Multisensorial Books: Improving Readers' Quality of Experience

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***Abstract*—Electronic books (e-books) are an alternative to traditional books and have some advantages over it. For example, they present dictionary function, allow searching for words in texts, are ecologically correct, among others. Moreover, research indicates e-books can improve the learning process. The learning process is also improved with the use of enhanced e-books, which includes multimedia resources (e.g., images, videos, sounds) to stimulate adapted and interactive learning. Similarly, multisensorial media (MulSeMedia) research presents the possibility of expanding the senses with additional media components, like haptic or gustatory devices, which can enhance the learner quality of experience. In this scenario, this work proposes a new model to combine enhanced e-books and MulSeMedia to improve the learning process. This model is named Multisensorial Electronic Books, or Multisensorial Books, for short. A prototype with auditory, haptic and olfactory effects is also created. This initial prototype showed promising results, indicating the present study may open avenues for further researches.**

***Index Terms*—Multisensorial Media, MulSeMedia, Enhanced e-books, Reading, Learning, Multisensorial Books**

I. Introduction

The scientific literature is replete with studies that highlight the importance of reading for the education of individuals [1]–[3]. Reading is a complex process involving several linguistic and cognitive challenges [4]. In this process, the reader reconstructs the meaning intended by the author, comparing information in the text with his previous knowledge and previous experiences [5].

Reading is a learning task [6], and its importance is highlighted from the early stages of human development to the more advanced stages. For example, the effects of early reading experiences are predictors of greater success in the reading process in more adult phases [7]. Furthermore, reading by older people helps increase self-esteem and satisfies ongoing curiosity about the world [8]. Reading is important in all stages of life [6]. This habit is a predictor of academic and economic success, and is positively related to almost all measures of personal and social behavior [9].

The reading of electronic books (e-books) has come as an alternative to the reading of traditional books and has shown a gain in popularity by readers [10]. E-books have some advantages over traditional printed books. Among them, it can be highlighted: (i) they are ecologically correct; (ii) they can be customized by the readers, that is, font style and font size can be modified; (iii) they have a dictionary function, allowing the reader to click on the word and receive a definition without interrupting the reading process; (iv) they allow searching for words or excerpts from texts; among others [11]. Concerning this, one can notice a significant growth in the sales of e-books. For example, the sale of children's e-books in the United States increased from 7$ million dollars in 2010 to 19.3$ million dollars in 2011 [12].

Electronic books have also been used for teaching and learning purposes, whether to aid in the development of reading or writing skills [13], [14]. The students' perceptions regarding the use of e-books for learning indicate high self-efficacy, and they emphasize that e-books can improve learning [15]. Additionally, other studies highlight the occurrence of improvements in the teaching/learning process [16], [17].

The teaching and learning processes can also be improved with enhanced e-books, which has the proposal to include multimedia resources (e.g., images, videos, sounds) to stimulate adapted and interactive learning [16], [18]. For example, in children's education, Korat and Shamir [19] describe that children prefer to learn from these e-books rather than printed ones. More than that, the authors point out that children remember content more efficiently and respond to questions related to the material more quickly.

A. Motivation and Contributions

Firstly, the motivation of the present study comes from the education field, since it detaches the importance of electronic books in the learning process. Secondly, it comes from enhanced e-books research, since several studies indicate it can improve the teaching and learning process. Moreover, it also comes from neuroscience, which highlights that learning can be deeper, richer, more memorable, and efficient with the use of multisensorial resources [20], [21]. Finally, all these motivations is combined with multiple sensorial media resources to construct the main contribution of this work.

Multimedia resources present the possibility of expanding the senses (i.e., extending multimedia applications with additional media components) by referring to a research area named multisensorial media (MulSeMedia) [22]. MulSeMedia applications include the combination of traditional senses (e.g., media components such as text, images, audio) with

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three or more human senses (also referred as non-traditional media), such as those which allow olfactory, haptic (e.g., apply forces, vibrations, or motions to the user, change the temperature, generate air-flow), gustatory, and so on [21], [23]. The literature indicates that the combination of these MulSeMedia resources alongside with traditional multimedia can enhance user/learner quality of experience (QoE) [21].

In this panorama, the present work introduces two main contributions. The first one combines a theoretical background in enhanced e-books and MulSeMedia areas to present a general model of a new e-book reading platform, named *Multisensorial electronic Books*, *Multisensorial e-Books* or, for short, *Multisensorial Books*. These books can leverage several advantages in the learning process, as described in the previous sections. The second contribution of the present work is the development of a prototype of a *Multisensorial Book* for mobile devices.

