Chapter 4
Smart University: Software Systems for Students with Disabilities

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Abstract Smart universities, smart classrooms and smart education are the wave of the future in a highly technological society. One of the distinctive features of a smart university is its ability of adaptation to and smooth accommodation of various types of students/learners such as regular students and life-long learners, in-classroom/local and remote/online students/learners, regular students and special students, i.e. students with various types of disabilities including physical, visual, hearing, speech, cognitive and other types of impairments. This chapter presents the outcomes of an ongoing research project aimed at systematic identification, analysis, and testing of available open source and commercial text-to-voice, voice-to-text and gesture recognition software systems—those that could significantly benefit students with disabilities. Based on obtained outcomes of completed research and analysis of designated systems we identified and recommended top text-to-voice, voice-to-text and gesture recognition software systems for implementation in smart universities.

Keywords Software systems · Students with disabilities · Text-to-speech · Voice-to-text · Gesture recognition · Smart university

4.1 Introduction

Smart universities (SmU) and smart classrooms (SmC) can create multiple innovative opportunities for students to learn material and communicate to classmates in a variety of highly technological ways. In addition, they can give students who

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would normally not have access to these learning materials opportunities to interact with digital learning content as well as the instructors and other in-classroom and/or remote/online students. Although not designed or even conceptualized to benefit students with disabilities, this concept would definitely have an impact on the learning process and access to learning content for students with different types of disabilities.

4.1.1 Literature Review

4.1.1.1 Smart Classrooms: Literature Review

Pishva and Nishantha in [1] define a SmU as an intelligent classroom for teachers involved in distant education that enables teachers to use a real classroom type teaching approach to teach distant students. "Smart classrooms integrate voice-recognition, computer-vision, and other technologies, collectively referred to as intelligent agents, to provide a tele-education experience similar to a traditional classroom experience" [1].

Glogoric, Uzelac and Krco [2] addressed the potential of using Internet-of-Things (IoT) technology to build a SmU. "Combining the IoT technology with social and behavioral analysis, an ordinary classroom can be transformed into a smart classroom that actively listens and analyzes voices, conversations, movements, behavior, etc., in order to reach a conclusion about the lecturers' presentation and listeners' satisfaction" [2].

Slotta, Tissenbaum and Lui [3] described an infrastructure for SmUs called the Scalable Architecture for Interactive Learning (SAIL) that "employs learning analytic techniques to allow students' physical interactions and spatial positioning within the room to play a strong role in scripting and orchestration".

Koutraki, Efthymiou, and Grigoris [4] developed a real-time, context-aware system, applied in a SmU domain, which aims to assist its users after recognizing any occurring activity. The developed system "…assists instructors and students in a smart classroom, in order to avoid spending time in such minor issues and stay focused on the teaching process" [4].

Given all the research publications that focus on SmUs, no literature was located on "SmC's software systems and students with disabilities" topic. This is the reason that this topic is in the center of our research activities.

4.1.1.2 Smart Universities: Literature Review

Coccoli in [5] argue that "…primary focus of SmU is in the education area, but they also drive the change in other aspects such as management, safety, and environmental protection. The availability of newer and newer technology reflects on how the relevant processes should be performed in the current fast changing digital era.

This leads to the adoption of a variety of smart solutions in university environments to enhance the quality of life and to improve the performances of both teachers and students. Nevertheless, we argue that being smart is not enough for a modern university. In fact, all universities should become smarter in order to optimize learning. By "smarter university" we mean a place where knowledge is shared between employees, teachers, students, and all stakeholders in a seamless way" [5].

Aqeel-ur-Rehman et al. in [6] present the outcomes of their research on one feature of future SmU—sensing with RFID (Radio frequency identification) technology; it should benefit students and faculty with identification, tracking, smart lecture room, smart lab, room security, smart attendance taking, etc.

Lane and Finsel in [7] emphasize the importance of the big data movement and how it could help to build smarter universities. "Now is the time to examine how the Big Data movement could help build smarter universities—in situations that can use the huge amounts of data they generate to improve the student learning experience, enhance the research enterprise, support effective community outreach, and advance the campus's infrastructure. While much of the cutting-edge research being done with Big Data is happening at colleges and universities, higher education has yet to turn the digital mirror on itself to innovate the academic enterprise" [7]. Big data analytics systems will strongly support inferring characteristic of a SmU.

Al Shimmary et al. in [8] analyzed advantages of using RFID and WSN technology in development of SmU. "The developed prototype shows how evolving technologies of RFID and WSN can add in improving student's attendance method and power conservation". RFID, WSN as well as Internet-of-Things technology are expected to significant parts of a SmU and strongly support sending characteristics of SmU.

Doulai in [9] presents a developed system for a smart campus. This system "… that offers an integrated series of educational tools that facilitate students' communication and collaboration along with a number of facilities for students' study aids and classroom management. The application of two widely used technologies, namely dynamic web-based instruction and real-time streaming, in providing support for "smart and flexible campus" education is demonstrated. It is shown that the usage of technology enabled methods in university campuses results in a model that works equally well for distance students and learners in virtual campuses".

Yu et al. in [10] argue that "… with the development of wireless communication and pervasive computing technology, smart campuses are built to benefit the faculty and students, manage the available resources and enhance user experience with proactive services. A smart campus ranges from a smart classroom, which benefits the teaching process within a classroom, to an intelligent campus that provides lots of proactive services in a campus-wide environment". The authors described 3 particular systems—Wher2Study, I-Sensing, and BlueShare—that provide sensing, adaptation, and inferring smart features of a SmU.

One area that so far has had a limited attention is "students with disabilities and SmU". Although features, components, and systems of SmU taxonomy have been discussed in [11], only one publication could be located that discussed SmU, SmC,

and students with disabilities [12]. Given that 10% of all school/college/university students have some kind of disabilities, this is definitely an area that needs a more thorough investigation.

4.2 Students with Disabilities and Software Systems

Categories of students with disabilities. Students of schools/colleges/universities may experience a variety of different categories of disabilities; they include but are not limited to:

(1) Deaf/hearing impairments
(2) Learning disabilities
(3) Physical disabilities
(4) Psychological/neurological disorders
(5) Speech or language impairments
(6) Visual impairments
(7) Cognitive impairments

Software systems for students with disabilities. Software systems allow students with disabilities equal access in the classroom and learning environments. Often these systems also help them learn more efficiently and effectively and in many cases allow them to interact better with their professor and classmates. Where traditional classrooms do not specifically address software systems and how students with disabilities could be impacted, the implementation of specific advanced software systems in SmU and learning environments would definitely approach learning barriers from the perspective of universal accessibility: providing greater learning opportunities for all students in the SmU classroom—including students with disabilities.

A list of possible software systems that may benefit students with various types of disabilities are listed in Table 4.1.

Bradley University and students with disabilities. Bradley University (Peoria, IL USA) is a top-ranked private university that offers 5,400 undergraduate and graduate students opportunities and resources of a larger university and the personal attention and exceptional learning experience of a smaller university. Bradley offers more than 185 undergraduate and 43 graduate academic programs in business, communications, education, engineering, fine arts, health sciences, liberal arts and sciences, and technology.

The Center for Learning and Access (CLA) at Bradley University is the University's primary academic support service responsible for helping students acquire skills essential to achieve academic and personal success (https://www.bradley.edu/offices/student/cla/). Under the CLA umbrella, the Office of Access Services currently serves approximately 310 students (or, about 6% of the total

Table 4.1 Types of students with disabilities and software systems that may be beneficial

Category of disabilities	Software systems that may benefit these types of students
Deaf/hearing impairments	Voice-to-text software systems, assistive listening systems, touch screen technology, eye gaze software, auditory tools (headset worn by user to limit distractions), writing software (Inspiration), closed captioning, video camera, real-time captioning
Learning disabilities	Text-to-voice, voice-to-text, gesture recognition and facial recognition software systems, touch screen technology, systems to improve auditory processing abilities, systems to develop basic math skills and mathematical reasoning, systems to improve organizational and memorization skills, systems to improve reading skills, talking word processors, word prediction software, spelling software, writing software (Inspiration)
Physical disabilities	Text-to-voice, voice-to-text, gesture recognition software systems, sip-and-puff systems, touch screen technology, switch access (clicker), eye gaze software, screen magnification software, talking word processors
Psychological/ neurological disorders	Text-to-voice, voice-to-text, gesture recognition and facial recognition software systems, touch screen technology, spelling software, writing software (Inspiration)
Speech or language impairments	Text-to-voice, voice-to-text, gesture recognition and facial recognition software systems, touch screen technology, speech synthesizers, talking word processors, word prediction software, spelling software, writing software (Inspiration)
Visual impairments	Text-to-voice software systems, voice-to-text software systems, screen magnification and readers software systems, talking word processors, screen review systems, audio books, spelling software
Cognitive impairments	Text-to-voice, voice-to-text, gesture recognition and facial recognition software systems, touch screen technology, switch access (clicker), eye gaze software, screen magnification software, talking word processors, word prediction software, spelling software

student number) that have provided appropriate documentation and registered for services.

