Human-Library Interaction: A Self-Service Library Management System Using Sequential Multimodal Interface

Manuel B. Garcia
College of Computer Studies
Institute of Technology, Far Eastern University
Manila, Philippines
hi@manuelgarcia.info

***Abstract*—An ideal library makes every last patron feels what it is like to have their own library where one can traverse a world of knowledge, and then build their personal learning environment. Parallel to this conception is the intensification of fine-tuning the conventional librarianship to transform it into a center for new digital learning. As a contribution to this digital revolution, this paper presents an innovative way of renovating the house of dusty books into the center of creativity, research, and partnership through the fusion of traditional librarianship, self-service solutions, and human-computer interaction. The self-service system employs technologies and modalities such as touch screen-assistive technology for the kiosk terminal with the inclusion of a built-in camera, speaker, microphone, and lights, Automatic Speech Recognition, Radio-Frequency Identification and Content-Based Image Retrieval for holdings circulation and monitoring. In conformance with the ISO 9241-210 (Human-centred design for interactive systems), a series of user-centered evaluations were accomplished to obtain early feedback, and to validate that the user requirements have been satisfied at a later stage of the project cycle. To integrate a humanistic approach, the HCSDLC, or Human-Centered Systems Development Life Cycle Methodology, was utilized to complement the four main user-centered design activities specified in the ISO 9241-210 standard. The prototype designs and final self-service library system were assessed in terms of efficiency, effectiveness, and user satisfaction using metrics defined in the ISO/IEC 25022.**

Keywords—Library Management System, Human-Computer Interaction, Multimodal Interaction, User Experience

I. INTRODUCTION

The highest level of quality education is where learners are equipped with the knowledge, skills and core transferable competencies that set them to a path of lifelong learning. As the technology for personal and business use evolves, so do the tools and platforms available for educational institutions that enrich quality education. The emergence of information technology in the 21st century has brought momentous changes in different areas of education from content delivery to classroom facilities like academic libraries. In light of this, the 21st century libraries [1] are extending its traditional role from reflecting the identity of the institution where it is under to providing future-ready holdings and platforms such as Library Management Systems (LMS) Online Public Access Catalog (OPAC), and Electronic Book (eBook), to name a few. Along with this ratification is the rise of an important question: do we still need the library in this modern time?

As a humble contribution in refining the conventional librarianship to transform it into a center for new digital learning, this paper presents another innovative way of renovating the house of dusty books and card files into the center of creativity, research, and collaboration through the fusion of traditional librarianship, self-service solutions, and human-computer interaction. The main objective of the paper was to establish a human-library interaction (HLI) by creating a self-service library system that strictly follows the recommendations and principles of ISO 9241-210 standards [2] through a sequential multimodality interface (touch, speech, image, light, text) that will be embossed in the systems architecture. In this paper, the author briefly defined HLI as an interface between people and library and how patrons interact with LMS preferably through the use of a multimodal interface. Deriving from the concepts of Human-Computer Interaction (HCI), the multimodal interface will not only be a means to present patrons with a wider choice of modalities for interacting with the self-service library system but also to communicate with it in a more natural way and use library services without the assistance of the librarian.

II. BACKGROUND OF THE STUDY

A central hub of information, like a library of modern times, is believed to date back as far as 2600 BC [3] which served as archives for empires, and depositories of literature propagating our culture, sanctuaries for sacred writings, and knowledge over centuries. Nonetheless, the ever-changing world questions the relevance of libraries in modern times. Are modern libraries becoming obsolete due to technological advancements? If libraries have been the gatekeepers of information people need dated back as far as 2600 BC, how do they maintain relevance in this new information-seeking paradigm? Some people might argue that technology would make libraries superfluous, unfitting or irrelevant, but the reality looks like quite the opposite – technology can help libraries become a center for new digital learning and a point of reference for educational institutions as stated on various literature from the dawn of library system automation [4-7] to the next generation of library management systems [8, 9]. With this in mind, this study intended to introduce the next possible generation of LMS by improving library automation using the unification of self-service solutions and human-computer interaction to construct a bridge between patrons and the library (Human-Library Interaction) that will allow them to build their personal learning environment.

