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Nova Interface de Usuário Baseada no Conceito de uma Única Cela Braille

New User Interface Based on a Single Braille Cell Approach

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Abstract: Access to information is usually a challenge for visually impaired people. Auditory and the Braille systems become an ally for them, allowing access to knowledge, identification of products and places, among others uses. However, technologies for printing and reading in Braille are expensive, constraining its dissemination and use. This work presents a Braille reading system, based on a single cell' approach, designed for computer interactions. The single Braille cell concept is closely related to fingertip's physiology and it is based on a static reading. The designed computer interface took into account accessibility standards preconized by IBM. The system features voice recognition, auditory feedback and provides two operation modules: training and reading. The system was evaluated by three blind participants with different kinds of Braille' knowledge and different computer's skills. The results promises an efficient way to learn Braille using the single Braille cell concept.

Keywords: Accessibility. Assistive technology. Braille. Human-Computer interface. Visually impaired people.

Palavras-chave: Acessibilidade, Tecnologia Assisitiva. Braille. Interface Homem-Computador. Pessoa deficiente visual.

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1 Introduction

Braille method, also known as the white writing, had become the reading and writing alphabet most used by blind people worldwide (COOK; POLGAR, 2015). However, nowadays, the cost and dimensions of printing and reading Braille technologies are expensive. This is the case of new Braille displays and the Braille books, for instance.

On the other hand, there are technologies that allow access to information other than the Braille. Those technologies generally employ auditory (i.e. screen readers) and/or tactile feedback as a substitute for vision. However, when information is based on a spatial dimension, expressions or illustrations, feedback is often lost, or would be tedious to articulate it verbally (XU et. al, 2011). Braille emerges as a solution, allowing interaction between the reader and texts in a unique way, because of the sense of the touch (ROSEN, 1997).

It is fact that people with visual impairments, who have not learned Braille before, have more difficulty writing and communicating their thoughts. In addition, students that were alphabetized in Braille write texts better, while those who only use a keyboard and auditory systems write texts and stories in a very disorganized and disarticulated way (BARANAUSKAS; MANTOAN, 2001).

The work in (MUNRO; MUNRO, 2013) explores the backgrounds and training of teachers who work with students with visual impairments. Authors showed the necessity of developing print literacy skills in Braille, including decoding, morphology, fluency, vocabulary and comprehension. Those issues could led to improve literacy outcomes for students who are visually impaired and for them who use Braille as their primary learning tool.

Numerous commercial solutions enable reading and writing Braille, like the Perkins Machine and the Braille tactile displays, for example (COOK; POLGAR, 2015). Tactile displays have important applications in areas such as virtual reality, teleoperation, telepresence, vision–tactile substitution, fundamental haptic science research, video games and online shopping (XU et. al, 2011).

From a hardware point of view, Braille devices are electromechanical devices, having between eight and eighty of piezoelectric cells (HERSH; JOHNSON, 2008). This sort of technology is expensive and the number of cells tends to increase as the more information contained on the computer´s screen will be represented.

Another important aspect is associated to the reliability of the hardware mechanisms. A simple malfunctioning of a single point of one cell, caused by an electrical or mechanical failure, for instance, would essentially turn the Braille display useless, since symbols recognition will be impossible with a faulty point.

From a software point of view, available solutions do not provide totally accessible interfaces to the users, i.e. the visually impaired individual does not interact freely with texts, since they are only sequentially reproduced in Braille (or by the auditory feedback). It is easy to imagine how difficult reading an entire book would be.

In this work, a single Braille cell was designed to contribute in the learning processes of the Braille alphabet, looking for a simpler hardware solution. In addition, a human-Braille-computer interface was designed to interact with texts and alphanumeric characters, based on accessibility standards. The results promised an accessible solution for visually impaired individuals. This work in started in 2006 thanks to the project entitled "Development of a Braille printing system", supported by FAPESC. Then, a new project was developed thanks to the "University Merit Award", in 2007, also from FAPESC. After a long period of study and maturation, a master's degree thesis was carried out, leading to the current proposal.

2 Bibliographical review

Braille cell is composed by a single rectangle with 6 or 8 points, Figure 1. Cell points are numbered as follows: left column 1, 2 and 3 –from top to the bottom, and right column 4, 5 and 6, from top to the bottom.

