

Web Application for Model, Share and Conversion of Entity-relationship Diagrams for Person Visually Impaired

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Abstract: Relational databases are an essential part of modern societies. However, the graphical nature of the entity-relationship diagram represents a barrier in the access of the visually impaired to the academic courses in the field of Informatics. Thus, this article presents Der-Acessível, a web application designed to assist the teaching of relational databases through the modelling, conversion and sharing of entity relationship diagram (ERD) with accessibility options for visually impaired people.

1 INTRODUCTION

Most people perform daily activities that make use of database systems. From financial transfers and hotel bookings to "simple" internet searches, databases have become essential in modern society playing a key role in several areas in which computers are used (Elmasri et. al., 2011; Vicci, 2014).

Understanding the basic fundamentals that relate to the design and development of databases is a fundamental skill for any student in the Informatics field. Even professionals, who are not directly connected to the area, need to have basic knowledge in order to communicate their needs related to the data that may be necessary in any system to be developed for them.

According to data from the 2010 Census of Brazil, released by the Secretaria de Direitos Humanos da Presidência da República (2012), 18.6% of the brazilian population had some type of visual impairment, and only 6.7% of brazilians with any type of disabilities completed an academic graduation. In addition to these facts, visually impaired students feel disadvantaged because they do not have access to the same resources as other colleagues in the same time frame (Mazzoni et. al., 2001).

The constructivist perspective of informatics in education corresponds to the application of the computer as an auxiliary tool for the learning

process. Within it, the machine is a resource that allows problem solving and idea building and has, among its benefits, the possibility of developing the autonomy of the students' own learning (Brito et. al., 2012).

The use of informatics in special education is not only about adapting the equipment, but also allowing students to be creative, offering a teaching-learning environment. Even the role of the teacher is transformed, and becomes "the facilitator of the process by which the student has the possibility to contribute" (Santarosa et. al., 2003).

According to Carvalho (2001), the difficulties faced by the visually impaired student in accessing academic education can be classified as barriers of: acceptance, communication, space and learning. The solutions to overcome these problems involve the adaptation of the procedures to the needs of the special student without changing their objectives and the implementation of interfaces, with minimal modifications, that conciliate the transfer of information between the course and the visually impaired student. That is, instead of offering a specially developed approach for the visually impaired student about a didactic resource, a tool must be offered that can connect it with the same methodology used by other students.

It would be interesting if reflections on methodologies and technologies for people with visual impairment were also considered in academic courses. For example, diagrams are widely used in

computer science courses, especially when it comes to relational database, where the diagram-entity relationship is well established.

There are many softwares that assist students and professionals in the conceptual development of database design through dynamic graphical interfaces, however these interfaces are often incompatible with screen readers and require some extra configuration, factors that make it difficult for users with visual impairments (Guedes et. al., 2016).

Presented by Magalhães et. al., (2010), AprenDER is a tool for designing ERDs with accessibility options for users with visual impairments, as an integrated screen-reader and navigation based on the numeric keypad. But it requires an installation process, is only available to Windows, has a hard limit to 9 entities per diagram, and 5 attributes for each entity.

Thus, this paper presents a website designed to assist the teaching-learning process of relational databases by manipulating entity-relationship diagrams with accessibility options for visually impaired people. The application, that is called Der-Acessível (and can be translated to “Accessible ERD”), offers a graphical and a textual interfaces for editing the diagram, share and conversion options, integrated screen-reader and optimized keyboard navigation. Still in development, the current phase involves usability testing with real users, which requires a certain bureaucratic process to satisfy the brasilian legislation.

2 RELATIONAL DATABASE COURSE

In Brazil, database courses are mandatory for all technical courses and academic graduations in the field of Informatics. This section, presents the basic concepts for relational databases and the use of the ERD during the conceptual project.