In accordance with information from Bradley's Center for Learning and Access (CLA) the current distribution of students with disabilities at Bradley by various designated categories is follows: (1) with a health impairment—19 students, (2) with a hearing impairment—6 students, (3) with learning disabilities—84 students, (4) with a physical disability—5 students, (5) with psych/neuro impairments —186 students, including 11 students with ASD (Autism Spectrum Disorder) and 61 students with ADHD (Attention Deficit Hyperactivity Disorder), (6) with a speech impairment—2 students, and (7) with a visual impairment—8 students.

The software systems currently in use at CLA by various categories of students with disabilities at Bradley University are summarized in Table 4.2.

Table 4.2 Software systems used by students with disabilities at Bradley University

#	Software system	Technical platform	Cost	Category of students served
1	Kurzweil Reading Edge	Windows/Mac	–	3, 5, 6, 7
2	CAR (Central Access Reader)	Windows/Mac	Free	3, 5, 6, 7
3	Inspiration	Windows/Mac	V9.2—$40; bundle pack—$60; household—$95	3, 5, 7
4	Jaws	Windows	Pro—$1,100; home—$900; 90-day trail—$180	7
5	Firefox Add on "Text to voice"	Windows/Mac/Linux	Free	3, 6
6	Dragon Naturally speaking	Windows/Mac	$75	2, 3, 4, 7
7	Zoom text	Windows	$600	7

The CLA specialists identified a list requirements for software systems to be used by students with various categories of disabilities—those features and functions should provide users with significant benefits; a list of CLA of most important requirements is presented in Table 4.3.

Table 4.3 CLA's list of most important requirements to software systems for students with disabilities

Requirement	Details (software systems should be able to …)
Maximal number of students to get benefits	Serve and be useful and beneficial for as many students with various categories of disabilities as possible.
Graphic user interface and pre-defined commands	Help users to navigate the system easily without any discomfort; the system should have a list of pre-defined commands, for example, to access folders and files, send email, etc.
Voice-to-text functionality	Accurately convert user's speech into text, structure text into notes, create emails, support punctuation, support spell checking using built-in vocabulary, word prediction functionality, optical character recognition (OCR) functionality (ability to scan the printed information or camera captured image's text and convert it into digital text which can be read by the software system), multi-lingual user interface language packs (MUI) functionality (ability to download and use different languages in graphic user interface), provide quick and accurate voice training, provide editing of built-in dictionary, support punctuation, email the outcome text file, etc.

(continued)

Table 4.3 (continued)

Requirement	Details (software systems should be able to …)
Text-to-voice functionality	Accurately convert user's text into voice (or, synthesize audio), use various types of "voices" (kid's, female, male voices, etc.), read web-based data, math data, data in tables, etc.
Input/output formats	Handle (i.e. work with) various types of input data, especially, PDF, TXT, DOC, HTML, etc. and provide output data in various formats such as DOC, TXT, MP3, MP4, etc.
Web-based content	Read data from the Web such as the content of web pages, web applications, web simulations, etc.
Titles and text on images	Read the text present in an image.
Math data	Recognize math notation (math equations), or, in other words, have a special math reader.
Data in tabular form	Read data presented in tabular form.

The outcomes of our research as well as CLA requirements clearly shows that (1) text-to-voice (or, text recognition), (2) voice-to-text (or, speech recognition; also including captioning of all lectures and video materials), and (3) gesture (and, face) recognition systems are among most actively systems that may be used by students with disabilities in SmU. This is the main reason that during initial part of our project we focused research activities primarily on these types of software systems.

4.3 Project Goal and Objectives

The performed analysis of above-mentioned and multiple additional publications and reports relevant to (1) SmU, (2) university-wide smart software and hardware systems and technologies, (3) SmC, (4) smart learning environments, (5) smart educational systems, and (6) students with disabilities undoubtedly shows that SmU-related topics will be in the focus of multiple research, design and development projects in the upcoming 5–10 years. It is expected that in the near future SmU concepts and hardware/software/technological solutions will start to play a significant role and be actively deployed and used by leading academic institutions in the world.

Project Goal. The overall goal of this ongoing multi-aspect research project is a) to research and analyze various open source and commercial software systems in the areas of text-to-voice, voice-to-text, and gesture recognition, and b) identify top systems that could be recommended for implementation and active use in SmU and/or SmC to aid students with disabilities (and possibly students without disabilities).

The premise is that these software systems will make the curriculum more accessible for students with and without disabilities and will help traditional universities to understand the impact this software could have on the learning of students with disabilities and how this software could aid universities to a possible transformation from a traditional university into a smart one.

Project Objectives. The objectives of this project are

(1) close collaboration with subject matter experts and identification of most desired features and functions for software systems to be used by students with disabilities in SmU and SmC;
(2) extensive research and identification of available software systems in text-to-voice, voice-to-text, and gesture recognition areas;
(3) identification and thorough analysis of available software systems in each designated area, including at least 10 commercial and 10 open-source systems,
(4) identification of a list of most important (i.e. most useful for students with disabilities) features (functions) of existing software systems in each designated area;
(5) perform analysis of most powerful (in terms of functionality) existing software systems in each area;
(6) ranking of analyzed systems, i.e. identification of top 3 commercial and top 3 open-source systems among analyzed systems in each area, and
(7) develop lists of open-source and commercial software systems in each designated area that are recommended for in-depth testing by actual students with various categories of disabilities and subject matter experts in smart classrooms and smart universities (and, probably, traditional universities).

The obtained research and analysis outcomes are presented below.

4.4 Research Outcomes: Analysis of Text-to-Voice Software Systems

There are many available text-to-voice software systems that could be implemented in a smart classroom within a SmU. This software will allow the user to convert text to voice so they can hear what information the text is trying to convey if they have issues with reading and comprehending text. Instead of students focusing on reading the text they can focus on comprehending it. For example, the act of reading for some students is a cognitive process. These students see words and have to figure out what letters are in the words, what the letters sound like, and what the actual word is so all there energy is spent on the task of reading, not comprehending the material. Using this software will make the material more accessible to the student with these difficulties. For other students, the actual act of reading is automatic and they can focus on comprehending what they are reading.

After investigating the desired features of text-to-voice software systems (Table 4.4) that, in our mind, should be available for students with disabilities in SmU, the next steps in our research and analysis project were:

(1) Identification and thorough analysis of about 10 commercial and 10 open-source text-to-voice available software systems,
(2) identification of a list of most important (i.e. most useful for students with disabilities) features (functions) of existing text-to-voice software systems,

(3) examples of obtained analysis outcomes of powerful (in terms of functionality) text-to-voice existing software systems, and our ranking of those systems,
(4) our recommendations, i.e. top 3 commercial and top 3 open-source text-to-voice software systems to be implemented and actively used in SmU.

The obtained research and analysis outcomes are summarized and presented in Tables 4.5, 4.6, 4.7, 4.8, 4.9, 4.10, 4.11, 4.12 and 4.13.

4.5 Research Outcomes: Analysis of Voice-to-Text Software Systems

There are many available voice-to-text software systems that could be implemented in a smart classroom within a SmU. This software will allow the user to convert their voice to text if they have issues with written expression. Instead of students focusing on the actual writing process they can focus their attention on producing a high quality product. For example, the act of writing for some students is a cognitive process. These students think of a word, have to think of the letters that make up this word, and then have to think of how the letter looks so they can retrieve it from memory and write it down. This process is very time consuming and by the time they have written a few words they have lost their thoughts on what they initially had planned to write. Using voice-to-test software systems will allow the student with a disability more access and the ability to produce higher quality written products. For other students, the actual act of writing is automatic (i.e., letter

Table 4.4 A list of desired features of text-to-voice software systems for SmU

#	Desired system feature	Feature details
1	Quick response	The system should convert text-to-voice instantly
2	Proof reading	Student or faculty should be able to listen to their notes or assignments, in order to improve the quality of information
3	Access on mobile-devices	It should allow users to convert text-to-voice anywhere
4	Drag-and-drop	This option should allow users to drag their external files to the software, so that it reads aloud for them
5	Multi-linguistic	The software should support several popular languages
6	Highlight word	The word that is read aloud should be highlighted
7	Pronunciation editor	Manually modify the pronunciation of a certain word
8	Batch convertor	Convert multiple documents to MP3, WAV, WMA, etc. files
9	Type-and-talk	A mute student should be able to communicate easily by simply typing what he/she wants to say
10	High quality	Speech should be of high quality with clear pronunciation and minimal errors

Table 4.5 Analyzed 10 commercial and 10 open source text-to-voice software systems

