Current Challenges of Interactive Digital Television

Kenneth Palacio-Baus*†, Magali Mejía-Pesántez*, Lissette Muñoz-Guillén*, Mauricio Espinoza-Mejía.*
*Department of Computer Science, University of Cuenca, Ecuador
†Department of Electrical, Electronic Engineering and Telecommunications, University of Cuenca, Ecuador
{kenneth.palacio, magali.mejia, lissette.munozg, mauricio.espinoza}@ucuenca.edu.ec

***Abstract*—This article presents a high level overview of the current challenges that Interactive Digital Television involves due to the changes in user's behaviour under the current TV watching experience. We present a short review of multiple works found in the literature which have addressed specific issues that arise on converting an only–watching setting onto an interactive experience. Moreover, we have envisioned a system architecture that evidence how second screen accompanying devices, such as mobile phones or tablets, can be used to facilitate the interactivity process from the technical and operative viewpoints. In particular, this architecture supports innovative interactive applications for automatic ad recognition utilizing a second screen device as a friendly user interface.**

***Keywords*—Second screen, Interactive Digital Television, mobile device, Android, Kinect, WhatsApp, remote control, Ginga Middleware, ISDB-Tb.**

I. Introduction

Many countries around the world have already replaced analogical television broadcasting infrastructure by newer digital systems. Modern digital television (DTV) transmissions have been conceived as systems that make a better use of the electromagnetic spectrum. This makes it possible to increase the amount of channels available to users, and to remarkably improve audio and video quality which can be received in high definition. Moreover, current DTV standards comprise the use of mobile devices as television receivers, including interactive applications compatibility. Such applications can be downloaded by users or sent by broadcasters for a specific TV program.

We would like to introduce the case of Ecuador, which as many other countries in Southamerica adopted the Brazilian-Japanese ISDB-Tb standard [1]. In particular, this country is currently in the transition process, which has established the year 2019 as the date when all analogical transmissions will be turned off. In general, this infrastructure change involves multiple society members, such as TV stations, governments, and users, each of them, playing a fundamental role and who will benefit from the advantages of the new technology. Users stand out as the main beneficiaries, however, they may have to completely replace their old incompatible televisions with modern equipment, or equivalently, incorporate to them a complementary DTV receiver widely known as Set-top box – STB.

Given that current infrastructure supports the traditional television broadcasting model only, we analyse the vast amount of changes that users, developers, and TV stations are facing during the transition process in order to fully leverage the advantages brought by DTV. In this new scenario, the passive role of TV viewers, yet considered as merely information receiver subjects, switches into a starring role, that includes information generation and the possibility of interaction with other peers. Interaction is possible due to the availability of a data link between broadcasters and televisions known as the return channel. The use of internet for such link has opened an unlimited chance for application developers to start a TV entertainment experience revolution.

Nowadays, many TV shows interact with their viewers through social networks, letting them to send greetings to family and friends, to vote for their favourite singers or even, to participate in live contests and raffles. Considering that the use of smart phones has become so natural, it is easy to note that most TV users utilize their phones while watching TV. We can visualize a simple example by imaging a group of friends watching a soccer game at different locations, but sharing their thoughts about the game in a WhatsApp[1] group conversation.

In this context, it is necessary to emphasize that DTV brings more than beautiful images and amazing sound, it also carries a new world of interaction that employs software applications developed not only for mobile devices but also for the TV equipment itself. This possibility has been envisioned as part of modern DTV standards mainly due to the incorporation of complementary software components (i.e. a Middleware layer) such as the one defined for the ISDB-Tb standard: Ginga Middleware [2], which among other features, facilitates the communication between software and hardware allowing the chance of interactivity [3].

The remainder of this article is organized as follows: Section II presents the current view of DTV towards an immediate future of interactivity and how television manufacturers have partially solved some of the problems that arise to smooth the TV-user interaction. Section III presents a short review of works found in the literature that describe very interesting approaches addressing some of the challenges we previously introduced. Section IV presents an architecture model proposal aimed to support interactive applications based on the use of a second screen such as a smart phone. As a concept proof, we present how this architecture can be used to support a DTV application aimed to recognize the commercials watched by the user in such a way that it is easy to use the phone to expand the information related to any topic of interest originated on

978-1-5386-3894-1/17/$31.00

[1]WhatsApp: https://www.whatsapp.com

the TV received content. Finally, in Section V we present our conclusions, future work and a vision of open problems on interactive DTV.