2.1 Database Design

According to Elmasri et al., (2001), the design of a database can be divided into the following steps: specification and analysis of requirements, conceptual design, logical design and physical design. The specification of the requirements consists of understanding the problem to be solved and contextualizing the system with the medium where it will be inserted.

The detailing of entities, relationships and constraints occurs in the next step. Created by Chen (1976), the entity-relationship model, is the most popular technique for the development of the conceptual design. Chen also defined a visual representation for this model, which has come to be known as entity-relationship diagram.

Introduced by Codd (1970), the relational model, widely used for logical design, describes the database as a collection of relations and the representation is closer to the structure of a table. The structured query language (SQL) is currently defined by international standards organizations. This is the most used technique for physical design and approaches the source code structure used in programming.

2.2 Entity-relationship Diagram

The entity-relationship model is usually represented by a diagram known as ERD. In addition, to being useful in the design phase, it is also a communication tool, since the diagrammatic representation of the database schema is much easier to display than the whole extension of the database (Elmasri et. al., 2009).

As presented by Guedes et. al. (2016), in the available web applications for drawing ERDs, there are practically no accessibility options for visually impaired people. Besides this fact, almost all tools are offered as a freemium service, which means the user has a free limited access (just enough to get to know the tool) and is required to pay for a subscription in order to have full access.

3 DER-ACESSIVEL

This section presents the methodology used in the development of the application and its main features, among which stands out the textual interface for browsing and editing an ERD using the keyboard and the integrated screen reader.

3.1 Methods

The development of the proposed tool has been happening in phases, each phase following the steps of research, modelling, prototyping and testing. Once a phase is completed, the result is integrated into the main application.

The exploratory research method is indicated by Gil (2002) so that the researcher can become familiar with the subject. This step provided the

theoretical basis and the discovery of free technologies that were used in the project.

To facilitate the functionalists of sharing, conversion and export between the interfaces, the JSON format was chosen as the data structure for the diagrams. This format is fast, flexible, easy for humans to read, can be manipulated in the server and in the client, and has simple serializable mechanisms (Nurseitov et. al., 2017).

The prototyping model aims for fast development, allowing the team to review the process multiple times, which minimizes the risks of developing a product that does not meet the real needs (Sommerville, 2011).

The software has only been tested by the project team. Following the Brazilian laws about scientific research's tests with humans, the present development phase involves acquire the necessary permissions for usability tests with real users.

3.2 Characteristics

The Der-Acessível requires a registration to be accessed. But even as an anonymous user, the visitor can change the color theme and the font-size, navigate with the keyboard, and receive the assistance of the integrated screen-reader.

There are many different themes available, most of them from Bootswatch (2014). The themes can change the colors and the typograph used in the website. Also, the user can chose between five different font sizes. This options affects all pages, with the exception of the drawing area of the graphical interface. This feature is very important, speciaall. More important than the aesthetic aspect, these characteristics are accessibility features for people with low vision.

After providing an email and password in the registration form, the user can create his diagrams using the graphical or textual interfaces. After that, he can convert an ERD to the relational and physical models, or send a copy of it to another user, by providing the receiver's email. Sharing a diagram simple creates a copy that cannot be modify. The owner can revogue the sharing and the receiver can copy the diagram to his own library, so he can edit it.

3.2.1 Integrated Screen-Reader

Using time diaries to collect data from users, Lazar et al (2007) states the three most commons causes of frustration to screen reader users are: page layout causing confusing screen reader feedback, conflict

between screen reader and application, poorly designed/unlabeled form.

To avoid this problems and also provide an equally acessible enviroment to any user connect to the website, an integrated screen-reader was designed using the Speech Synthesis (W3C, 2014).

This API (Application Programming Interface) provides an simple, but limited, way to convert text in audio played direct by the browser. It was necessary to develop a controller to watch the size of the messages sended to the API (Application Programming Interface), manage the queue of requests generated by the user navigation and take over the flow of the played audios.