#	Systems analyzed	Company-developer	Technical platform	Ref.
Commercial systems				
1	Natural Reader	NaturalSoft Limited	Windows/Mac	[13]
2	Text Speech Pro	NetHint	Windows/Mac	[14]
3	Read The Words	True Logic	Windows/Linux	[15]
4	TextAloud3	Nextup	Windows/Linux/Mac	[16]
5	Verbose	NCH Software	Windows/Linux/Mac	[17]
6	Voki	Voki	Windows/Mac	[18]
7	Oddcast TTS	Oddcast	Windows/Linux/Mac/Android	[19]
8	Ultra Hal	Zabaware	Windows/Linux	[20]
9	Neo Speech	NeoSpeech	Windows/Mac	[21]
10	Texthelp Read&Write	Texthelp Ltd.	Windows/Mac/IOS/Android with add on to Google Chrome	[22]
Open source (free) systems				
1	Balabolka	Balabolka	Windows/Mac	[23]
2	Text-to-Speech Reader	Speech Logger	Windows/Linux/Mac	[24]
3	Text-to-Speech (TTS)	Poon Family	Windows	[25]
4	Microsoft Word TTS	Microsoft	Windows/Mac	[26]
5	ClipSpeak	Code Plex	Windows/Mac	[27]
6	WordTalk	WordTalk	Windows	[28]
7	Imtranslator	Smart Link	Windows/Linux	[29]
8	iSpeech	Apple	Mac	[30]
9	Google Translate	Google	Windows/Linux/Mac	[31]
10	Power Talk	Atis4all	Windows/Linux	[32]

Table 4.6 A list of most important for SmC/SmU features in existing text-to-voice software systems

#	Existing important features	Details of existing important features
1	High quality	The high speech quality allows users to clearly and better understand information that is produced
2	Pronunciation editor	Allows to manually modify pronunciation of a certain word
3	Batch converter	Allows to convert multiple documents to MP3 at same time
4	Reading speed	Can change the reader and reading speed at any point of time
5	Read documents	Students can listen to any kind of documents like electronic textbooks, PDF files, Microsoft Word documents and web pages
6	Highlight text	Allow students with learning difficulties to hear the material and simultaneously see the words highlighted on screen
7	Spell checking	Can read text as typed, by word or by sentence, and delivers critical real-time feedback to help students with dyslexia improve coordination of sounds and letter combinations

(continued)

Table 4.6 (continued)

#	Existing important features	Details of existing important features
8	Optical Character Recognition (ORC)	Works with scanner to convert printed characters into digital text
9	Natural voice	Includes a great selection of natural-sounding voices
10	Floating bar	Integrate add-in toolbars in MS Word, Outlook and PowerPoint which offers a simple way of reading texts directly on page
11	Multi-linguistic	Supports several popular languages like English, French, German, Spanish etc.
12	Saving formats	Allows saving audio in a file of different formats like MP3, WAV etc.
13	Response time	Conversion to speech is done instantly without much waiting time
14	Mobile-devices	Allow students to listen even on mobile-devices from remote locations
15	Read as typed	Allows a student without speech to easily communicate with faculty or in a group by just typing what he/she wishes to say

Table 4.7 *Natural Reader* [13] commercial text-to-voice system: the analysis outcomes

#	System's characteristics	System's details
1	Main most important system's features and functions	• It can read to the user various types of textual information such as Microsoft Word files, webpages, PDF files, and e-mails • It can be synchronized with iPhone, iPad and Android apps • Textual files can be converted into audio files • Easy-to-use software system with natural-sounding voices; a wide variety of speakers to choose from; it has a selection of over 11 languages and over 50 voices, including children's voices • Speech specs (speed, frequency, etc.) can be easily adjusted • It converts any text or document into natural-sounding voices and even to MP3 or WAV files • The floating bar is a handy tool where user can listen to text in other applications • It allows multi-tasking processing, for example, listening of eBooks while walking, running etc. • For users with low vision, it can display text in large fonts and highlight text while reading aloud • It has high contrast color interface

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Table 4.7 (continued)

#	System's characteristics	System's details
2	Strengths and opportunities	• It allows students to listen to textbooks, class notes, assignments, emails, etc. • It can convert multiple documents into MP3 files at same time with Batch Converter tool • It considerably assists students with dyslexia, reading challenges or visual impairments • It saves eye strain due to ergonomic GUI • It makes proof reading effective • It has very useful features—spell checking and word predicting
3	Possible weaknesses and threats	• It cannot handle some text features and symbols, for example, bullets or dashes
4	Technical platform	• Windows, Mac OS
5	Prices	• $70 (personal) • $130 (professional) • $200 (ultimate) • Various packages are available for schools—details are available at http://www.naturalreaders.com/exploring.html
6	Colleges/universities that currently use this system	• Hamburg University of Technology • University of Pennsylvania
7	System's ranking	**Our ranking of this system: 1** Main reasons: • It works in 11 different languages and has over 50 voices available • It has spell checking and word predicting features • It works with e-books and/or e-textbooks from various vendors

Table 4.8 *Read the Words* [15] commercial text-to-voice system: the analysis outcomes

#	System's characteristics	System's details
1	Main most important system's features and functions	• It supports three different languages and 15 different voices • Virtual Reader avatar helps students to read along and improve their reading skills • It illustrates how words are spoken by native speakers • It can upload any Microsoft Office document, Adobe PDF, TXT or HTML document • It easily converts textual files into MP3 files • It helps non-native speaker to speak English correctly
2	Strengths and opportunities	• 2 levels of quality for audio—highest and high • Relatively easy integration with most popular applications • Highly accurate text interpretation • It is useful for students learning English, French and Spanish

(continued)

Table 4.8 (continued)

#	System's characteristics	System's details
3	Possible weaknesses and threats	• Recording speed cannot be adjusted
4	Technical platform	• Windows OS, 100 MB hard disk (at least), 256 MB RAM (at least)
5	Prices	• $100 per year or $20 per month
6	Schools/universities that currently use this system	• Hodges University • Monroe Public School • Springfield Elementary School • St. Charles Parish Public Schools
7	System's ranking	**Our ranking of this system: 2** Main reasons: • Grammatical errors can be fixed by listening to the typed notes • Podcast feature enables students to broadcast their paper to everyone instantly

Table 4.9 *TextHelp Read&Write* [22] commercial text-to-voice system: the analysis outcomes

#	System's characteristics	System's details
1	Main most important system's features and functions	• System reads texts from TXT and PDF files • It supports typing echo feature • It includes fact finder where the user can be able to search information from the provided search engines • It contains a picture dictionary which provides the relevant pictures for the words searched • It contains a built-in dictionary • It contains a translator for a selected text to be translated into selected other language • The scan feature is able to scan 5-8 image formats such as the.JPG,.PNG,.GIF,.BMP to text. • Daisy reader can be used to read any digital e-books • Uses PDF aloud feature to read PDF files • Word prediction feature is available which will be able to provide suggestions for the next required word • It also includes the speech to text software

(continued)

Table 4.9 (continued)

#	System's characteristics	System's details
2	Strengths and opportunities	• Based on the type of disability, the user can use needed feature: Reading, Writing or Research • Students can make use of typing echo where the software reads the words as soon as the student completes writing it • Spell checking is available—it provides word suggestions for the misspelled words • Screenshot reader helps users to take screen shot of any text which is then read out to them • Verb Checker helps users to check for specific verbs, later receive the examples about how the verb is used • Voice note helps students to record speech, replay it, save the audio into a file, and, if needed, insert it into a document • Picture dictionary can help users who have problem remembering the context; in this dictionary every word is presented as a picture
3	Possible weaknesses and threats	• Cannot read data from the DOC file
4	Technical platform	• Supports Windows and Mac operating systems
5	Price (if any)	• $145/copy
6	Colleges/universities/companies that currently use this system	• Colorado College • Los Angeles City College
7	System's ranking	**Our ranking of this system: 3** Main reasons: • Can read the text from PDF files • Helps students with reading and writing disabilities • Also includes speech to text software

Table 4.10 *Balabolka* [23] open-source text-to-voice system: the analysis outcomes

#	System's characteristics	System's details
1	Main most important system's features and functions	• It allows to save the converted file in WAV, MP3, MP4 or WMA • Every line of text can be converted to an audio file if necessary • It has a timer and it can be controlled by hot keys • It can read the clipboard context and view text from documents saved as DOC, EPUB, HTML, PDF, RTF, etc. • It can extract text from PDF files directly • It offers fine tuning of text-to-speech voices • It can alter how fast the voice reads, what pitch it reads in and can even use custom dictionaries to improve pronunciation

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Table 4.10 (continued)