978-1-7281-3044-6/19/$31.00 ©2019 IEEE

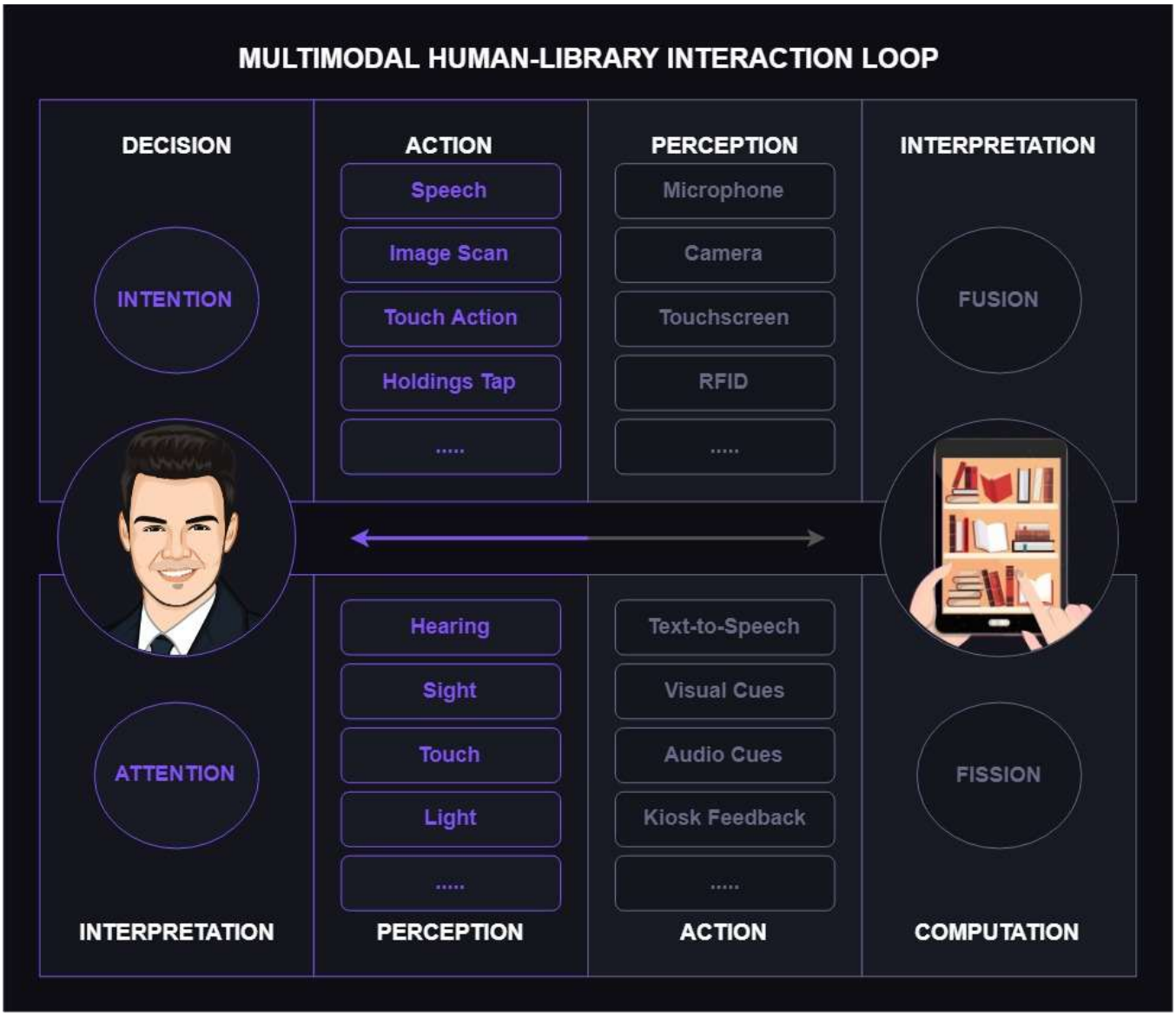

Fig. 1. A representation of the multimodal Human-Library Interaction (HLI) loop from the perspective of the library system and its users (administrators, patrons, and librarians), and how they interact with one another through collective technologies and modalities.