When the user changes the navigation focus, the controller will read the element content or the alternative text for it, provided with a custom attribute, slice in to small messages and add to it's own queue to be sended to the API. Depending on the situation, the queue can be broken, and the new message is instantly played.

For input fields, the integrated screen-reader will read every typed key and, if the user stops typing for a few seconds, the last typed word.

3.2.2 Keyboard Navigation

A script using JQuery (2017) controls the keyboard navigation in the page. It was design to work in two different ways: basic navigation, for almost every page in the app, and limited navigation, for the textual interface. In basic navigation, it watches the Tab key and move the focus based on a predefined path. This way, the user will navigate first trough the content. The arrow keys are free and will follow the default behavior provided by the browser.

In the limited navigation, the keyboard is “locked” to a specific area in the page. Inside the textual interface, it is useful to provide fast cycle through the interface options, without allowing the user to get lost in other elements that exists in the page. For this mode, the user can navigate with the arrow keys and press Tab to go back to the beginning. This functionality is better described in the section 3.2.4.

3.2.3 Graphical Interface

Using the JointJS (2017) core library, distributed under the Open Source Mozilla Public License, the graphical interface allows users to create an ERD using the mouse, through a familiar environment that follows the pattern existing in other software. As seen in Figure 1, there is an element's toolbar on the left, buttons with general options at the top, and

a drawing area in the middle. In Figure 2, there is a diagram using all available types in the interface.

To prevent invalid diagrams from being exported to the textual interface, the system does some validation. For example, an attribute cannot exist loose and relationships can only connect entities.

This interface also provides an auto-layout option. Since all elements created with the textual interface will have the same position (coordinates [0,0], the center of the drawing area), this option tries to reposition everything, so all elements may be visible at once. It creates an oriented graph based on the diagram and uses the Dagre (2017) library, licensed under the terms of the MIT License, for calculating the new positions.



Figure 1: The graphical interface for ERD modelling.

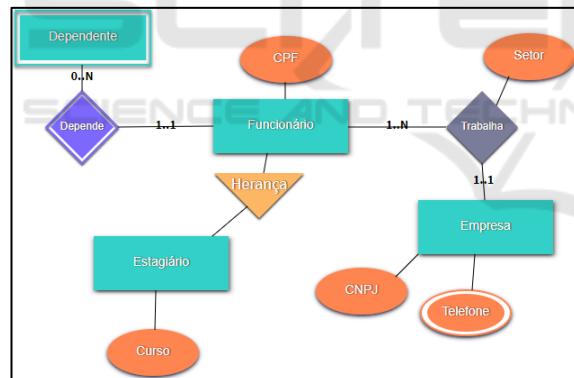


Figure 2: Example of diagram made with the graphical interface.

3.2.4 Textual Interface

The textual interface is composed of dynamic menus (Figure 3) based on the elements in the diagram, only one menu is accessible at any time. When the page loads, the keyboard navigation is locked to the active menu. The user can navigate using the Up and Down arrow keys, select an option with Enter, go back with Esc, go directly to the home menu with Tab and play the predefined help audio with Ctrl. This concept was based on the automated phone

menus used by many companies in the customer service field.

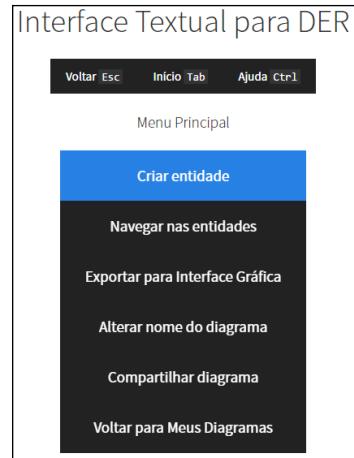


Figure 3: Main menu of the textual interface.

This interface is optimized for the integrated screen-reader, not only reading a menu option when the user navigates to it, but announcing the transition between menus. As shown in Figure 4, when the interface requires some user input, the user cannot navigate outside of the text field using the keyboard, except for the Esc key.