#	System's characteristics	System's details
2	Strengths and opportunities	• It supports around 32 languages • The HELP support files are available in 7 different languages • It allows to customize the window appearance with downloadable skins • It allows to use regular expressions like "Find" and "Replace" • It can run in full screen mode or in a window
3	Possible weaknesses and threats	• Importing documents does not retain its format • The quality of outcomes (deliverables) may vary
4	Technical platform	• Windows XP/Vista/7/8/10 • Mac OS
5	Price (if any)	• Open Source
6	Colleges/universities that currently use this system	• University of Edinburgh, Scotland • The Open University, UK
7	System's ranking	**Our ranking of this system: 1** Main reasons: • The audio is of high quality and users can alter voices, pitch, cadence and speed • It can use language modules from Microsoft Office for spell checking

Table 4.11 *Text-to-Speech Reader* [24] open-source text-to-voice system: the analysis outcomes

#	System's characteristics	System's details
1	Main most important system's features and functions	• It supports multiple languages • This is ideal system to listen class notes, articles etc. • It can adjust speed of speech • It helps students with learning disabilities and visual impairments to read text aloud in natural sounding voices • It highlights text that is read aloud • It has a user-friendly interface • It allows "copy and paste" procedure
2	Strengths and opportunities	• It reads text aloud with natural sounding voices • It is very useful for mute users; they can simply type in and click on play button • The user interface is easy to understand • It helps to avoid contact with computer screen for reading long textual information • It allows to listen to hours of textual podcasts with close to zero data consumption • It is a multi-linguistic system
3	Possible weaknesses and threats	• It needs continuous internet connection • It cannot drag and drop files

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Table 4.11 (continued)

#	System's characteristics	System's details
4	Technical platform	• Windows, Mac OS • Any standard Web browser like Chrome, Safari can be used • Decent Internet connection is required
5	Price (if any)	• Open Source
6	Colleges/universities that currently use this system	• Kurzweil Educational Institutions • Albany Hills State School, Australia • Hamilton State School, Australia
7	System's ranking	**Our ranking of this system: 2** Main reasons: • Students with visual impairments can listen to very long textual data files—this is a great benefit for those students • The system saves a lot of data from mobile traffic • It has a very simple and intuitive GUI

Table 4.12 *Text-to-Speech TTS* [25] open-source text-to-voice system: the analysis outcomes

#	System's characteristics	System's details
1	Main most important system's features and functions	• User can type, copy and paste, or open text files • "Click to Speech" begins enunciating the contents of user's text, highlighting the current part as it is being read • Operation in 32 different languages is available for users • It allows to listen in the background while working on other applications • It allows speech speed control • It can work with any webpage
2	Strengths and opportunities	• It makes communication easier for people with speech disorders, vision impairments, and dyslexia • It is multi lingual system • It highlights text when reading • It allows multi-tasking processes
3	Possible weaknesses and threats	• It cannot read PDF files • It lacks speed-reading control feature • It has no spell checker available
4	Technical platform	• Windows 8.1, 10, Windows 10 Mobile, Windows Phone 8.1 • Architecture × 86, × 64, ARM
5	Price (if any)	• Open Source
6	Colleges/universities that currently use this system	• University of Kent, UK • University of Michigan
7	System's ranking	**Our ranking of this system: 3** Main reasons: • Users can listen audio in the background while working on other applications • Highlighting the text when read aloud is an useful advantage • Wide range of languages is available for users

Table 4.13 Our recommendations: existing top 3 commercial and top 3 open-source text-to-voice software systems to be implemented and actively used in SmC/SmU

#	System	Company-developer	Details	Ref.
Commercial systems				
1	Natural Reader	NaturalSoft Limited	$70/copy (personal), $130 (professional), $200 (ultimate)	[13]
2	Read The Words	True Logic	$100 per year or $20 per month	[15]
3	Texthelp Read&Write	Texthelp Ltd.	$145/copy	[22]
Open source (free) systems				
1	Balabolka	Balabolka	Windows/Mac	[23]
2	Text-to-Speech Reader	Speech Logger	Windows/Linux/Mac	[24]
3	Text-to-Speech (TTS)	Poon Family	Windows	[25]

formation, word spellings, punctuation, etc.) and they can focus on the content of the message or assignment they are involved in writing.

Based on our current and past research project and obtained research outcomes, a generalized list of desired features of voice-to-text software systems for SmU is presented in Table 4.14.

After investigating the desired features of voice-to-text software systems (Table 4.14) that, in our mind, should be available for students with disabilities in SmU, the next steps in our research and analysis project were:

Table 4.14 A list of desired features of voice-to-text software systems for SmU

#	Desired system feature	Feature details
1	Dictate continuously	It should help faculty to dictate notes continuously in a normal, conversational pace without slowing down pace or over-enunciating words
2	Robust documentation	It should allow users to create documents with punctuation marks
3	Accent support	It should allow faculty from different locations to communicate easily
4	Hands-free	It should help students with disabilities such as repetitive strain injury (RSI), dyslexia, vision impairment, etc.
5	Recognition speed	The text should appear on screen as it is dictated, without any delay
6	Accuracy	The text should be accurate without any major errors
7	Mobility	Documents should be easily integrated with cloud technology
8	Web search	Students should be able to search the Web by just dictating
9	Multi-lingual support	System should be able to listen to text in native language voices and recognize voices with quality
10	Easy-to-use	It should help users to dictate, and, when finished, simply copy-paste dictated text where needed

Table 4.15 Analyzed 10 commercial and 10 open source voice-to-text software systems

#	Systems analyzed	Company-developer	Technical platform	Ref.
Commercial systems				
1	Dragon Naturally Speaking Premium (Home Edition)	Nuance	Windows/Mac/Android/iOS	[33]
2	Dragon Professional Individual	Nuance	Windows/Mac/Android/iOS	[34]
3	Braina Pro	Brainasoft	Windows/Android	[35]
4	Tazti Speech Recognition Software	Voice Tech Group Inc.	Windows	[36]
5	SpeechGear Compadre Interact	SpeechGear	Windows/Mac	[37]
6	Dictation Pro	Desk Share	Windows/Mac/Linux	[38]
7	e-Speaking	e-speaking	Windows	[39]
8	Voice Finger 2.6.2	Robson Cozendey	Windows	[40]
9	Text Shark	textshark	Windows	[41]
10	Speechmatics	Speechmatics	Windows	[42]
Open source (free) systems				
1	Windows Speech Recognition	Microsoft	Windows	[43]
2	Apple Dictation	Apple	Mac	[44]
3	TalkTyper	TalkTyper	Windows/Mac	[45]
4	Jasper	Jasper Project	Windows/Mac/Linux	[46]
5	Dictation 2.0	Digital Inspiration	Windows/Mac	[47]
6	Speechnotes	SpeechNotes	Windows/Mac/Linux	[48]
7	Digital Syphon Sonic Extractor	Digital Syphom	Windows/Mac	[49]
8	Balabolka	Ilya Morozov	Windows	[50]
9	Speech Logger	Speehclogger	Windows/Mac	[51]
10	Google Docs—Speech Recognition	Google	Any platform that supports Google Chrome browser	[52]

(1) identification and thorough analysis of about 10 commercial and 10 open-source voice-to-text available software systems,
(2) identification of a list of most important (i.e. most useful for students with disabilities) features (functions) of existing voice-to-text software systems,
(3) examples of obtained analysis outcomes of powerful (in terms of functionality) voice-to-text existing software systems, and our ranking of those systems,
(4) our recommendations, i.e. top 3 commercial and top 3 open-source voice-to-text software systems to be implemented and actively used in SmU.

The obtained research and analysis outcomes are summarized and presented in Tables 4.15, 4.16, 4.17, 4.18, 4.19,4.20, 4.21,4.22 and 4.23.

Table 4.16 A list of most important for SmC/SmU features in existing voice-to-text software systems

#	Existing important features	Details of existing important features
1	Dictate continuously	It helps faculty to dictate notes continuously in a normal pace, without slowing down pace
2	Collaboration	Students can collaborate on group projects by sending e-mails or instant messages entirely by voice
3	Enhanced diction	It can save information like name, relationships and send e-mails to friends and professors easily
4	Accent support	It allows users from different locations to document reports
5	Flawless report	It generates reports and documents with almost zero errors
6	Edit and format	Users can edit and format documents and reports all by voice
7	Web search	Students who cannot type can easily search the Web for any information and save the required data
8	Instant translator	Faculty can communicate with deaf students easily
9	Compatibility	The system is compatible with device's screen of the user using even outside the smart classroom
10	Voice control	Users can control their computers by performing various functions such as (a) launching application, (b) selecting menu items, (c) switch between windows, and other functions using voice commands
11	Mobility	Users can easily use cloud technology and access documents from anywhere
12	Robust documentation	It allows the user to write documents with punctuation marks like "period" for ".", "question mark" for "?", etc.
13	Multi-lingual support	It supports multiple language inputs
14	Word suggestions	It provides suggestions for words pronounced similarly
15	Import audio	Students can import different audio lecture files and convert them into a textual file

Table 4.17 *Braina Pro* [35] commercial voice-to-text system: the analysis outcomes

#	System's characteristics	System's details
1	Main most important system's features and functions	• It uses natural language interface and speech recognition to interact with its users and allows them to use English language sentences to perform various tasks on their computer • It can find information on the Internet, take dictation, find and open files, set alarms and reminders, perform math calculations, etc. • It adapts to the user's behavior over time to better anticipate needs • It is a multi-functional software that provides a single window environment to control user computer and perform wide range of tasks using voice commands • It can remember notes, automate various computer tasks, read e-books, etc.