II. Current challenges in DTV Interactivity

Since the beginning of the television era, the viewers' watching experience scenario has been evolving as technological progress reaches homes. From open television broadcasting to the arrival of on-demand services and streaming services provided through the Internet, users have taken control of the content they want to receive and to enjoy, however, current telecommunications technology allows the transmission of additional information, or data, along with audio and video, and developers are taking advantage of it. Parallel data transmission incorporates aggregated services that are transforming the way television can be enjoyed.

Modern television receivers, commonly known as smart TVs, incorporate direct access to the Internet, as a way to receive and transmit information. Currently, users can browse the Internet using the TV as quickly as through a laptop computer or tablet device. Traditional TV functions have been complemented by new features that address modern needs like simple and everyday tasks such as email reading, online video gaming and social networking. Nonetheless, there is a common issue that must be improved: the way how users physically interact with the television set, which up to date, revolves around a conventional remote control. Such a limited device has delayed the full TV integration process into a real interactive experience. Using a remote control may provide users an intuitive way to select options, move a cursor and introduce text following a similar manner as personal computers, however, trivial tasks such typing a user name or password may become cumbersome and tedious, decreasing the user's willingness to deal with such a primitive interface, hence limiting interactivity chances for TV.

In recent years, well known manufacturers have introduced the possibility to connect TV sets to their smart phones through dedicated applications and proprietary software, remarkably improving the interactive viewers' experience since the second screen is used for extended applications. Nonetheless, such systems are not compatible with other manufacturers equipment due to the lack of standards that rule inter-device communications. Although these attempts represent important progress on facilitating the process of user-television interaction, current development is focused in such standardization.

Through past paragraphs, we can infer that there is a plenty of challenges that need to be faced, many of them under very different scenarios occurring during the TV watching experience. Up to date, Internet has become the most suitable mean to support the integration of different technological platforms, therefore a natural choice for DTV. It is important to point out, however, that Internet penetration indexes still remain at very low levels when compared to open television broadcasting indexes [4], at least in developing countries such as Ecuador [5]. By the end of the analogical black out, open television stations should expect to achieve a coverage area greater or equal than current coverage, regardless of Internet penetration indexes, which evokes to think of ways to create ways and mechanism to facilitate interactivity in digital television that do not absolutely rely on the availability of Internet. It is very likely then, to think that Personal Area Networks (PAN) will start playing a fundamental role in interconnecting and synchronizing personal devices with TVs.

In this concern, identifying all the possible scenarios under potential interactive conditions corresponds to a very extensive task, however, one can find in the literature different approaches aimed to solve immediate issues that have already shown up in the current state of interactivity development. This article provides a vision of the current development degree of interactive digital television. We would like to mention few example areas that will benefit from the use of interactivity through DTV: i) T-Learning, which comprises applications related to education, ii) Interactive Games, iii) Online shopping and commercial marketing.

As mentioned in [6], future DTV applications should allow the presence of several users watching a program in a main screen, but interacting through independent mobile devices. Social network sharing will become very popular and automatic systems will play a fundamental role in understanding users needs and expectations.

III. Some Second Screen Proposals

User interaction levels in social networks have dramatically increased in recent years, which has originated the need of developing new and better technologies that allow synchronization and multimedia content distribution through different devices, such as televisions, smart phones, tablets, etc. Second screen devices provide users alternate ways to explore extended content and to transmit information back to the broadcaster or to the TV set. In this concern, synchronization arises implying a process that tracks user's activity as a function of the TV shows currently being watched such that, a truly improvement in capturing user's attention can be achieved. From an infrastructure viewpoint, second screens devices seem to be connected to the TV set, although a logical connection may be established directly to the broadcaster while a software application deals with synchronization. The work presented in [7] suggests that many techniques can be used to support applications synchronization, mainly based on the use of different sources of information such as video, audio and Internet communication. The most relevant techniques presented up to date are the following:

- Digital watermarking embedded in audio signals.
- Acoustic fingerprinting, so that specific audio signals can be clearly and uniquely identified.
- Video recognition based on image fingerprinting, similar to the approach used for audio.
- TV set synchronization, where the second device connects directly to the television as a base station device.
- Internet based synchronization, where all devices are connected to a web based service that supports applications data and user activity.