In its basic form, self-service initiates and requires more human element to interact with the system. As people naturally interact with the world multimodally, a multimodal interface embedded in the core of the system will move the balance of interaction closer to the patrons, which will allow them to maximize the library services without the assistance of a librarian. As part of the review before the start of LMS development, a multimodal man-machine communication model [10] was analyzed and used as a basis to develop the multimodal HLI loop, as depicted on Figure 1. The model was considered as a foundational concept as it is grounded on recognized research results apart from the concepts that it contains which are needed to ponder when developing a multimodal system. On this model, there are four states such as decision, perception, interpretation, and computational. Other important components of the multimodal HCI loop model, which are mandatory for multimodal systems, are the fusion of multimodal inputs and the multimodal fission for outputs. On this model, the technologies and modalities for the proposed LMS was included. To make the interaction simple for patrons, a sequential multimodality interface that allows them to experience multiple modes (although only one mode at a time) will be employed instead of a parallel multimodality. Albeit the parallel multimodal will be part of the recommendation as a future direction of this paper, the sequential method was chosen just for the sake of grasping the feedback of the patrons and librarians first, and this is, in fact, how users really interact in a multimodal system [11].

III. Methodology

The research approach for this study was developmental research whereas the development process is primarily described, and the final output is evaluated [12]. The final project aims to fine-tune the conventional librarianship and hopefully introduce the next generation of library systems by integrating concepts of self-service solutions and human-computer interaction, and introduce HLI. The development model utilized in this study was Human-Centered Systems Development Life Cycle Methodology (HCSDLC) [13] because of one reason: to close the gap between human-computer interaction (HCI) and software engineering (SE). Evidently, methodologies derived from both respective fields alone are not suggested to be used in this kind of research study as SE models only focuses on system implementation

(system-centered) and HCI models only focuses on the system usability (user-centered). Instead, a project methodology that captures the expertise of both fields, and amalgamated into one is needed if the system must establish a tangible human-library interaction through the use of a multimodal interface. The HCSDLC methodology resemblances a typical Software Development Life Cycle (SDLC) model but with coverage of HCI and Systems Analysis and Design (SA&D). HCSDLC has four main activities that must be accomplished such as the project selection and planning, analysis, design, and finally implementation, which are all the same activities that occur in both SA&D and HCI development. With this methodology, the final system can be expected to be both system-centered and user-centered complying the concepts from HCI and SE. Moreover, the four user-centered design (UCD) activities specified in the ISO 9241-210 standard, as listed below, were incorporated all throughout the project life cycle and systems development methodology stages to ensure the presence of the focus on both system and user requirements.

1) Understand and specify the context of use.
2) Specify the user requirements.
3) Produce design solutions to meet user requirements.
4) Evaluate the designs against requirements.

A. *Project Selection & Project Planning*

This phase intends to determine the actuality of a problem, and whether the desired solution is feasible or not. At this stage, several activities and tasks were rigorously performed from understanding the problem to defining the initial system architecture. A user-centered evaluation was also conducted in the beginning of the project to obtain early feedback as suggested by the ISO 9241-210. Hence, one iteration of its main UCD activities was performed through gathering of information in the form of descriptive survey with close-ended questions for 223 patrons. The information collected during initial data gathering was thoroughly used to define the context of use, the characterization of patrons, and their initial requirements. As a result, the initial prototype in the form of wireframe was created. An initial system sitemap consisting of the modules of the library management system for both platforms (kiosk terminal in the frontend and web information system in the backend), as can be seen on Figure 2, was also presented to patrons to give them an idea on what kind of interactions they can do with LMS.

B. *Analysis*

A baseline for the systems architecture was established during the analysis phase by understanding the requirements collected on the previous phase. Another iteration of the main UCD activities was performed to design the second prototype of the self-service library system. Because more information was needed, individual informal interviews were performed with the assistance and support of 12 students in a private conference room inside the university, in which their privacy was assured and data confidentiality was guaranteed, raising questions pertaining to the second prototype design of the system in preparation for the next phase.