(continued)

Table 4.17 (continued)

#	System's characteristics	System's details
2	Strengths and opportunities	• "Easy to learn and easy to use" graphic user interface • Easy to set up; no need of voice training • User can ask system to learn information from file using "Learn from File" feature
3	Possible weaknesses and threats	• Currently it can only understand simple English language at present • It gets confused if complex sentences are used
4	Technical platform	• Operating system: Window 10/8.1/8/7/Vista/XP • Dependencies: msvcr100.dll • Internet connection required to use some features
5	Price (if any)	• $40 per year
6	Companies that currently use this system	• TechRadar • Wikipedia • Brainasoft, the Intel Software Partner
7	System's ranking	**Our ranking of this system: 1** Main reasons: • It allows user to customize voice commands and replies • Users can schedule events like class times and when homework is due just by giving commands

Table 4.18 *Dragon Naturally Speaking Premium (Home Edition)* [33] commercial voice-to-text system: the analysis outcomes

#	System's characteristics	System's details
1	Main most important system's features and functions	• It allows users to dictate words three times faster than typing with up to 99% accuracy of word recognition • It allows user to speak, and up to 160 words per minute are transcribed and appear on computer screen; it can read back transcribed text to ensure that the material is truly what the user intended to say • It allows users with blindness/low vision, dyslexia, dyspraxia, mobility or dexterity impediments are able to show proof of what they know because they can speak out their ideas to compose an essay or writing an answer • It allows students who have dyslexia to complete assignments orally and still produce written output for grading purposes • It allows users to send email and instant messages to collaborate on group or classroom projects to students, faculty, parents, administrators—entirely by voice • It provides users with an easier way to control a computer that is less physically and cognitively taxing

(continued)

Table 4.18 (continued)

#	System's characteristics	System's details
2	Strengths and opportunities	• Users who would normally write incomplete or simple sentences have the ability to use more complex sentence structures to appropriately describe their ideas • Teachers can dictate feedback more quickly because students work is completed electronically • It has 99% accuracy of word recognition; the outcome text will be spell-checked • It has an integrated dictionary that takes care of all spell checking; as a result users can focus on their thoughts and do not worry a lot about the process of typing and spell checking • It allows user to speak, and up to 160 words per minute are transcribed and appear on computer screen; it can read back transcribed text to ensure that the material is truly what the user intended to say
3	Possible weaknesses and threats	• Outdated computers may not be able to cope with this system • The initial task to set up the program for a new user is quite complex—users need to read a lengthy passage • It takes time to "teach" the system to recognize/learn user's voice style and to help it recognize how certain words are pronounced by that particular user; in some cases, it may be a frustrating experience for some users
4	Technical platform	• Operating systems—Windows 7, 8, 8.1 (32bit and 64bit), Windows Server 2008 64bit, 2012 64bit • RAM—2 GB for 32-bit Windows 7, 8 and 8.1, 4 GB for 64-bit Windows 7, 8 and 8.1 and Windows Server 2008 R2, Windows Server 2012 • CPU—min 2.2 GHz Intel dual core or equivalent AMD processor • Free hard disk space—4 GB • A sound card supporting 16-bit recording • A Nuance-approved microphone • An Internet connection for automatic product activation
5	Price (if any)	• About $100 per copy • About $130—Dragon for Mac Student/Teacher Bundle
6	Colleges/universities that currently use this system	• Yale Center for Dyslexia and Creativity (YCDC) • Arizona State University
7	System's ranking	**Our ranking of this system: 2** Main reasons: • It is exclusively developed for educational purposes and is widely used by educational institutions

Table 4.19 *Dragon Professional Individual* [34] commercial voice-to-text system: the analysis outcomes

#	System's characteristics	System's details
1	Main most important system's features and functions	• It adapts to user's unique voice, environment and becomes more accurate as user dictates his/her information • It is designed with next generation speech engine leveraging Deep Leaning Technology • User can tailor the vocabulary with the terms used every day • It allows users to add formatting rules by voice, such as bold or underline • It is available in English, French, Dutch, Japanese, Spanish, Italian and German languages
2	Strengths and opportunities	• It "learns" the words and phrases that users use the most to minimize corrections • It optimizes accuracy for speakers with accents or in slightly noisy environment such as a classroom • Smart Format Rules automatically adapt to how student/lecturer want abbreviations, dates, phone numbers, etc. to appear • It allows faculty to speak as long as possible without pausing to wait for the software to transcribe the already pronounced information • It allows to import and export to/from popular cloud-based document-sharing tools like Dropbox and note-taking apps like Evernote
3	Possible weaknesses and threats	• It works with most common Web browsers but not Edge • If there is a considerable noise in the environment, it is likely to get far more errors • There should be minimum background noise • It is relatively expensive software
4	Technical platform	• RAM: Minimum 4 GB • CPU: Intel dual core or equivalent AMD processor • Free hard disk space: 8 GB • Operating systems: Windows 7, 8.1, 10(32-bit and 64-bit); Windows Server 2008 R2 and 2012 R2 • Built-in microphone or a Nuance-approved microphone • An Internet connection for product download and automatic product activation
5	Price (if any)	• Starts at $300 per copy
6	Colleges/universities that currently use this system	• Lamas College, Iowa • Youth Villages (Health and Human Services)
7	System's ranking	**Our ranking of this system: 3** Main reasons: • It can transcribe from .MP3, .AIF, .WAV, .MP4 audio files to text easily • It significantly saves time and eliminates reliance on costly transcription services; for example, out of 250 words dictated only one was incorrectly transcribed

Table 4.20 *Google Doc–Speech Recognition* [52] open-source voice-to-text system: the analysis outcomes

#	System's characteristics	System's details
1	Main most important system's features and functions	• Voice typing of the document with the help of microphone • The Google documents are saved to user's Google drive thereby making it easier to view documents later • Corrections can be made while voice typing process takes place • It supports many languages alongside different dialects of the same language • Punctuation can be added to the text by using special pre-defined phrases such as the period ('.'), comma, question mark, exclamation point…etc. • Commands can be used to edit, select or format the text • The users can stop or resume voice typing by using special pre-defined commands • It can create tables • User can dictate continuously without the use of the Internet connection, but need a proper connection for saving of files • Accuracy is pretty favorable without many mistakes
2	Strengths and opportunities	• It is a very helpful system for users to prepare documentation anywhere and anytime • It can be installed by anyone as long as they have Google Chrome browser • No tension of losing the information in document due to any technical errors; this is because the system automatically regularly saves document • It does not require lengthy voice training from the user • Spelling mistake can be corrected • Speaking can be stopped or resumed whenever needed • It is a free add-on for any operating system that supports Google Chrome browser
3	Possible weaknesses and threats	• If there is no proper Internet connection, saving of a document automatically is impossible • If there is loud background voice or noise, then there might be high chance of errors • If the microphone is far from the user, then accuracy (or, quality) of outcome text may decrease
4	Technical platform	• Any operating system that supports Google Chrome browser
5	Price (if any)	• Free
6	Colleges/universities that currently use this system	• Google • Many local schools in the United States use this system
7	System's ranking	**Our ranking of this system: 1** Main reasons: • It supports many languages and dialects • Commands can be given for punctuation signs • Editing and formatting the document can also be done • It proved to be a very feasible system

Table 4.21 *Windows Speech Recognition* [43] open-source voice-to-text system: the analysis outcomes

#	System's characteristics	System's details
1	Main most important system's features and functions	• Users can type and use simple commands with their voices • The system can be trained to better understand your language • It uses speech profile to store information about user's voice • It can navigate your computer through commands • It has about 97.8% accuracy • Users can dictate text within documents • Opening, closing, switching and scrolling programs' functions are very easy • Users can dictate their e-mails and the system will type them • Filling forms can also be done using voice commands • The accuracy of speech recognition increases through active use • Individual speech profiles can be created on a per-user basis • Users can say "How do I … (specify a task)", and the system will act accordingly
2	Strengths and opportunities	• Permanent on-going adaptation to both your speaking style and accent continually improves speech/voice recognition accuracy • The new interface provides a simple and efficient experience for dictating and editing text, correcting mistakes and controlling user's computer by voice • It has support for multiple languages—English (United States), English(United Kingdom), German(Germany), French(France), Spanish(Spain), Japanese, Traditional Chinese and Simplified Chinese • It can help people who has trouble using their fingers and/or hands • It can help users who have cognitive disabilities • No extensive training is required for users • It increases productivity; for example, faculty can dictate their feedback/evaluation more quickly because student/learner work is completed electronically • It is free and in-built for Windows operating system • It has long term benefits for students/learners
3	Possible weaknesses and threats	• If there is a background noise or some other sound in the room, the number is errors will increase • More distant (at a distance) microphones from users will tend to increase the number of errors • It has an initial period of adjusting to each user's voice • It may not work properly in a cubicle environment
4	Technical platform	• Windows 7 or 8 or 10 OS
5	Price (if any)	• Free (since it is in-built Windows OS)
6	Colleges/universities/companies that currently use this system	• Many leading companies like Microsoft, IBM, Symantec, Oracle, SAP