Figure 1 – A traditional 2x3 Braille cell

1	4
2	5
3	6

Source: The authors

These dots represent embossed characters, which can be read by using the sense of touch. Each dot combination represents certain symbol or letter (COOK; POLGAR, 2015).

Braille displays usually have something between eight and eighty cells, allowing the user to read the alphabet by using the fingers. In particular, it is necessary to slide the fingers to recognize the Braille characters. This is known as active reading (LINDEN, 2016). Generally, a primary finger has to be moved through the cells, in a linear way, differently to the reading using the eyes. Looking to a forty cells display, for instance, while the user reads a character, the other thirty-nine are idle. Which means that they are not being read with the other fingers.

On the other hand, Braille recognition is intrinsically related to the sensory nerves perception. When Louis Braille designed his writing system, he had no prior knowledge of the properties of mechanosensors in the fingertip, like the Merkel endings. He just used his own tactile experience to careful set the spacing of the dots (LINDEN, 2016). Years after, Kenneth Johnson and his colleagues at the Johns Hopkins University School of Medicine, demonstrated that Merkel fibers faithfully represented the Braille dots' pattern. In (GIBSON, 1962) the impression made on the skin involves the excitation of nerve endings, known as receptors, resulting in a sensation, which is known as passive touch.

Nowadays researchers had begun to develop displays composed by a single Braille cell, based on how Braille is read, which means, one character at a time. Within this new approach, it would be enough to lay the finger on the cell, or the cell upon the finger, for immediate recognition.

From the software point of view, existing solutions for the single cell approach do not provide fully accessible interfaces. For example, users do not interact with texts freely, so they are reproduced sequentially. This fact motivated this question: Is it possible to improve this interaction?

This research aims to investigate the design of a single Braille cell for reading. In addition, a software based on accessibility recommendations, analyzes the impact of this approach on visually impaired users.

3.1 Related works

This section presents a brief review related to Braille cells designs.

In 2005, Jun Su Lee and Stepan Lucyszyn presented the design of a new refreshable Braille cell (LEE; LUCYSZYN, 2005). A micromachined refreshable Braille cell, actuated by using hydraulic pressures from the volumetric expansion of a paraffin wax, was successfully done and tested.

In (CHO et. al, 2006) authors propose the use of piezoelectric technology in portable devices. They designed a Braille cell, consisting of six piezoelectric linear motors. The details of the Braille cell were discussed and evaluated.

In 2009, Supriya and Senthilkumar designed a device that reads computer files and translates text characters to a six Braille cells. Each Braille cell was actuated by 36 Volts solenoids, with fast magnetization and demagnetization properties. Visual Basic was used as a front-end tool with a variety of specialized user interaction features such as, cursor location, routing buttons, file selection and increment and decrement of reading speed. The system complements tactile information with sounds, in order to improve the learning of less experienced Braille users (SUPRIYA; SENTHILKUMAR, 2009).

In (RANTALA et. al, 2010) a Braille prototype using piezoelectric active principles to create a tactile feedback under the cell screen, was developed. An evaluation of three input gestures (moving, squeezing and stroking) was conducted, identifying preferred methods for creating haptic messages using a hand-held device. Two output methods, using one or four haptic actuators, were also investigated.

In (MATSUDA; ISOMURA, 2011), authors presents a system designed for teaching Braille to deaf blind users. The system converted the speech of a non-disabled person to Braille, improving the learning process.

In (KENJIRO et. al, 2011) authors present a sheet-type Braille display by integrating organic thin-film transistors (TFT) and soft polymer actuators using low voltage for driving actuators.

A refreshable Braille cell as a tactile display prototype, based on a 2 × 3 pneumatic microbubble actuator array and an array of commercial valves, has been developed in (WU et. al, 2012). The device has also been designed to meet the criteria of lightweight and compactness to facilitate portable operation.

A new design and fabrication of a tactile display array was presented in (LEE et. al, 2014). It was based on dielectric elastomer actuators. The display stimulates the Merkel cells as well as the Meissner corpuscles.