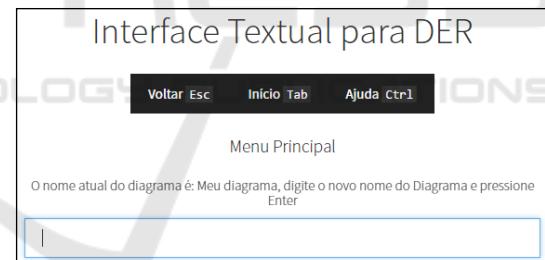


Figure 4: Option for renaming the diagram in the textual interface.

To better explain how a visually impaired person can read and modify a diagram using the textual interface, the next paragraphs will describe what happens when an empty diagram is opened, and the user creates two entities: article and author, a relationship between them, and the attribute "name" for "author". The application is localized to Portuguese, but for simplification, we will use the equivalent English translations for the menu options and screen reader audio.

When the page is loaded, the main menu (from the Figure 3) is visible at the screen and the integrated screen-reader will say "Opened the diagram [diagram's name]. Main menu. Selected

option create entity". Pressing the enter key will load an input like the one on Figure 4, and the integrated screen-reader will say "Type the name of the new entity". While the user types the word "article", the integrated screen-reader will read any pressed key. If he stops typing, but take a few seconds to confirm with Enter, the screen-reader will say the word "article".

After confirming the name of the entity, the integrated screen-reader will say "Entity article created" and the entity's menu will be loaded. The integrated screen-reader will say "Menu of entity author. Selected option change name". Pressing the Esc key, the user will return to the main menu and can repeat the process and create the entity "author".

Now, the user is in the author's menu, pressing the arrow down key three times he will navigate to the option "Create relationship", and the screen-reader will say "Selected option create relationship". Using Enter to confirm, he will hear "Type a name for the relationship". This input works in the same way as the one for the naming an entity. After typing "writes" and pressing Enter, the user hear "Relationship writes created. Menu of relationship writes. Selected option change name" and he will know he entered the relationship's menu.

Pressing the arrow down key one time will make the user hear "Selected option change element A, actual entity author". Pressing again, will make he hear "Selected option set element B". Using the Enter key, the user will hear "Choose an element. Selected option entity article". There are two options in this menu: article and author, and the user could navigate to author to create a self-relationship. Instead, if he presses the Enter key, he will establish a relation between author and article. After that, he is back in the writes' menu.

Since the user accessed the "writes" menu through "author", if he press the Esc key, he will navigate back to "author". If he need to access another entity, he could press Esc multiple times, until he gets back to the main menu, or the shortcut with the Tab key. From the main menu, he can choose the option "Navigate through entities" to access a menu with a list of all entities in the diagram.

From the author's menu, the user can navigate to the option "Create attribute", hear "Selected option create attribute", press Enter, hear "Type a name for the attribute", type "name", press Enter and hear "Attribute name created".

3.2.5 Converting the ERD

The conversion from ERD to relational tables is based on the algorithms explained by Heuser (2009) and Elmasri et. al. (2011). For the prototype presented in this article, the more general rules have been prioritized, which work for a greater variety of situations. A different approach could include the situational rules resulting in a more efficient relational model. This converter was designed to specifically meet the requirements of the presented web application, being developed with Javascript, so it can be executed in the browser and using the JSON format.

```
EMPRESA (CNPJ)
FUNCIONARIO (CPF)
ESTAGIARIO (ID, FUNCIONARIO_CPF, CURSO)
    FUNCIONARIO_CPF referencia FUNCIONARIO
DEPENDENTE (FUNCIONARIO_CPF)
    FUNCIONARIO_CPF referencia FUNCIONARIO
TRABALHA (EMPRESA_CNPJ, SETOR, FUNCIONARIO_CPF)
    EMPRESA_CNPJ referencia EMPRESA
    FUNCIONARIO_CPF referencia FUNCIONARIO
TELEFONE (TELEFONE, EMPRESA_CNPJ)
    EMPRESA_CNPJ referencia EMPRESA
```