(continued)

Table 4.21 (continued)

#	System's characteristics	System's details
		• Many sister companies of Microsoft such as NextBase, Fox Aoftware, Netwise, PlaceWare, Groove Networks, Metanautix
7	System's ranking	**Our ranking of this system: 2** Main reasons: • It allows users to dictate emails and documents easily • It increases an independence for students with physical disabilities and possibly other disabilities

Table 4.22 *TalkTyper* [45] open-source voice-to-text system: the analysis outcomes

#	System's characteristics	System's details
1	Main most important system's features and functions	• It is a free software in Web browser • It can get started right away after user gives microphone permission to talk to the application • Allows to translate all the text into another language • Various options are available to correct the outcome text • It can copy to clipboard, add punctuation, print, and clear all texts • It can send an e-mail, and tweet your text • English Language students/learners can speak English, play it back, and correct it until it "sounds right" and expresses their ideas correctly
2	Strengths and opportunities	• Users can bypass poor typing skills, dysgraphia, dyslexia and physical disabilities • It doesn't require any additional downloads onto user computer • Writing an e-mail to classmates or lecturer is easier as student needs to just click the e-mail button after dictating the text
3	Possible weaknesses and threats	• It is not completely hands-free system; some editing must be done with mouse and keyboard • It needs a constant connectivity to the Internet • If paused for a short time (even a fraction of second), the system may cut user off)
4	Technical platform	• Internet
5	Price (if any)	• Free
6	Colleges/universities that currently use this system	• Clinton County Regional Educational Service Agency (www.ccresa.org) • The Australian Disability Clearing House on education (www.adcet.edu.au) • TeachersFirst (http://www.teachersfirst.com)
7	System's ranking	**Our ranking of this system: 3** Main reasons: • Users with physical disabilities, dyslexia, dysgraphia and poor typing skills may get a great advantage to improve content and overcome problems related to writing and/or typing

Table 4.23 Our recommendations: existing top 3 commercial and top 3 open-source voice-to-text software systems to be implemented and actively used in SmC/SmU

#	System	Company-developer	Details	Ref.
Commercial systems				
1	Braina Pro	Windows/Android	$40 per year	[35]
2	Dragon Naturally Speaking Premium (Home Edition)	Windows/Mac/Android	$100 per copy	[33]
3	Dragon Professional Individual	Windows/Mac/Android	$300	[34]
Open source (free) systems				
1	Google Docs—Speech Recognition	Any platform that supports Google Chrome browser	Open Source	[52]
2	Windows Speech Recognition	Windows	Open Source	[43]
3	TalkTyper	Windows/Mac/Linux	Open Source	[45]

4.6 Research Outcomes: Analysis of Gesture Recognition Systems

Gesture recognition software systems, in general, will allow the user to communicate with the machine naturally, using human-machine interface (HMI) and without any mechanical devices. For example, using the gesture recognition technology, it is possible to point a finger at the computer screen so that the computer cursor on a screen will move accordingly. Potentially, this technology could make conventional input devices such as mouse, keyboards and even touch-screens redundant. For the individual with any type of motor difficulties this could make a huge contribution to them having access to content in the Smart Classroom.

Currently, there are several gesture recognition software systems available that potentially in the future could be implemented in a smart classroom within a SmU. Unfortunately, most of them are not mature enough to be recommended at this moment for an implementation and active use in SmU.

Based on the outcomes of extensive literature review and creative analysis of existing gesture recognition systems, we arrived with a generalized list of desired features of gesture recognition systems suitable for SmU; those features are presented in Table 4.25.

After investigating the desired features of gesture recognition software systems (Table 4.24) that, in our mind, should be available for students with disabilities in SmU, the next steps in our research and analysis project were:

(1) identification and thorough analysis of about 10 commercial and 10 open-source available gesture recognition software systems,

Table 4.24 A list of desired features of gesture recognition software systems for SmU

#	Desired system feature	Feature details
1	Provide alternatives	Alternatives to mouse and keyboard input should be provided for users with hearing or visual impairments or physical disabilities
2	High-speed recognition	The system should have no difficulty to recognize high speed hand movements/signals and input from multiple users at the same time
3	User-friendly system	The system should be easy to learn, easy to use and easy to understand by students with disabilities
4	Transcribe to text	It should be able to understand quickly and with a good quality the sign language's elements/components and transcribe them into a text
5	Interact with digital content	Tracking cameras should be able to detect hand movement to allow user or multiple users to interact with digital content on a screen
6	Engage every user	It should allow multiple users to participate at once, making sure that nobody is left behind
7	Multimodality	It should be adaptable to users with wide range of communication (gesture) styles
8	Immediate feedback	It should be able to provide immediate feedback (reaction of the system)
9	Portability of a system	It should be easy to move a system to different locations and assemble it
10	Technical platform independent system	The system should be work on multiple operating systems

(2) identification of a list of most important (i.e. most useful for students with disabilities) features (functions) of existing gesture recognition software systems,
(3) examples of obtained analysis outcomes of powerful (in terms of functionality) gesture recognition existing software systems, and our ranking of those systems,
(4) our recommendations, i.e. top 3 commercial and top 3 open-source gesture recognition software systems to be implemented and actively used in SmU.

The obtained research and analysis outcomes are summarized and presented in Tables 4.25, 4.26, 4.27, 4.28, 4.29, 4.30, 4.31, 4.32, 4.33.

Table 4.25 Analyzed 10 commercial and 10 open source gesture recognition software systems

#	Systems analyzed	Company-developer	Technical platform	Ref.
Commercial systems				
1	Kinect	Microsoft	Windows/Mac	[53]
2	Intel RealSense	Intel	Windows/Linux/Mac	[54]
3	IISU	SoftKinetic	Windows/Linux/Android	[55]
4	G-Speak	Oblong	Windows/Linux/Mac	[56]
5	Kinems	Kinems	Windows/Mac/Linux	[57]
6	Elliptic Labs Software	Elliptic Labs	Windows	[58]
7	Leap Motion	Leap Motion	Windows/Mac	[59]
8	UbiHand	Petr Musilek	Windows	[60]
9	Kinect Education	KinectEDucation	Windows	[61]
10	ArcSoft 3D hand gesture recognition	ArcSoft	Windows/Linux/Mac	[62]
Open source (free) systems				
1	HandVu	Moves Institute	Windows/Linux/Mac	[63]
2	FUBI (Full Body Interaction Fr.)	Augsburg	Windows/Linux	[64]
3	Wiigee	Ninttendo	Windows/Linux	[65]
4	ControlAir	Apple	Mac	[66]
5	GestTrack3D	GestureTek	Windows	[67]
6	iGesture	Globis	Windows/Linux/Mac	[68]
7	OpenCV	IntoRobotics	Windows	[69]
8	KinectCAD	Catia	Windows	[70]
9	Accelerometer Gesture Recognizer	David Uberti	Windows	[71]
10	Gesture Clustering toolkit (GECKo)	Jacob O. Wobbrock	Windows	[72]

Table 4.26 A list of most important for SmC/SmU features in existing gesture recognition systems

#	Existing important features	Details of existing important features
1	High-speed recognition	The system is able to recognize high-speed hand signals
2	Multiple-users	The system is able to handle multiple users at the same time
3	Transcribe to text	The system is able to take sign language and transcribe it into text
4	Engage every student	The system is able to handle multiple participating students at once
5	Friendly GUI	Dome systems have friendly GUI
6	Camera tracking	Tracking cameras are able to detect user hand movement and allow the user to interact with digital content
7	Sign language recognition	The system is able to detect/recognize elements/components of sign language; it helps mute students to communicate with a system and digital content
8	Multimodality	System supports user's different communication styles
9	Interactivity	Students with disabilities are immersed in a variety of interactives with a physical (in-classroom) and online (remote) students
10	Platform independent	Some systems work on different operating systems

Table 4.27 *Microsoft Kinect* [53] commercial gesture recognition system: the analysis outcomes