All these synchronization options allow smoothing user-TV set interactivity process that minimizes potential delays between the second screen device and the TV received content. Implementing a specific technique depends on the application kind, transmitted content and Internet service availability. This section describes related work in this area, in particular, we present some approaches aimed to envision the role of second screen devices and the technical features related to each one.

A. Enriching the User Viewing Experience.

1) Using an Internet Based Access Link: The work presented in [8] presents a user experience enrichment model based on facilitating the user access to relevant information related to content he is currently watching. In this approach, multimedia content can be transmitted in parallel to the second screen device considering information extracted from the user profile and meta data related to the broadcasted TV show. Authors present a non-invasive data retrieving method that allows inferring user preferences and interests that are reflected on to the second screen device. This also relates to the use of recommendation systems such as the one presented in [9]. On the other hand, a user profile enrichment procedure using social networks is presented in [10]. Meta data related to TV programs are usually extracted directly from the information frame included in the open television signal, known as *transport stream*, which is coded using the MPEG-2 standard. It is important to mention that authors stressed out the lack of meta data consistency and the ineffective search results derived from such inconsistent data. They also emphasize how their work requires a minimum intervention of the user such that the watching television experience becomes more enjoyable.

The following open research question shows up in need for an answer:

- How meta data inconsistency can be resolved?
- How to achieve effective web searches related to user's interests and TV programs?

The work is supported by the assumption of the omnipresence of Internet as the most suitable way to interconnect distinct devices, of course, as the mean to access the world wide web.

2) A mobile device as a secondary screen to interact with DTV: The use of mobile devices is leveraged in the work [11] which makes use of either smart phones or tablets to interact with a TV set. The authors present a system architecture and characterize a *framework* that allows working with second screen devices. The proposed system presents a DTV receiver STB based on the Android operating system, which acts as a concentrator device that coordinates the actions of hand-held devices that operate as clients. The STB device comprises a DTV services server that facilitates the access to programming guides, audiovisual content storage, teletext services, etc. Such services can be simultaneously used by the STB itself as well as by the connected clients. Given the processing power differences of the devices involved in such architecture, multimedia signals are modified and eventually downgraded according to each device capabilities, for example, a video signal played in a mobile device is presented in a lower resolution and lower frame rate than the original aimed for the TV set. The proposed architecture requires mobile devices to locally execute a specific application, that allows the interaction with the TV set. As a concept proof, authors show several features of the system they developed such as programming guide presentation, content guide browsing, user comments and channel previews accessing, etc. Moreover, TV interaction is processed through remote control modules developed for mobile devices such that phones can emulate the functions of a conventional remote with the aggregated value of a powerful processing device.

3) A System Architecture for TV Sets and Mobile Devices through WiFi: The authors of [12] suggest a system architecture that integrates mobile phones as secondary screen devices allowing interaction with one or more TV sets in a contextualised and synchronized manner. Second screens allow users to intuitively command TV applications using a touch sensitive device. These architecture is based on four principal components:

1) Transmission: which provides delivery of audiovisual and interactive content.
2) A STB/TV that processes the multimedia content delivered to users and executes the interactive applications through linking mobile devices.
3) Mobile devices, that may reproduce and explore the multimedia content presented on the main screen and also, allows interactivity as a user friendly interface that includes a return communication channel.
4) An application server that manages systems communications such as the return channel operation.

This architecture model is based on the classic client-server approach, where the STB plays the role of a server which is able to run NCL and Lua libraries. Clients are represented by mobile devices which run the Android operating system and communicate to each other through specific sockets. Several devices may be connected to the same WiFi network using quick reply codes (QRCode).