B. Paper Organization

This paper is organized as follows. Section II discusses prior work related to enhanced e-books and multisensorial platforms. Section III introduces the proposed model of *Multisensorial Books*. Section IV presents the first prototype for modeling *Multisensorial Books*. Section V concludes by briefly presenting the contributions and directions for further research.

II. Related work

The work presented by Zou et al. [21] evaluates if multisensorial media can improve learner experience. The authors developed a test-bed to play video content enhanced with haptic, olfaction and airflow effects. The experimental results indicate the majority of the users are open to technology-enhanced learning, as it can increase their learning experience. Recently, Ghinea et al. [24] proposed a multisensorial educational game named Fragrance Channel. The authors investigated how the learning performance, engagement, and quality of experience can be improved with olfactory stimulation. The results showed that stimulating olfact in educational game engages the users and can improve the learning process.

Lee and Spence [25] evaluated if multisensorial stimuli can help drivers to avoid potential accidents on the roadway ahead while operating a mobile phone. The authors conducted experiments with unimodal (visual) and multimodal (visual, auditory, and tactile) feedback. Experimental results indicate the drivers react more rapidly to avoid accidents when given trimodal feedback than when given unimodal feedback. The authors state that multimodal feedback can maximize human cognition and abilities related to attention, working memory and decision making.

Sanchez et al. [16] designed an electronic book (for use in mobile devices) that includes multimedia resources to enhance the teaching/learning process. The multimedia resources consist of video, audio, interconnectivity, and advanced browsing. The authors inform this is a work in progress, so there are no experiments described in this study.

Alam et al. [26] proposed a particular type of e-book reader, named Haptic e-book (HE-book), which provides vibrotactile haptic feedback by using a haptic sofa and a haptic jacket. The authors motivate their study by giving an example of a sea storm scene, which can provide vibrotactile feedback. The authors also present the haptic data annotation scheme and produce preliminary experiments to evaluate the user feedback. Preliminary results indicate positive user feedback.

There are several studies concerning the development of enhanced e-books, multisensorial applications, and applications to improve the teaching/learning process. However, as the authors know, this is the first reference to the development of *Multisensorial Books*. Moreover, it is important to note that MulSeMedia has not been employed in technology-enhanced learning [21].

III. Multisensorial Books

This section describes the concept of *Multisensorial Books*. Since reading is a learning task, the main goal is to produce a general model of a new e-book reading platform to enhance the QoE of users in the reading/learning task. Fig. 1 shows the proposed model. It is composed of a mobile device (represented with visual, haptic and auditory feedbacks), a MulSeMedia device control platform and a set of sensorial stimuli controlled by this platform.

It is important to mention that, nowadays, mobile devices already can provide tactile (haptic), visual and auditory feedback. However, an extension of these effects is proposed to improve the QoE of the end-user. As in [27], the *Multisensorial Books* model is generalized with the five traditional senses: visual (sight); auditory (sound); tactile/haptic (touch); Olfactory (smell) and Gustatory (taste).

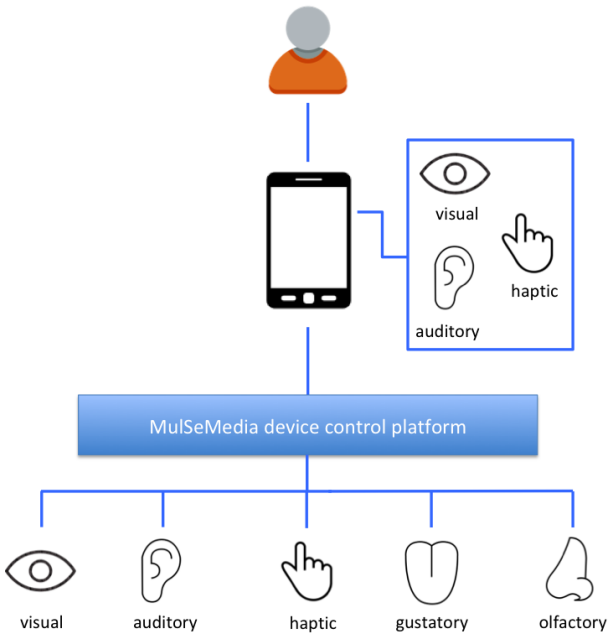

Fig. 1. Multisensorial books model.