Figure 5: Visualization of the relational model generated from the diagram in the Figure 2.

```
CREATE TABLE EMPRESA(
    CNPJ VARCHAR(255) NOT NULL,
    PRIMARY KEY (CNPJ)
);
CREATE TABLE FUNCIONARIO(
    CPF VARCHAR(255) NOT NULL,
    PRIMARY KEY (CPF)
);
CREATE TABLE ESTAGIARIO(
    CURSO VARCHAR(255) NOT NULL,
    ID VARCHAR(255) NOT NULL,
    FUNCIONARIO_CPF VARCHAR(255) NOT NULL,
    PRIMARY KEY (ID, FUNCIONARIO_CPF),
    FOREIGN KEY (FUNCIONARIO_CPF) REFERENCES FUNCIONARIO (CPF)
);
CREATE TABLE DEPENDENTE(
    FUNCIONARIO_CPF VARCHAR(255) NOT NULL,
    PRIMARY KEY (FUNCIONARIO_CPF),
    FOREIGN KEY (FUNCIONARIO_CPF) REFERENCES FUNCIONARIO (CPF)
);
CREATE TABLE TRABALHA(
    SETOR VARCHAR(255) NOT NULL,
    EMPRESA_CNPJ VARCHAR(255) NOT NULL,
    FUNCIONARIO_CPF VARCHAR(255) NOT NULL,
    PRIMARY KEY (EMPRESA_CNPJ),
    FOREIGN KEY (EMPRESA_CNPJ) REFERENCES EMPRESA (CNPJ),
    FOREIGN KEY (FUNCIONARIO_CPF) REFERENCES FUNCIONARIO (CPF)
);
CREATE TABLE TELEFONE(
    TELEFONE VARCHAR(255) NOT NULL,
    EMPRESA_CNPJ VARCHAR(255) NOT NULL,
    PRIMARY KEY (TELEFONE, EMPRESA_CNPJ),
    FOREIGN KEY (EMPRESA_CNPJ) REFERENCES EMPRESA (CNPJ)
```

Figure 6: Visualization of the physical model generated from the diagram in the Figure 2.

To exhibit the result provided by the conversion, two processors were developed: one that formats the output as a relational scheme and another that generates a script compatible with the database management system MySQL. Basically, both processors generate a HTML (Hypertext Markup Language) fragment based on the diagram content, in a way that, combined with CSS (Cascading Style Sheets) rules, that fragment, when injected in the page, produces the familiar visualization of the relational (Figure 5) and physical models (Figure 6). Since it is plain text, this is compatible with the integrated screen-reader and the responsive layout.

4 CONCLUSIONS

The tool presented in this article can be capable of demonstrating that using the computer as a facilitator of the learning process can also include students with special needs. Thus, it is expected that this application, when finalized, will lower the barriers to the access of academic courses in the field of Informatics for visually impaired people.

In the current development phase, the team is preparing for usability tests with real users divided in two groups: people with visual impairment and without. For the next phase, the addition of basic functionalities of the virtual classroom is already planned. Thus, teachers can create assignments for their students and they can answer with diagrams made in any of the available interfaces.

Additionally, for future projects there are many possibilities, as mobile compatibility for the graphical interface, local executable versions of the software capable of running without internet access (using almost the same source code) and improvements of efficiency and customization for the results produced by the converters.