4) Multimedia Second Screen Broadcasting through Image Codification: Second plane multimedia content transmission is the proposal of the work presented in [13]. The main idea is to present a tiled-like mosaic of TV live content and other DTV services on the secondary screen device. These services may include the electronic programming guide, subtitles options, personal video recording and advance remote control functions for the TV or the STB. Hence, the mobile device becomes a suitable tool to facilitate interaction. The system includes an Android based STB device and a second screen compatible hand-held device immediately available to users. Due to the small sized screens of mobile devices and the limited bandwidth available in wireless networks, image codification is used such that, the information flow is significantly lower than the case of full size images being used.

B. Social Media Integration.

1) WhatsApp as an Interaction Mean for TV Programs: As social networks have become part of most people everyday activities, it has been observed their suitability as interaction interfaces for iDTV. In [14], the popular texting application WhatsApp is used to transmit text to a TV program broadcaster in order to display greetings and comments in a real time basis. As *Big Data* analysis can be performed from the information retrieved from TV viewers, the authors propose a system architecture to retrieve social networks users data in addition to a second component aimed to process and adequate data such that, a third component can analyse and learn from users interactions to generate knowledge.

Architecture data flow suggests that initially, audiovisual content is delivered to users, who enjoy watching it and provide feedback through text messages transmitted via WhatsApp. Opinions and expressions provided by users are retrieved by and API that utilizes a *Machine Learning Application (MLA)* to infer emotions and user's reactions. In the case of DTV, MLAs are known as ML-ITV, which relates to Interactive TV. Inferred data is fed into a system that utilized such information to correlate the emotions inferred with the historical context of user profiles and TV programs. It is then possible to use collective thought trends for future TV shows ideas.

2) Social Networks for Screen Sharing and Scene Repetition: Second screen devices can be exploited to enhance user experience. We imagine a soccer game that is being watched by many people who beyond enjoining the actual game, may want to receive statistics and data related to the players, tweets from other fans watching the same game and so on. In [15] it is mentioned that current users wish to be heard and transmit their feelings through social networks.

In [16], a system that involves a smart phone as a second screen device that allows recording, sharing and playing multimedia content captured from DTV or IPTV is presented. The proposal comprises the aggregation of social networks such as Facebook as information sources, and the possibility to use recorded media for other applications. With such an application, we predict a near future in which a group of friends share a short video clip that shows the repetition of a goal just scored in a soccer match, or simply, how they discuss in twitter if a penalty kick fault is legit or not.

C. Navigation Improvement

1) Introducing User's Information on DTV Systems: In [17], the problem of how users introduce information into a DTV based system is addressed. The process of integrating television as an absolutely interactive device faces the problem of having a primitive and limited interaction device: the conventional remote control. Currently, standard remote controls are used as computer mouse cursors that can be moved on the screen to select different buttons and options. Simple tasks such as text typing have to be performed using a device that was designed for different goals which transform this activity into a complex and tedious operation that is addressed by such work in the context of interactive digital television - iDTV. The limitations of the use of this device are clearly identified in the literature and reviewed, such that, adequate methods can be developed to facilitate the introduction of information into a DTV system which is analysed to an experimental approach based on testing a universe of heterogeneous users. The authors of this work recommend to review the references to find further information about this evaluation. The proposal is based on three study stages that can be summarized as:

1) Virtual keyboard test under different key locations and multi-tap methods.
2) Identifying problems and test improvements to the methods evaluated.
3) Test more complex environments that include special characters, such as email address, numbers, etc.

2) Use of Tablets as Second Screen Support Devices for Kinect and Wiimote based Video Gaming: It is well known that video games represent a clearly example of user immersion and absolute interactivity. The work [18] explores the advantages and limitations of new video games controllers in the context of iDTV. They compare video game controls with the use of a tablet device. The computational power evolution of such devices currently allows to use them as second screen devices very suitable for iDTV. The work focuses on studying the Microsoft Kinect device, and the Nintendo Wiimote controller. Their experimental approach evaluates how users interact with a parallel screen for some game instances.

The experimental results obtained allowed to identify that commercial video gaming devices can be easily and effectively used as input devices for iDTV. In particular, the Wiimote device presents an effective, friendly and easy to learn operation that would remarkably improve DTV user experience as long as the viewers are accustomed to use it. However, user interface would be limited by the fact that all user information must be presented on the main screen. The Microsoft Kinect device on the other hand, seems to be more attractive in the sense that it can currently be easily connected with several other devices, for instance with an Android tablet. Nonetheless, extended periods of interaction may lead to physical fatigue, which is added to well known issues related to this device which are interference, non uniform room light conditions, slow response performance and high communication error rates.