Finally, in (ROS, 2014) it was discussed the design, implementation and test of a new dynamic tactile display for reconfigurable Braille. The display features a high-resolution tactile stimulation area allowing for customization of the Braille layout, as well as the timing of the braille rendering, offering a flexible solution to match user's skills.

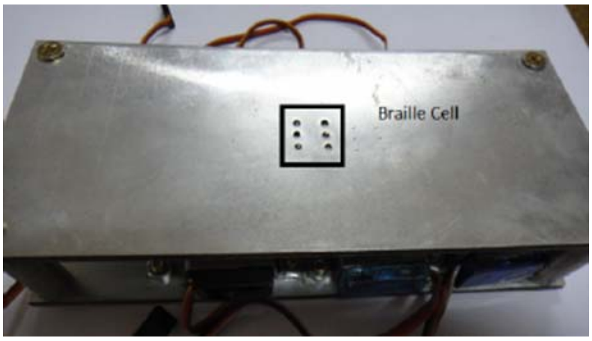
4 Materials and Methods

In this work, a single Braille cell based on six Pulse Width Modulation (PWM) servos, was designed. The cell dimension is bigger than common Braille cells, in order to properly recognize Braille characters by using the passive touch.

In the standalone Braille cell concept, differently of Braille displays, the cell should be large enough. Therefore, that it would be far enough laying the finger on the cell, or the cell upon finger, for immediate recognition. Furthermore, each point would be clearly remarkable from the others because each one touches in the same part of the finger. In this new Braille display concept, the finger would remain static in the cell, and the dots are triggered depending on the character that will be displayed.

Figure 2 shows the Braille cell. Six steel's needles was attached to the servos axes. The spacing between columns is 8 mm, and between each row is 3 mm. Each needle has a diameter of 1.0 mm. The pins displacement is around 0.8 mm and each one vibrates at 50 Hz.

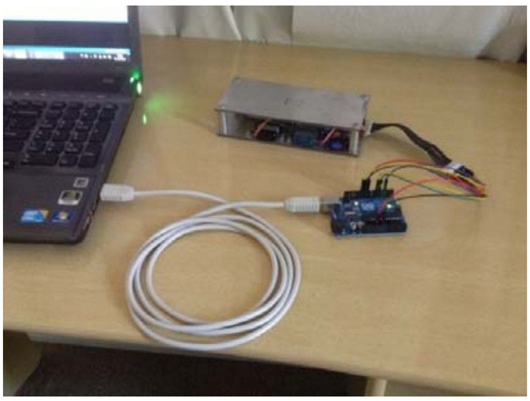
Figure 2. Braille cell.



Source: The authors

An embedded system, based on the Arduino Uno board, was linked to the serial port of a computer. The microcontroller generates the appropriate PWM signal to actuate each servo after decoding the characters sent by the software. Figure 3 shows the picture of the system.

Figure 3. The elements of the system.



Source: The authors

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The software is featured in two modules. The first one is the training module and its goal is to familiarize the user with the system. The second one is the reading module, which allows reading entire text files stored in the computer, Figure 4.

Figure 4. Software interface.

Source: The authors

The training module was divided into three operation modes: sequential, random and demand.

In the sequential mode, alphabet characters (a - z) and some special symbols, i.e. : ,.!?", are sent to the Braille cell in a conventional order by using the time rate configured for the user, Figure 5. For example, characters can be sent to the cell every 2 seconds. This is the ideal mode for those who are not yet familiarized with Braille.

Figure 5. Training module.

Source: The authors

In the random mode, alphabet characters (a -z) and special symbols (,.!? ") are sent to the Braille cell like in the sequential mode, but, randomly.

In those two operation modes, the user can interact with the software by using speech commands, like: start, stop, restart or going back to the previous character.

On the other hand, the demand mode allows the user recognizing a Braille character by pressing any key of the computer keyboard. This mode is particularly important to users less familiarized with the computer resources and unfamiliar with the keyboard layout.

The reading module allows the user to load files from the computer memory and start to read them. The user can start reading from the last character read, if the file has been opened and paused, for instance.

The software uses voice recognition engine avoiding the user having to remove the finger of the Braille cell. In addition, voice synthesis is used to provide auditory feedback to the user about the current state of the application, facilitating the interaction.