C. *Design*

Aside from the embellishments for the second prototype design from the previous phase to create the final prototype, one of the main results in the design phase was the system architectural design that was derived from the requirements obtained from previous phases. Moreover, W3C Multimodal Interaction Framework [14] was also integrated and used to build the systems architecture. Within this phase, the user interfaces were also designed, and the functionality was coded. The final prototype was then evaluated using ISO/IEC 25022 Systems and Software Quality Requirements and Evaluation (or also known as SQUARE [15]), which is strictly focused on various usability metrics (efficiency, effectiveness, and user satisfaction). Patrons likewise answered the system usability scale (SUS) questionnaire [16] containing 10 items, each one with a Likert scale of 1–5.

Fig. 2. Self-Service Library System Hierarchy.

D. *Implementation*

Before the implementation of LMS, a final refinement of the solution was warranted to minimize the possible problems. From the start of the project cycle up to the system release to the public, system evaluations by users were conducted in order to validate the resulting designs as suggested by the ISO 9241-210. The first prototype was evaluated by two librarians and eight students; the second prototype was evaluated by two librarians, and 10 students; and finally, the third prototype (final library software) was evaluated by four librarians, 120 students, 24 teachers, and five software developers.

IV. Results and Discussions

A. *Understand and specify the context of use*

The first activity in the ISO 9241-210 standard, namely "understand and specify the context of use", covered the findings derived from the descriptive surveys conducted on the first phase of HCSDLC. During the survey on the first phase of the project, participants were showed different ICT strategies and possible technology-based advancements for the 'renovation' of the library. Among the strategies proposed to patrons, (see Table 1), adding a holdings locator was the most preferred one by the users followed by the use of different modalities. This proves that technology is perceived by the patrons as a vital companion of the library to enable educational proposition to meet their needs. The least-accepted strategy was the use of SMS messaging for receiving information about library-related transactions.

TABLE I. SUMMARY OF PATRONS' RESPONSES REGARDING ICT STRATEGIES AND TECHNOLOGIES FOR LIBRARY ENHANCEMENT

Strategies	Respondents (n=223)			
	Yes		No	
	N	%	N	%
Use self-service in the library	159	71.3	64	28.7
Make the system social-ready	169	75.8	54	24.2
Use speech for searching	212	95.1	11	4.9
Install a kiosk terminal	198	88.8	25	11.2
Use image search engine	219	98.2	4	1.8
Receive message through SMS	124	55.6	99	44.4
Use light as feedback indicator	125	56.1	98	43.9
Add a holdings locator	223	100	0	0
Use touchscreen for the system	209	93.7	14	6.3

B. Specify user requirements

The results of the descriptive surveys and the individual interviews during the first and second phase of HCSDLC formulated the user requirements, system architecture, and the data flow diagram (DFD) which is presented in Figure 3. The Level 0 DFD represents the activities a user (Patron, Administrator, Librarian) can perform using the LMS from circulation, cataloging, report generation (librarian-centered) to searching and holdings locator (patron-centered).

C. Produce design solutions to meet user requirements

Design prototypes were created during the first up to the third phase of the system development life cycle. The aim of the prototype creations was to gather early and continuous feedback from the direct users (patrons and librarians) early in the project lifecycle, before the project goes into the final development to ensure their requirements were included in the final system, and to avoid wasting time and resources.

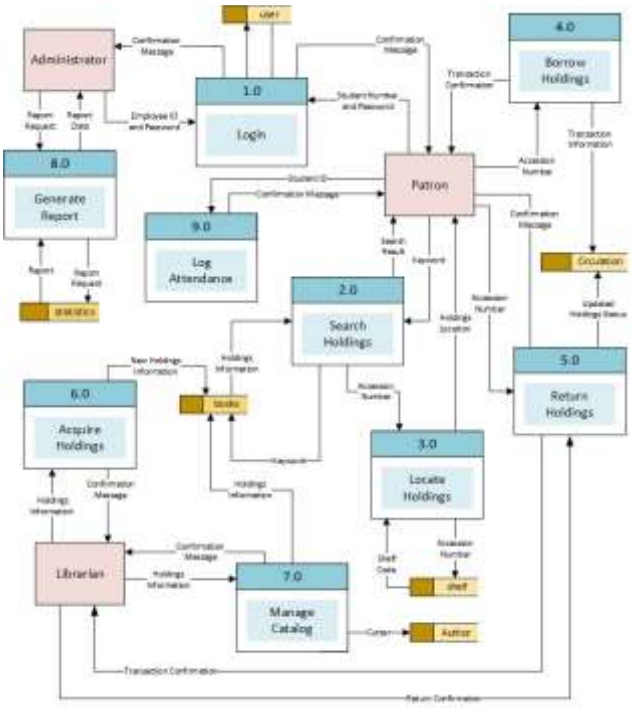

Fig. 3. Level 0 Data Flow Diagram.