#	System's characteristics	System's details
1	Main most important system's features and functions	• Faculty can enhance traditional lesson plans, special education, physical education, school communication and collaboration and after-school programs with immersive full-body experiences that help students get engaged in learning, stay on task and inspire creativity and camaraderie with peers • It tracks as many as six complete skeletons and 25 joints per person • It allows the sensor to see in the dark; the IR capabilities produce a lighting-independent view • It has four microphones to capture sound, record audio, as well as find the location of the sound source and the direction of the audio wave
2	Strengths and opportunities	• It will track every user and so is very adaptable for wheelchair users
3	Possible weaknesses and threats	• For students with Specific Learning Disability (SLD), the program is quite visually messy • Although it can track wheelchair users it is not 100% ready for this • It requires skilled faculty to use; faculty development is required • Visually impaired students cannot use the system
4	Technical platform	• Xbox Kinect Sensor • Kinect SDK • 64-bit (× 64) processor • 4 GB Memory (or more) • Dual-core 3.1 GHz or faster processor • USB 3.0 controller dedicated to the Kinect for Windows v2 sensor • Microsoft Kinect v2 sensor, which includes a power hub and USB cabling • Projector, Smart Board, or large screen or a big TV screen
5	Price (if any)	• The Kinect SDK is free to download; however, the Kinect Sensor Bar will cost around $60–$100
6	Colleges/universities that currently use this system	• Los Angeles Unified School District (California) • Chicago Public Schools (Illinois) • Houston Independent School District (Texas) • Scottsdale Unified School District (Arizona) • Flagstaff Unified School District (Arizona) • Fairfax County Public Schools (Virginia) • Loudoun County Public Schools (Virginia) • University of Washington
7	System's ranking	**Our ranking of this system: 1** Main reasons: • Schools which used this system reported that it showed a trend of improved executive function, which is the portion of the brain responsible for planning, problem-solving and working memory

Table 4.28 *Intel Real Sense* [54] commercial gesture recognition system: the analysis outcomes

#	System's characteristics	System's details
1	Main most important system's features and functions	• It provides facial recognition, hand gestures, background removal, depth enabled photo, scene perception, 3D scanning and other functions • It supports Augmented Reality • The camera is advanced—it measures depth and enable the computer to read facial expressions and gestures and swap out backgrounds
2	Strengths and opportunities	• Device can be accessed by logging in with student's or faculty's face and it has a good security • It enables person detection and tracking, skeleton tracking, gestures, object recognition etc.
3	Possible weaknesses and threats	• The camera to be used is intended solely for use with Intel RealSense SDK for Windows • The camera drivers need to be downloaded separately
4	Technical platform	• Microsoft Windows 8.1 or 10 OS 64-bit • 4th generation (or later) Intel Core processor • 8 GB free hard disk space • An Intel RealSense camera SR300 (Front-Facing) or R200 (Rear-Facing) • The RealSense Camera F200 has three cameras in one—a 1080p HD camera, an infrared camera and infrared laser projectorC# (Microsoft.NET 4.0 Framework is required) • Java (JDK 1.7.0_11 or later) • Microsoft Visual Studio 2010-2015 or newer
5	Price (if any)	• Intel RealSense SDK is free to download • Intel RealSense Developer Kit R200 will cost $99 • Intel RealSense Developer Kit SR300, which is the next version, will cost $149
6	Companies that currently use this system	• Acer • Dell • Lenovo • HP • Fujitsu
7	System's ranking	**Our ranking of this system: 2** Main reasons: • Intel RealSense SDK can create the next generation of natural, immersive and intuitive software applications • It has many capabilities like facial recognition, hand gestures, background removal, depth enables photo, scene perception, 3D scanning, etc. • The key features involve depth video recording and replay with frame by frame navigation

Table 4.29 *IISU* [55] commercial gesture recognition system: the analysis outcomes

#	System's characteristics	System's details
1	Main most important system's features and functions	• It offers full-body skeleton tracking as well as precise hand and finger tracking • IISU's toolbox provides access to live data and performance analytics during development
2	Strengths and opportunities	• It offers a robust solution from individual finger tracking up to full-body skeleton tracking • The middleware enables developers to easily and rapidly produce gesture based applications for both Close Interaction (3 feet) and Far Interaction (10 feet) experiences • Setup time will be reduced to zero and will not require the multiple calibration steps necessary with other gesture recognition systems
3	Possible weaknesses and threats	• The different plug-ins permits the faculty and students to control the monitors using hand gestures only while sitting comfortably • The free version can only actively track one person • The updates have been discontinued since the release of specialized DepthSense Libraries
4	Technical platform	• Windows 7, Windows 8, Linux and Android 4.1. • Plugins are available for (a) Adobe Flash—access all IISU SDK functions in Action Script 3, (b) Unity3D (V3.0 +)—retrieve and send data in real time using mono-native support of the Unity platform • It supports powerful legacy camera such as the original Kinect, the Asus Xtion, the Panasonic D-Imager and the SoftKinetic DepthSense 331 and 325
5	Price (if any)	• It is free for non-commercial use for three months • Commercial license for IISU can be bought for a one-time fee of $1,500
6	Colleges/universities that currently use this system	• Seneca School, Canada • GURU training Systems • Disney's "The Sorcerer's Apprentice"
7	System's ranking	**Our ranking of this system: 3** Main reasons: • IISU's features are turned to use minimal CPU and memory resources with rapid refresh rates at 25/30/50/60 fps • It is optimized for higher performance

Table 4.30 *Hand Vu* [63] open-source gesture recognition system: the analysis outcomes

#	System's characteristics	System's details
1	Main most important system's features and functions	• It is intended to track and record hand gestures • It discovers and reports three key pieces of information about the tracked hand, including the x and y coordinates and its "posture". The system has 26 hand postures recognitions • The software collection implements a vision-based hand gesture interface. It detects the hand in a standard posture, then tracks it and recognizes key postures—all in real-time • The output is accessible through library calls
2	Strengths and opportunities	• The system can work under various degrees of background lightening conditions • It has 26 hand standard postures recognitions • It has about 90% average recognition rate • It is available free of charge • It is well documented with full reference manual • It has user friendly graphic interface
3	Possible weaknesses and threats	• Tracking is not very effective with fast hand motion • The tracking will get off more frequently and recognition rates might suffer if there is a very hard contrast in the background • It requires sensor cameras that usually very expensive; it does not work with miniature cameras
4	Technical platform	• Windows, Mac OS
5	Price (if any)	• Free download
6	Colleges/universities that currently use this system	• Pennsylvania State University • University of Electronic Science and Technology, China • Montana State University
7	System's ranking	**Our ranking of this system: 1** Main reasons: • It has about 90% average recognition rate (this is a very good technical outcome) • It can be integrated into more complex software systems that can add significant benefits to users with disabilities

Table 4.31 *FUBI (Full Body Interaction Framework)* [64] open-source gesture recognition system: the analysis outcomes

#	System's characteristics	System's details
1	Main most important system's features and functions	• It recognizes full body gestures and postures in real time from the data of a depth sensor • It records gesture performances and can generate valid XML file • It supports gestural interaction by using gesture symbols • It provides buttons and swiping menu to implement freehand GUI interaction • The download comes with Visual Studio 2010 and 2013 solutions • It is written in C ++ and additionally includes a C# - wrapper
2	Strengths and opportunities	• It distinguishes between four gesture categories: (a) static postures (configuration of several joints, no movement); (b) gestures with linear movement (linear movement of several joints with specific direction and speed); (c) combination of postures and linear movement (combination of above two with specific time constraints); (d) complex gestures (detailed observation of one or more joints over a certain amount of time) • It supports gestural interaction by using gesture symbols
3	Possible weaknesses and threats	• It requires the installation of additional files and a compliant middleware to support full body tracking • Testing and fine tuning of gestures could be an issue; it is a time consuming process
4	Technical platform	• Modern Windows operating systems • It requires the installation of OpenNI (OpenNI binaries) and a complaint middleware supporting full body tracking
5	Price (if any)	• Freely available under the terms of the Eclipse Public License—v 1.0
6	Colleges/universities that currently use this system	• Augsburg University • Ontario College of Art & Design • MukiBaum Treatment Centers
7	System's ranking	**Our ranking of this system: 2** Main reasons: • High percent (90% +) were recognized in third-party research of this product • It has a freehand GUI interaction component

Table 4.32 *Wiigee* [65] open-source gesture recognition system: the analysis outcomes

#	System's characteristics	System's details
1	Main most important system's features and functions	• It's main goal is to allow the training and recognition of arbitrary gestures using the Nintendo remote controller by utilizing state of the art probability theory methods • It delivers reliable results in a fast and efficient way • It is able to handle multiple wiimotes
2	Strengths and opportunities	• User can connect to Wii Remote controller like any other Bluetooth device • Wii Remote controller does not need special handling anymore
3	Possible weaknesses and threats	• It requires to purchase additional hardware—wiimote's hardware; it includes infrared camera, LED lights, vibration motor, etc. • It runs only on one technical platform—Linux
4	Technical platform	• Linux OS • Wiimotes
5	Price (if any)	• Free; http://wiigee.org/download/download.htm
6	Colleges/universities that currently use this system	• University of Oldenburg
7	System's ranking	**Our ranking of this system: 3** Main reasons: • Utilizes state of the art probability theory that delivers reliable results quickly in an efficient way

Table 4.33 Existing top 3 commercial and top 3 open-source gesture recognition software systems among analyzed systems

#	System	Company-developer	Details	Ref.
Commercial systems				
1	Kinect	Microsoft	$60–100	[53]
2	Intel RealSense	Intel	$99 or $149	[54]
3	IISU	SoftKinetic	$1500 one-time fee	[55]
Open source (free) systems				
1	HandVu	Moves Institute	Open Source (free)	[63]
2	FUBI	Augsburg	Open Source (free)	[64]
3	Wiigee	Ninttendo	Open Source (free)	[65]

4.7 Research Outcomes: Strengths and Weaknesses of Tested Text-to-Voice and Voice-to-Text Systems

The next step of research and analysis was to

(1) download the actual trial or demo versions of selected ranked software systems,
(2) test and evaluate those systems against CLA requirements (Table 4.3), and
(3) summarize lists of strengths and weaknesses of analyzed systems.