3) Using Smart Phones as Main Screen Cursor: In [19], an interactive cursor system is presented aimed to facilitate large distance screen control. The system makes use of an acoustic location estimation technique in combination with the gravity sensor of the smart phone. The system comprises a DTV set, stereo speakers and a smart phone (assuming that all smart phones include a microphone and most a gravity sensor). A program running in the phone, estimates the location of the screen pointer as a function of the signal received by the microphone and the gravity sensor, considering

the geometric settlement of the stereo speakers set. The experimental evaluation of the system demonstrates that a very high accuracy in setting the pointer can be achieved, which can be exploited to incorporate the smart phones as accessing devices under personal area networks.

Pointer location accuracy presents a differential error below ten degrees for all tested frames, which can be justified by the nature of the system principle, using an acoustic signal which is very prone to interference and noise.

The following section presents an interactive application architecture we have envisioned as a proof of concept. This proposal considers some of the problems presented in this work and a way to support them. This application is deeply documented in [20] but will be summarized here to evidence how interactivity is feasible in the current state of iDTV development.

IV. Taking Advantage of the Availability of Second Screen Accompanying devices

In this section we describe some development opportunities that we have identified as a function of user behaviour evolution in the context of the iDTV experience. We believe that the use of secondary screens is becoming more frequently among TV viewers, who expect to be able to watch their favourite shows in multiple devices. In general, recent approaches found in the literature take advantage of the high level of interactivity that can be achieved by incorporating smart phones to the TV watching experience. Moreover, new interactive services that originate in the new ways users behave have generated new challenges for the design, development, user model exploitation, personalization and implementation of user interface adaptive techniques.

An innovative proposal [20], presents an automatic ad recognition application based on the use of second screen devices. The work establishes several research challenges for these devices that derive technical questions such as: i) how to improve content recognition assertion rate and the synchronization among distinct accompanying devices?, ii) How to support multiple screen applications development considering a single version of the system for distinct platforms?, and iii) How to exploit user behaviour data as to provide personalized content?

These challenges can be addressed by the use of a system architecture such as that shown in Figure 1. The architecture includes the following main components:

- *Ad Inventory Management:* This module allows monitoring and storing ads that need to be classified, improved and delivered to users through multiple complementary devices. It is also used for content analysis and feature extraction.
- *Interactive Ad Content Enrichment:* Represents a key module aimed to enrich digital ads with a contextualized, interactive and personalized content that is suitable for implementation in several complementary devices.
- *Synchronized Interactive Ad Delivery*: From a technical point of view, this module aims to provide the best user experience using a second screen device.
- *Ad Analytic*: This module manages an analytic strategy that aims to help sellers and marketing agencies to understand customers in a holistic way.

This work suggests that the development of such platform requires the convergence of multiple technologies with the main goal of gaining users attention through audiovisual interactive experiences.

V. Conclusions

This work presented a short review of different scenarios that appear in the current state of development of iDTV. It is clear that secondary screen devices show up as the most suitable option to facilitate interactivity. Moreover, we have found that several alternatives have been already tested to check different communication channels in the physical media at the level of personal area networks PAN and local area networks LAN, and also, at the level of the use of current popular applications such as WhatsApp. As a conclusion of this work we have presented a system architecture model that we have envisioned and propose to support an innovative marketing application which is deeply documented in a another article.

As a future vision of our work we believe that TV-mobile device synchronization mechanisms need to be studied and tested in depth, independently of the presence of an Internet access link. Those alternative methods include the use of ultrasounic signals based protocols, infra red communication, and Bluetooth interfaces.

In relation to the challenges addressed up to date, the authors of this work consider that devices communication standardization among TV sets manufacturers and mobile phones manufacturers would facilitate and speed up the software application development process. Although the incipient state of iDTV has revealed serious inconsistencies for the possible scenarios suitable to test user interaction, most proposals have established assumptions that are not necessary always true, like the presence of an Internet based return channel. Therefore, it is clear that a vast amount of topics arise from exploring ways to communicate multiple devices with a simple TV.