Visual and auditory stimuli Although visual and auditory stimuli are common in enhanced books [28], research in MulSeMedia area can bring changes in the environment. For example, light devices can change the ambient light level accordingly with the MulSeMedia content automatically [29]. It can also change light color and project images in the environment [30]. Furthermore, auditory stimuli can recreate ambient noise and soundscapes [31].

Haptic stimuli Receptors in the skin can sense variations in pressure, texture, temperature, surface details and so on [32]. In this case, haptic devices can recreate the sense of touch with forces, vibrations or motions [33]. It can also change the temperature and humidity, simulate wind conditions (e.g., computer case fan), and spray water [34].

Olfactory stimuli Olfaction is the sense of smell or the act of smelling [35]. Ghinea and Ademoye [36] state that olfaction diffusion devices have the potential to improve the QoE of users. The authors also state that it can invoke different feelings and experiences. Olfactory devices can be based on natural diffusion or can adopt an air-flow based diffusion [37].

Gustatory stimuli Sulema [38] states that gustatory information is very important. However, not much attention has been paid to it in MulSeMedia area. The author states that the only real example of gustatory stimuli in MulSeMedia application is 3D printing of food. Gustatory stimulation of taste is difficult because taste relies on chemical transduction, and we do not know how to digitize it [39]. For example, to simulate the sensation of taste, Ranasinghe et al. [40] presented a methodology to apply electrical and thermal stimulation to the tongue.

It is important to mention that the *Multisensorial Books* can make use of traditional media, such as images and videos. It can provide haptic feedback in the mobile device since this is a common function in mobile devices. However, advanced media can be configured to change the environment or to provide stimuli directly to the user.

IV. First Prototype Proposed

This section describes a preliminary prototype to evaluate the actual stage of this research. An application is developed, in Android studio[1], to be used in mobile devices such as mobile phones or tablets. The application, named *MultiSensorial Books*, was tested on a Galaxy S7 smartphone. It is illustrated in Fig. 2 (A). In this first prototype, the application displays the poem "The Wind, One Brilliant Day", by Antonio Machado, which ranks among Spain's greatest 20th-century poets. The *MultiSensorial Books* application is connected to the *MulSeMedia device control platform* via bluetooth.

The *MulSeMedia device control platform* was implemented on a Raspberry Pi 3 board, as exhibited in Fig. 2 (E). Three effects were configured in this first prototype, as also showed in Fig. 2: auditory (B), olfactory (C), and haptic (D).

(B) **Auditory:** an iHome was connected to the 3.5mm Raspberry Pi audio jack to produce the auditory stimuli. In this case, the system plays a sound of wind blowing through trees.

(C) **Olfactory:** a simple scent diffuser device was created with a Glade® jasmine Scented Gel, a case to adapt the gel and a computer case fan. When the fan is turned on, the jasmine scent is emitted in the air. It simulates the jasmine odor written in the poem: "...an odor of jasmine...".

(D) **Haptic:** a computer case fan generates an air-flow. It is used to simulate the wind, as written in the poem: "The wind, one brilliant day...".

Fig. 2. Multisensorial books application configured with a Raspberry Pi and three devices to provide auditory, olfactory and haptic stimuli.

It is important to mention that when the application starts, a signal is emitted to the MulSeMedia device control platform. Then, the auditory, olfactory and haptic stimuli begin simultaneously.

V. Discussion and Future Work

This work presents basic concepts related to the literature of MulSeMedia and enhanced e-books. Several studies indicate that the use of enhanced e-books can improve the learning process. Moreover, many works state that the incorporation of MulSeMedia components can enhance user/learner QoE. Thus, these two research areas can be combined to improve the learning process.

In this scenario, this work explored theoretical background in enhanced e-books and MulSeMedia areas to propose a new model of enhanced e-book which combines traditional multimedia components (e.g., audio, video) with MulSeMedia components. This model is named *MultiSensorial Books* and can adopt several multisensorial effects: visual, auditory, haptic, gustatory and olfactory. The main goal is to improve readers QoE.

To achieve this goal, the first prototype of *MultiSensorial Books* was created. This prototype is composed of an Android application and a Raspberry Pi to control multisensorial devices. The Raspberry was configured to provide three multisensorial effects: auditory (playing music), olfactory (diffusing a scent) and haptic (generating an air-flow). This first prototype worked well and enabled us to validate our model, indicating the present study may open avenues for further researches.

[1] 1 https://developer.android.com/studio/intro/index.html

In future work, the *MultiSensorial Books* will be extended to be configurable, that is, if the user wants the effects to occurs in the tablet or smartphone, it will be possible. Other possibilities include the generation of other stimuli, for example, to change the environment temperature and the light color.

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