5 Methodology

The study was performed with three blind volunteers, involving the following activities:

a) Explanation of the Braille cell characteristics and its relationship with the computer, as well as the goal of the system designed.

b) Explanation on how to get access to the system resources, like navigating through reading and training modules, verifying the user interaction using voice recognition and voice synthesizer and computer keyboard access to perform the modes described previously.

c) Perform the sequential mode, adjusting the speed rate, stopping, returning to the previous character and restarting the sequence.

d) Perform the random mode, making the same operations like in the sequential mode.

e) Perform the demand mode. In the demand mode the user presses any key and guess the character represented in the Braille cell, speaking aloud what character it believes it is. The hit rate and the required time to identify each character were computed for the subsequent analysis.

f) Perform the reading module using the same procedures cited in item c, but alternating between different files.

5.1 Participants

Users manipulate the system by alternating between voice recognition and keyboard commands. They find out the character printed on the Braille cell.

Participant A is an engineer. He was 73 years old. He was born with a rare case of hyperopia. Over the years, the hyperopia has been getting worse and, when he reached the age of 40, remained only with 5% of vision. This user is very smart and has a good knowledge of Braille. He is a university professor and had former experience as a programmer. He used the Dosvox system, later replacing it by Jaws.

Participant B is 11 years old and is blind. He partially knows the Braille system and up to date, he has not regular contact with computers and do not have a good knowledge of the standard QWERTY, having minimal affinity with those resources. Therefore, he showed some difficulties when using the keyboard.

Participant C is 28 years old and born blind. He is one of the greatest experts of Braille system in the state of Santa Catarina. He is an employee of the Santa Catarina Foundation for Special Education (FCEE). He acts in the pedagogy area, giving support to users who are also educators. He is a computer expert, knows the QWERTY keyboard layout and uses the Jaws system. He is independent and lives alone. His opinion was of a great value to this study.

The participants' interaction with the system was oriented and observed through the tests performed. When the tests were concluded, a questionnaire was applied in order to register the benefits and the negative points of the system.

5.2 Experiments

This section discusses the experiments performed and the main results obtained. In this work, we were concerned about the accuracy and completeness of the goals, as in (OSGOOD; SUCI; TANNENBAUM, 1957) under the scope of the usability ISO standard 9241:11. On the other hand, we are also concerned about the satisfaction using the system.

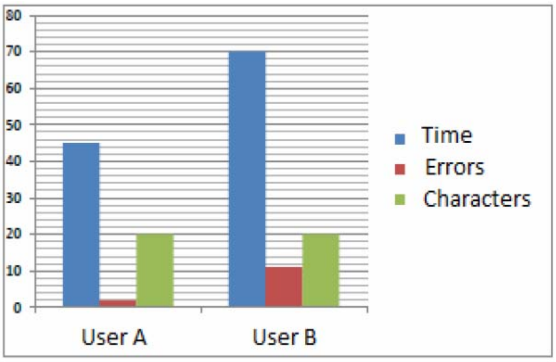
The training module was selected as the starting point, knowing the system. Each user could select the training mode via keyboard shortcut (T key). In addition, each user could use the voice command "Training". It was verified the need to create new voice commands, such as: repeat phrase, repeat word, back phrase or next line.

Figure 6 shows the results of the demand mode. It was possible to store some quantitative information, such as:

a) Detection Time: The detection time was measured, in seconds, from the moment the key was pressed until the user recognized it.

b) Characters recognition: In this test, each character was sent twice, by using a random sequence. Time, characters recognition and errors were computed for each user.

Figure 6. Results of the Demand mode.



Source: The authors

By analyzing Figure 6, user B spent more time (70 seconds) to recognize the same quantity of characters (20) as User A. User B also made more mistakes (10). On the other hand, user A took 45 seconds to perform this activity and made only two errors.

In addition, the missing characters rate of user A is only 10 %. This means that the character recognition rate is 90%. According to (LEE et. al, 2004) a suitable average recognition rate could reaches up to 60% or higher.

On the other hand, user A read 2.25 characters per second, which is a slow rate. According to (MUNRO; MUNRO, 2013), previous work with fluent and experienced Braille readers suggests that readers prefer to move their reading fingers from, approximately, five Braille cells per second, up to eleven cells per second. It is important to remark that each Braille cell prints one character at a time.