Acknowledgements

This work is part of the project *Platform Analysis for Application Development for Terrestrial Digital Television* (Análisis de Plataformas para el Desarrollo de Aplicaciones para la Televisión Digital Terrestre) and it has been supported by the Research Direction of the University of Cuenca, Ecuador (Dirección de Investigación de la Universidad de Cuenca, DIUC) to which the authors present their acknowledgements.

References

[1] Superintendencia de Telecomunicaciones, “Informe para la definición e implementación de la televisión digital terrestre en el Ecuador,” 2010. [Online]. Available: http://www.supertel.gob.ec/pdf/publicaciones/informe_tdt_mar26_2010.pdf

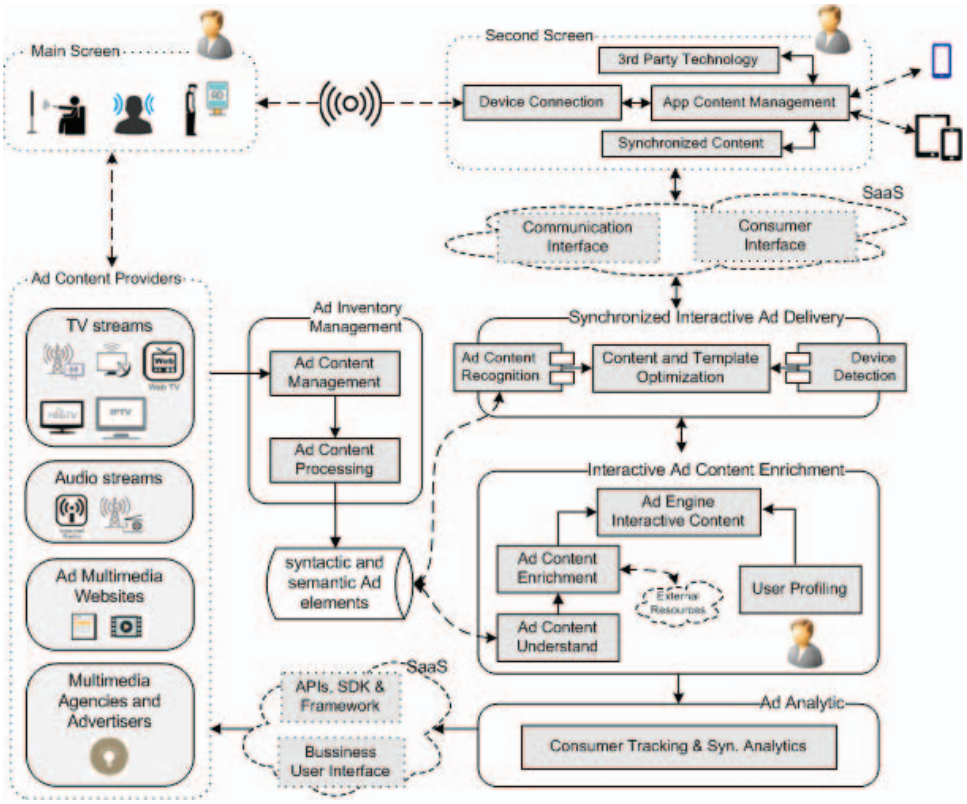

Fig. 1. General Architecture of the Interactive Ad Delivery Platform [20].

[2] R. de Mello Brandao, G. de Souza Filho, C. Batista, and L. Gomes Soares, "Extended features for the ginga-ncl environment: Introducing the LuaTV API," in *Computer Communications and Networks (ICCCN), 2010 Proceedings of 19th International Conference on*, Aug 2010, pp. 1–6.

[3] L. F. G. Soares, M. F. Moreno, C. D. S. S. Neto, and M. F. Moreno, "Ginga-ncl: Declarative middleware for multimedia iptv services," *IEEE Communications Magazine*, vol. 48, no. 6, pp. 74–81, June 2010.