The outcomes of systems' testing and lists of identified strengths and weaknesses of each system (using evaluation criteria from Table 4.3) are presented in Tables 4.34, 4.35, 4.36, 4.37.

Based on outcomes of the performed SWOT (Strengths-Weaknesses-Opportunities-Threats) analysis and obtained testing outcomes of designated

Table 4.34 Strengths and weaknesses of ranked commercial text-to-voice software systems

Rank	System ref	Strengths	Weaknesses
1	Natural Reader [13]	• Accepts files in DOC, DOCX, TXT and HTML formats • Reads text in an image • Reads text in a tabular form • Typing echo is available • Spell checker is available • Built-in dictionary is available • Supports OCR functionality • Provides natural voices • Supports 7 languages • Highlights the text while reading • Word prediction functionality is available	• Does not support reading of math equations • Cannot read the e-mails
2	Read the Words [15]	• Accepts files in DOC, DOCX, TXT and HTML formats • Reads text in a tabular form • Supports 5 languages • Saves audio in audio files • Incorporates the created audio files into emails	• Does not support reading of math equations • Merges data in the tabular form • No spellchecker • No OCR functionality • No e-mail reader • No built-in dictionary • No highlighting text functionality while reading • No word prediction functionality

Table 4.35 Strengths and weaknesses of ranked open source text-to-voice software systems

Rank	System ref	Strengths	Weaknesses
1	Balabolka [23]	• Accepts files in DOC, DOCX, TXT and HTML formats • Reads titles/text in an image • Reads text in a tabular form • Supports 30 languages • Saves audio in audio files • Highlights the text while reading	• Does not support reading of mathematical equations • Spell checker is not able to detect typos • No built-in dictionary • Merges data in the tabular form • No optical character recognition (OCR) functionality • Cannot read the e-mails No word prediction functionality
2	Text to Speech Reader [24]	• Accepts files in TXT and PDF formats • Reads text in a tabular form • Highlights the text while reading • Supports 10 languages	• Does not support DOC and DOCX formats • Cannot read text in an image • Merges data in the tabular form • Does not support reading of mathematical equations • Spell checker is not able to detect typos • No built-in dictionary • No optical character recognition (OCR) functionality • Cannot read the e-mails • No word prediction functionality • Do not save audio into an audio file

systems, we recommend the following systems to be considered for an implementation, testing by actual students with disabilities of various categories, and active use in SmU, and, probably, traditional universities:

(1) **text-to-voice systems:** *Natural Reader* [13] (about $ 70/copy) and *Read The Words* [15] (about $ 40/year) commercial systems, and *Balabolka* [23] and *Text to Speech Reader* [24] open source systems;
(2) **voice-to-text systems:** voice-to-text systems: *Braina* [35] (about $ 30/year) and *Dragon Naturally Speaking Home Edition* [33] (about $ 100/copy) commercial systems, and *Google Docs–Speech Recognition* [52] and *Windows Speech Recognition* [43] open source systems.

Table 4.36 Strengths and weaknesses of ranked commercial voice-to-text software systems

Rank	System ref	Strengths	Weaknesses
1	Braina [35]	• Output format is in DOC, DOCX and TXT formats • Transcribes the entire audio files into text • Supports 40 languages • Does not require lengthy voice training • Editing of a dictionary is available • Supports punctuation • Can e-mail the outcome text file • Can access files and/or folders • Note-taking feature is available • Enables users with predefined and customized commands • Provides reading of math equations • Can also convert text to speech • Can set alarms and reminders	• Cannot e-mail the output text files • Spell checking is not available
2	Dragon Naturally Speaking Home Edition [33]	• Output format is in DOC and DOCX formats • Supports about10 languages • Does not require lengthy voice training • Spell checking is available • Can e-mail the output text file • Enables users with predefined and customized commands • Can also convert text to speech • Mobile dictation is available	• Does not support reading of mathematical equations • Cannot access files and/or folders • Does not support punctuation

Table 4.37 Strengths and weaknesses of ranked open source voice-to-text software systems

Rank	System ref	Strengths	Weaknesses
1	Google Docs–Speech Recognition [52]	• Output format is in DOC and DOCX formats • Supports 70 + languages • Does not require much voice training • Editing of a dictionary is available • Spell checking is available • Supports punctuation • Can e-mail the text document • Pre-defined commands are available	• Does not support reading of mathematical equations • No customization of commands • Cannot access files and/or folders
2	Windows Speech Recognition [43]	• Output format is in DOC and DOCX formats • Supports 6 languages • Supports punctuation • Pre-defined commands are available • Can access files and/or folders • Editing of a dictionary is available • Spell checking is available	• Does not support reading of mathematical equations • Requires MUI language pack for additional languages • Requires lengthy voice training • No customization of commands. • Cannot e-mail the text directly

4.8 Conclusions. Future Steps

To be successful in a college/university environment, students with disabilities need more support than students without disabilities. We believe the implementation of specific software systems in SmU and SmC is a key for this to happen. Software systems that address speech-to-text, text-to-speech, and gesture recognition will help students with disabilities to be more successful in the educational setting. In addition, students without any disabilities may benefit as well.

We are suggesting that SmC be equipped with various software systems so that all students (a) will have better access to the content being delivered, (b) be able to adequately interact with the professor and classmates, and (c) feel they are an integral part of the innovative learning environment—SmC in SmU.

Although not all university professors have knowledge or experience with students with disabilities, all of them should try to include them in the learning environment.

Conclusions. The performed research helped us to identify new ways of thinking about "students with disabilities in smart classroom and smart university

environment" concept. The obtained research findings and outcomes enabled us to make the following conclusions:

1. Smart universities and smart classrooms can significantly benefit students with disabilities even though they are not the focus.
2. Many technologies that are geared towards students without disabilities will actually impact the learning of students with disabilities.
3. Some students with disabilities may need specialized technology to have equal access in the classroom.
4. Some technologies and software systems focusing on the success of students with disabilities may help students without disabilities to be successful.
5. There are a variety of commercial and open-source software systems in the areas of text-to-voice, voice-to-text and gesture recognition to aid students with disabilities.
6. Given the variety of commercial and open-source software systems an in-depth hands-on assessment of these systems by actual students with disabilities and subject matter experts should be conducted.
7. Each of the commercial and open-source software systems in the areas of text-to-voice, voice-to-text and gesture recognition have different features and capabilities.
8. More research and testing in real-world scenarios needs to be completed addressing commercial and open-source software systems in the areas of text-to-voice, voice-to-text and gesture recognition to decide which of them would have the most benefits for students with disabilities.
9. More research needs to be completed where actual students with disabilities experience and evaluate commercial and open-source software systems in various learning environments and scenarios.
10. More research needs to be completed that directly focuses on students with disabilities in smart classroom and smart university environment.

Next steps. The next steps of this multi-aspect research, design and development project deal with

1. Implementation, analysis, testing and quality assessment of numerous components of text-to-speech, speech-to-text, and gesture recognition software systems in Bradley Hall (the home of majority of departments of the College of Liberal Arts and Sciences) and in some areas of the Bradley University campus.
2. Implementation, analysis, testing and quality assessment of text-to-speech, speech-to-text, and gesture recognition software systems (a) in everyday teaching of classes in smart classrooms and (b) with actual students with disabilities.
3. Organization and implementation of summative and formative evaluations of local and remote students and learners with and without disabilities, faculty and professional staff, subject matter experts, administrators, and university visitors with a focus to collect sufficient data on quality of implemented text-to-speech, speech-to-text, and gesture recognition software systems.

4. Creation of a clear set of recommendations (technological, structural, financial, curricula, etc.) regarding a transition of a traditional university into a smart university pertaining to software and students with and without disabilities.

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