By selecting the L key, or by using the voice command "Reading" the user could select the reading module. This module makes use of a files repository.

5.3 Evaluation

The first step consisted in identifying the user characteristics. Important things, like which is the level of knowledge of Braille and the expertise on computer uses, was noticed. Such information allowed the system configuration with standard values. In this collaborative process, the system was improved by taking into account the users' opinions and the answers to the next questionnaire:

a) Is a sound feedback necessary after sending the characters?

b) Which are the commands you would like to add in order to enhance interaction with the Braille cell?

c) Which is the greatest difficulty when using the system?

d) Is necessary to add new modules/modes? If yes, which new resources would be interesting?

e) In your opinion, which are the system's advantages and disadvantages compared to traditional Braille reading?

All the process was monitored, registering eventually anomalies on the system or the benefices. It should be remarked that participant's skills were used to continuously adjust the defaults values of the system.

The analysis was started with the study of the hardware, where a problem related to the fixed distance between the columns, was detected. According to User C, standard Braille sheets have less separated cells, which difficult the identification of the character being printed. According to this user, each visually impaired individual must discover his own tactile field. Some more expertise people would feel the Braille points with the most external side of the finger, while others, possibly for having shorter fingers, would find it more difficult. With the current Braille columns' separation, User A was able to identify the Braille character without the necessity of moving the finger, while User C needed to move the finger throw every dot identifying the pattern. So a mechanical analysis would be required, adjusting cell columns' width.

A point well accentuated by the three users was the need of some identification for the right finger position. According Users A and C, the creation of some static mark identifying the boundary points of each column would be interesting. That way, fingers' initial position could be easily understood.

In relation to the software, its use, commands, system timing and modes, was evaluated as easy. However, according to the User C, existing modes have low relevance to more experienced users. The main point strengthening this statement is the fragility of the reading system based on a single cell. The need of reading the characters, one by one, to form a complete word, to make sense in the context of an entire phrase, is not very practical.

On the other hand, according to the users, the training mode could be extremely useful for learning processes, as it reduces the monotony of current approaches. User C perceives their great passion for computers. According to him, children find the classical learning methods boring and less motivating. In addition, users positively evaluates the reading module.

Many challenges emerges, as for instance, gamifying. User C suggests developing a game to unravel the greater number of characters as fast as possible.

6 Conclusions

This article presents a hardware and software solution to assist the Braille reading process. In particular, a single Braille cell approach was adopted bringing advantages and disadvantages to the solution. The system featured accessibility based on recommended standards. It uses low cost technologies. The software features two modules and three different operation modes, which were developed to interact with the system, including speech recognizing and auditory feedback.

Between the positive features, were founded: the device's costs reduction, because of the use of the one single cell approach; the inexistence of the break line problems, which are typically found in the traditional systems; and the lesser effort when compared to the use of traditional Braille displays. On the other hand, the difficulty of reading large texts (partially resolved with auditory commands) and the impossibility of reading using both hands, which is a feature of more advanced users, were noticed.

The system evaluation was made by case studies involving three users with different knowledge of Braille and different computers' skills. The experiments were concerned with users' behavior and their evolution using the system. The software interface was considered friendly, even though in case of the less experienced users. In addition, it was observed that the success of the hardware approach was closely related to the success of the computer's interface.

The character recognition rate of one of the users was 90%. According to (LEE et. al, 2004) a suitable average recognition rate could reaches up to 60% or higher, showing a good result. On the other hand, user A read 2.25 characters per second, which could be considered a slow rate, according to (MUNRO; MUNRO, 2013).

This is an applied research, which aims to promote an affordable solution for Braille reading.

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References

COOK; A. M.; POLGAR. J. M. *Assistive technologies: principles and practices*. St. Louis: Mosby Elsevier, 2015. 472 p.

XU, Cheng; ISRAR, A.; POUPYREV, I.; BAU, O.; HARRISON, C. Tactile Display for the Visually Impaired Using TeslaTouch. In: CHI 2011 Interactivity. Vancouver, BC. Canada. 2011.

ROSEN, S. Kinesiology and sensorimotor function. In: BLASCH, B. B.; WIENER, W. R.; WELSH, R. L. (Ed.). *Foundations of orientation and mobility.* 2nd Ed. New York: AFB Press. 1997. P. 170–199.