[4] Banco Mundial, "Usuarios de internet (por cada 100 personas)," 2015, accessed 26/03/2017. [Online]. Available: http://datos.bancomundial.org/indicador/IT.NET.USER.P2

[5] Signum Research, "Sectorial de tv abierta," 2015, accessed 26/03/2017. [Online]. Available: http://www.latibex.com/act/esp/estudios%5C2015/Signum-Sectorial-TV-abierta-04-05-2015.pdf

[6] V. Vinayagamoorthy, P. Allen, M. Hammond, and M. Evans, "Researching the user experience for connected tv: A case study," in *CHI '12 Extended Abstracts on Human Factors in Computing Systems*, ser. CHI EA '12. New York, NY, USA: ACM, 2012, pp. 589–604. [Online]. Available: http://doi.acm.org.proxy.cc.uic.edu/10.1145/2212776.2212832

[7] R. M. C. Segundo and C. A. S. Santos, "Second screen event flow synchronization," in *2013 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB)*, June 2013, pp. 1–7.

[8] C. A. G. Ferraz, D. V. e. Silva, and J. S. da Silva, "A collaborative tv-internet application model to enrich tv viewing experience in a pervasive way," in *Pervasive Computing and Communication Workshops (PerCom Workshops), 2015 IEEE International Conference on*, March 2015, pp. 148–153.

[9] J. Ávila, X. Riofrío, M. Espinoza-Mejía, V. Saquicela, and K. Palacio-Baus, "Sistema de recomendación de contenidos audiovisuales: Algoritmo de inferencia semántica," *Maskana Magazine, University of Cuenca - DIUC*, pp. 125–137, 2014.

[10] M. Espinoza-Mejía, V. Saquicela, K. Palacio-Baus, and H. Albán, "Extraccion de preferencias televisivas desde los perfiles de redes sociales," *Revista Politécnica, Escuela Politécnica Nacional - EPN*, 2014.

[11] N. Soskic, D. P. Tapavicki, M. Subotic, N. Kuzmanovic, and M. Savic, "A proposal for second screen dtv and remote control application," in *2013 IEEE Third International Conference on Consumer Electronics, Berlin (ICCE-Berlin)*, Sept 2013, pp. 1–3.

[12] H. Simon, E. Comunello, and A. Von Wangenheim, "Enrichment of interactive digital tv using second screen," *International Journal of Computer Applications*, vol. 64, no. 22, 2013.

[13] N. Soskic, D. P. Tapavicki, D. Rapić, S. Medić, and N. Kuzmanović, "Remote control android application for second screen DTV environment," in *2014 3rd Mediterranean Conference on Embedded Computing (MECO)*. IEEE, 2014, pp. 272–274.

[14] V. M. Mondragon, V. García-Díaz, C. Porcel, and R. G. Crespo, *Adaptive contents for interactive TV guided by machine learning based on predictive sentiment analysis of data*. Springer, 2017.

[15] A. F. Pase, "Inbound and outbound: When applications invade tv and change our rooms," in *Unstable Platforms: The Promise and Peril of Transition Conference*, 2011, pp. 13–15.

[16] T.-H. You, Y.-J. Wu, C.-L. Lin, and Y. Chuang, *Enhancing People's Television Experience by Capturing, Memoing, Sharing, and Mixing*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2013, pp. 510–518. [Online]. Available: http://dx.doi.org/10.1007/978-3-642-39143-9_57

[17] A. Barrero, D. Melendi, X. G. Paneda, R. Garcia, L. Pozueco, and J. L. Arciniegas, "A research on typing methods for interactive Digital Television Applications," *IEEE Latin America Transactions*, vol. 13, no. 11, pp. 3612–3620, Nov 2015.

[18] D. Cox, J. Wolford, C. Jensen, and D. Beardsley, "An evaluation of game controllers and tablets as controllers for interactive TV applications," in *Proceedings of the 14th ACM international conference on Multimodal interaction*. ACM, 2012, pp. 181–188.

[19] T. Horiuchi, S. Takayama, and T. Kato, "Acoustic-based passive pointing system for distant screens," in *2012 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, March 2012, pp. 1689–1692.

[20] F. Vega, J. Medina, V. Saquicela, K. Palacio-Baus, and M. Espinoza, "Towards a multi-screen interactive ad delivery platform," in *43th Latin American Computing Conference, Lat. Am. Symp. on Computer Graphics, Virtual Reality, and Image Processing*, 2017.