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REFERENCES

Bootswatch. (2014). Bootswatch/License. (online)

- Available at: <https://github.com/thomaspark/bootswatch/blob/master/LICENSE> (Accessed 5 Dec. 2017).
- Brito, G. S. and Purificação, I. (2012). *Educação e novas tecnologias: um (re)pensar*. Curitiba: InterSaberes.
- Carvalho, J.O.F. (2001). *Soluções tecnológicas para viabilizar o acesso do deficiente visual à Educação a Distância no Ensino Superior*. PhD. Universidade Estadual de Campinas.
- Chen, P. P. (1976). The entity-relationship model—toward a unified view of data. *ACM Trans. Database Syst.* 1, 1 (March 1976), 9-36.
- Codd, E. F. (1970). A relational model of data for large shared data banks. *Commun. ACM* 13, 6 (June 1970), 377-387.
- Dagre. (2014). Dagre/License. (online) Available at: <https://github.com/cpettitt/dagre/blob/master/LICENSE> (Accessed 5 Dec. of 2017).
- Elmasri, R and Navathe, S. B. (2011). *Sistemas de banco de dados*. Tradução por Daniel Vieira; revisão técnica Enzo Seraphim e Thatyana de Faria Piola Seraphim. 6th ed. São Paulo: Addison Wesley.
- Gil, A. C. (2002). *Como elaborar projetos de pesquisa*. 4th ed. São Paulo: Atlas.
- Guedes, R. A., Paixão, R. S. S. and Sena, C. P. P. (2016). Ferramenta de Apoio ao Processo de Ensino Aprendizagem para Pessoas com Deficiência Visual na Construção do Diagrama Entidade Relacionamento. In: *XVI Escola Regional de Computação Bahia - Alagoas - Sergipe*, 2016, Maceió - AL. Anais do Workshop de Inclusão Digital da ERBASE (WInDBASE), pp. 5-14.
- Heuser, C. A. (2009). *Projeto de Banco de Dados*. 6. ed. Porto Alegre: Bookman.
- JointJS. (2017). License. (online) Available at: <http://www.jointjs.com/license> (Accessed 5 Dec. 2017).
- JQuery. (2017) License. (online) Available at: <https://jquery.org/license> (Accessed 5 Dec. 2017).
- Lazar, J., Allen, A., Kleinman, J., Malarkey, C., 2007. What Frustrates Screen Reader Users on the Web: A Study of 100 Blind Users. *Int. J. Human-Computer Interact.* 22, 247–269.
- Mazzoni, A. A., Torres, E. F. and Andrade, J. M. B. (2001) Admissão e permanência de estudantes com necessidades educativas especiais no ensino superior. *Acta Scientiarum Human and Social Sciences*, v. 23, p. 121-126.
- Magalhães, R. L. and Neto, M. M. F. (2010). ApreNDER: Ferramenta de Apoio à Construção de Diagrama Entidade Relacionamento para Deficientes Visuais. *Rio de Janeiro: Instituto Federal Fluminense*, pp.1-10.
- Nurseitov, N. et al. (2009). Comparison of JSON and XML Data Interchange Formats: A Case Study. *Caine*, v. 2009, pp. 157-162.
- SDH/PR - Secretaria de Direitos Humanos da Presidência da República. (2012) Cartilha do censo 2010 - Pessoa com deficiência. Brasília.
- Sommerville, I. (2011). Engenharia de Software. Tradução por Ivan Bosnic e Kalinka G. de O. Gonçalves;

- revisão técnica Kechi Hirama. 9. ed. São Paulo: Pearson Hall.
- Santarosa, C., Sonza, A.P. (2003). Ambientes digitais virtuais: acessibilidade aos deficientes visuais, in: *1º Ciclo de Palestras Sobre Novas Tecnologias Na Educação*. CINTED-UFRGS, Porto Alegre.
- Vicci, C. (2014). *Banco de dados*. São Paulo: Pearson Education do Brasil.
- W3C. (2014). *Web Speech API Specification*. (online) Available at: <https://dvcs.w3.org/hg/speech-api/raw-file/tip/webspeechapi.html> (Accessed at 5 Dec. 2017).

