Sybex.                                                         **
**
** Program Structure:                                                         **
**
**   Program DECTalk_Program;                                                 **
**   ($I GENERAL.INC)                                                         **
**   ($I INTER.INC)                                                           **
**   ($I DATACOMM.INC)                                                         **
**   ($I DECTALK.INC)                                                         **
**   begin                                                                    **
**     RS_Initialize(1,B9600,None,1,8);                                       **
**     DECTalk_Initialize;                                                     **
**     : : : : :                                                             **
**     RS_Cleanup();                                                          **
**   end.                                                                     **
**
** Author: Simon Lock                                                         **
**
** Date: March, 1989.                                                         **
**
**=====**)

const CR = #13; { Carriage Return }
      ESC = #27; { Escape character }
      XOFF = #19; { Input buffer full signal }
      XON = #17; { Input buffer available signal }
      Sentence_Delimiters : set of char = ['.', '!', '?'];
      Phrase_Delimiters : set of char = [' ', ' ', ' ', ' ', ' '];
      Word_Delimiters : set of char = [' ', '-'];

type Str255 = String[255];

var DT_PHOTEXT, DT_TALK, DT_SYNC, DT_SYNC_SIGNAL, DT_ENABLE_SPEAK, DT_DISABLE_SPEAK,
    DT_INDEX, DT_INDEX_REPLY, DT_INDEX_QUERY, DT_DICT : String[20];
    Input_String : Str255;

Procedure DECTalk_Initialize;
{ Define useful escape sequences }
begin
  DT_PHOTEXT := ESC+'P0;0z';
  DT_TALK := ESC+'P0;10z'+ESC+'\\';
  DT_SYNC := ESC+'P0;11z'+ESC+'\\';
  DT_SYNC_SIGNAL := ESC+'P;32;z'+ESC+'\\';
  DT_ENABLE_SPEAK := ESC+'P0;12;1z'+ESC+'\\';
  DT_DISABLE_SPEAK := ESC+'P0;12;0z'+ESC+'\\';
  DT_INDEX := ESC+'P0;20;';
  DT_INDEX_REPLY := ESC+'P0;21;';
  DT_INDEX_QUERY := ESC+'P0;22z'+ESC+'\\';
  DT_DICT := ESC+'P0;40z'
end;

```

APPENDIX A (Continued)

```

{ :::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::: }
{ ::                S P E A K I N G   R O U T I N E S                :: }
{ :::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::: }

Procedure Send(Ch:char);
{ Send an 8-bit data to DECTalk through communication port 1 }
begin
  if RS232_Avail
  then begin
    Get_Response;
    if Input_String = XOFF { Check buffer full }
    then repeat Get_Response
      until Input_String = XON { Buffer not full }
    end;
    while ((Port[RS232[RS_Com].LSR] and $20) (<) $20)
    do Delay(1);
    Port[RS232[RS_COM].THR] := Byte(Ch);
    RS_Error := 0
  end;
end;

Procedure Speak(Message:Str255);
{ DECTalk speaks a given message without synchronization }
var i : integer;
begin
  for i:=1 to length(Message)
  do Send(Message[i]);
  Send(CR);
  Send(CR)
end;

Procedure SyncSpeak(Message:Str255);
{ DECTalk speaks a given message with synchronization }
begin
  Speak(Message+DT_SYNC+DT_INDEX_QUERY)
end;

Procedure Get_Response;
{ Wait for a response from DECTalk }
begin
  repeat until RS232_Avail;
  Input_String := '';
  while RS232_Avail do
  begin
    Input_String := Input_String + RS232_In;
    Delay(10)
  end
end;

Procedure Get_SyncSignal;
{ Wait for a synchronization signal }
begin
  repeat Get_Response
  until Input_String=DT_SYNC SIGNAL
end;

{ :::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::: }
{ ::                D I S P L A Y I N G   R O U T I N E                :: }
{ :::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::: }