BARANAUSKAS, M. C.; MANTOAN, M. T. Acessibilidade em ambientes educacionais: para além das guidelines. Rev Online da Biblioteca Prof. Joel Martins, v. 2, n. 2, p. 13-23. 2001.

MUNRO, Michel P.; R. MUNRO, Heather. Infusion of Print Literacy Methodology into Braille Instruction for Students with Visual Impairments. Journal of Blindness Innovation and Research, v. 3, n. 2. 2013.

HERSH, Marion; JOHNSON, Michael A. Disability and Assistive Technology Systems. In: HERSH, Marion; JOHNSON, Michael A. (Ed.). *Assistive Technology for Visually Impaired and Blind People*. Springer. 2008. P 1- 50.

LINDEN, David J. *Touch: the Science of hand, heart and mind*. Penguin. 2016. 250 p.

GIBSON, J. J. Observations on active touch. Psychological Review, v. 69, n. 2, p. 477-491. 1962.

LEE, Jun Su; LUCYSZYN, Stepan. A Micromachined Refreshable Braille Cell. Journal of Microelectromechanical Systems, v. 14, n. 4, August. 2005.

CHO, H. C.; KIM, B. S.; PARK, J. J.; SONG. J. B. Development of a Braille Display using piezoelectric linear motors. International Joint Conference SICE-ICASE. 2006. P. 1917-1921.

SUPRIYA, S.; SENTHILKUMAR, A. Electronic Braille pad. International Conference on Control, Automation, Communication and Energy Conservation. 2009. P. 1-5.

RANTALA, J.; RAISAMO, R.; LYLYKANGAS, J. et al. The role of gesture types and spatial feedback in haptic communication. In: *IEEE Transactions on Haptics*, v. 4. n. 4, pp. 295–306. 2010.

MATSUDA, Y.; ISOMURA, T. Improvement of Interfaces for Finger Braille Teaching System. In: *Journal of Computer and Information Technology*, v.1, n. 2, pp.19-28, 2011.

KENJIRO F., SEKITANI, T.; ZSCHIESCHANG, U. et. all. A 4V Operation, Flexible Braille Display Using Organic Transistors, Carbon Nanotube Actuators, and Organic Static Random-Access Memory. In: *Advances Functional Materials*. v. 21, pp. 4019-4027. 2011.

WU, X.; KIM, S-H.; ZHU, H.; JI, C-H.; ALLEN, M. A. A Refreshable Braille Cell Based On Pneumatic Microbubble Actuators. In: *Journal of Microelectromechanical Systems*, v. 21, n. 4, pp. 908 - 916. 2012.

LEE, H. S.; PHUNG, H.; LEE, D-H.; KIM, U. K. et. al. Design analysis and fabrication of arrayed tactile display based on dielectric elastomer actuator. In: *Sensors and Actuators*. A: Phys., v. 205, pp. 191–198. 2014.

ROS, Paolo Motto, DANTE, Vittorio, Mesin, Luca ; PETETTI, Erminio; GIUDICE, P. Del; PASERO, E. A new dynamic tactile display for reconfigurable Braille: implementation and tests. In: *Frontiers in Neuroengineering*, v. 7. n. 6. 2014.

OSGOOD, Charles Egerton, SUCI, George J.; TANNENBAUM, Percy H. *The measurement of meaning*. University of Illinois Press, 1957. 342 p.

LEE, Sangwon; JUNG, Kwangmok; KOO, Jachoon; LEE, Sungil; CHOI, Hoogon; JEON, Jaewook; NAM, Jaedo; CHOI, Hyoukryeol. Braille display device using soft actuator. In: Proc. SPIE 5385 Smart Structures and Materials 2004: Electroactive Polymer Actuators and Devices (EAPAD), v. 368. 2004.

ROSSETO, E. Recuperação Histórica das Políticas de Inclusão no Ensino Superior. In: SEMINÁRIO NACIONAL DE ESTUDOS E PESQUISAS HISTEDBR, 8, 2009, Campinas, SP. *História, Sociedade e Educação no Brasil.* Campinas, SP: UNICAMP, 2009. P. 1-16.

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