Procedure Display(Message:Str255;Character_Delay,Word_Delay,
                  Phrase_Delay,Sentence_Delay:integer);
{ Display a given message with delay controls }
var i : integer;
begin
  i := 1;
  Write(Message[1]);
  while (i < Length(Message)) do
  begin
    i := i + 1;
    Write(Message[i]);
    if (Message[i] in Sentence_Delimiters)
    then Delay(Sentence_Delay)
    else if (Message[i] in Phrase_Delimiters)
    then Delay(Phrase_Delay)
    else if (Message[i] in Word_Delimiters)
    then Delay(Word_Delay)
    else Delay(Character_Delay)
  end
end;
end;

```

APPENDIX A (Continued)

```

{ :::::::::::::::::::::::::::::::::::::::::::::::::::::::::::: }
{ ::          M I S C E L L A N E O U S   R O U T I N E S          :: }
{ :::::::::::::::::::::::::::::::::::::::::::::::::::::::::::: }

Procedure Speaking_Rate(SpkRate:integer);
{ Program DECTalk to speak at SpkRate wpm approximately }
var S : String[3];
begin
  if SpkRate<120
  then SpkRate := 120;
  if SpkRate>250
  then SpkRate := 250;
  Str(SpkRate,S);
  Speak([':ra '+S+'])
end;

Procedure Comma_Pause(MSec:integer);
{ Program DECTalk to pause 160*MSec msec. after commas }
var S : String[3];
begin
  if MSec<0
  then MSec := 0;
  Str(MSec,S);
  Speak([':cp '+S+'])
end;

Procedure Period_Pause(MSec:integer);
{ Program DECTalk to pause 640*MSec msec. after periods }
var S : String[3];
begin
  if MSec<0
  then MSec := 0;
  Str(MSec,S);
  Speak([':pp '+S+'])
end;

Procedure Change_Voice(Voice:byte);
{ Change the voice of DECTalk }
begin
  case Voice of
    1 : Speak([':np']); { Perfect Paul - Standard male voice }
    2 : Speak([':nb']); { Beautiful Betty - Standard female voice }
    3 : Speak([':nh']); { Huge Harry - Deep male voice }
    4 : Speak([':nf']); { Frail Frank - Older male voice }
    5 : Speak([':nk']); { Kit the Kid - Child's voice }
    6 : Speak([':nr']); { Rough Rita - Deep female voice }
    7 : Speak([':nu']); { Uppity Ursula - Light female voice }
    else Speak([':np'])
  end
end;

Function Update_Dictionary(Old_Word,New_Word:Str255):char;
begin
  Speak(DT_DICT+Old_Word+' '+New_Word+ESC+'');
  Get_Response;
  Update_Dictionary := Input_String[8]
end;

```

APPENDIX B

Program DECTalk_Demonstration_Program;

```

{$I GENERAL.INC}
{$I INTER.INC}
{$I DATACOMM.INC}
{$I DECTALK.INC}

const Passage : array [1..8] of Str255 =
  ('In this paper, we describe a library of Turbo Pascal routines',
   'to control the basic operations of DECTalk on an IBM PC compatible',
   'computer. These routines are compiled with the Turbo Pascal',
   'compiler on a VAXmate computer. The objectives of the library are',
   'twofold. Firstly, it contains a number of useful routines to',
   'simplify the technical details for controlling the basic features',
   'of DECTalk. Secondly, it contains a general displaying routine',
   'which can present a given text passage in many ways.');
```

var i : Integer;

APPENDIX B (Continued)

```
begin
  RS_Initialize(1,B9600,None.1,8);
  DECTalk_Initialize;

  ClrScr;
  Speak('This is a DECTalk Demonstration Program');
  Display('DECTalk Demonstration Program',100,0,0,0);
  WriteLn;
  WriteLn('-----');
  for i:=1 to 8 do
  begin
    Change_Voice(i);
    SyncSpeak(Passage[i]);
    Display(Passage[i],1*20,1*30,1*40,1*50);
    WriteLn;
    Get_SyncSignal
  end;

  RS_Cleanup
end.
```

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