1) First Prototype

The first prototype (low-fidelity prototype) was created during the project selection and project-planning phase. The initial prototype was a wireframe designed digitally using an online wireframe tool. In this prototype, a sample layout and graphical user interface were already included. Since there were different users during the first batch of data gathering, there were also many prototype designs created. Examples of the prototype designs are shown in Figures 4 and 5.

Fig. 4. First prototype of the Kiosk homepage.

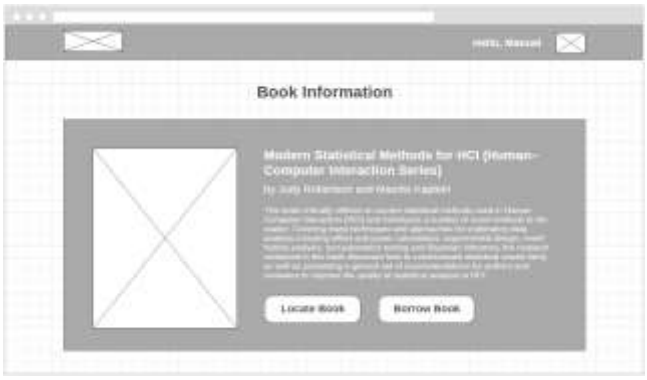

Fig. 5. First prototype of the book information page.

2) Second Prototype

The second prototype (high-fidelity) was created during analysis phase. It was about typography, color palette, and user interface designed using Google Web Designer tool, and then converted to HTML, CSS, and JavaScript. During the interview in the analysis phase, the prototype was shown to the participants to gather their feedback.

3) Third Prototype

From the designs created during the second prototype, the final prototype emerged. At this stage, a sample of system interactivity and experience that be offered to users was built using different programming languages. Examples of the final design are presented in Figures 6 and 7.

Fig. 6. Final prototype of the Kiosk homepage.

Fig. 7. Final prototype of the book information page.

D. Evaluate designs against requirements

For the evaluation of designs against the requirements, all of the system prototype designs were assessed by users in terms of efficiency, effectiveness, and user satisfaction using metrics defined in the ISO/IEC 25022 standard.

1) Evaluation of the first prototype

The evaluation of the first prototype (digital wireframes) was focused on assessing the initial design in terms of GUI layout, and media elements location (buttons, menus, icons, and image placeholders). During this stage of evaluation, user satisfaction and effectiveness were not part of the evaluation since it was a low-fidelity prototype. The focus of the evaluation, efficiency, was in a form of a test explained using a PDF guide and short discussion whereas the users (2 librarians and 8 students) had to perform and asses four major tasks. Table 2 contains the results of the evaluation. Based on the results, the following system revisions were performed as improvements for the second prototype before final iteration:

- **Self-Service Circulation** - Simplify the process of circulation by offering self-service method, and add a visual or textual guide on how to use the RFID when borrowing and returning a library material.
- **Holdings Locator** - Construct a graphical user interface (GUI) of the library shelves to show the exact row and position of the holdings in the shelf instead of using a web sitemap breadcrumb like "Circulation Shelf → Third Row → Fifth Item".
- **Multimodal Search Facility** - Develop a smarter search engine facility by including different filters and metrics as search variables (ISBN, Publisher & Author), and other mode of searching.
- **Patron Engagement** - Allow the patrons to add their feedback and reviews on the library materials they have borrowed and read to boost engagement.

2) Evaluation of the second prototype

Based from the feedback of the first prototype, changes were made to improve the second version. Additionally, it was converted to HTML & CSS to allow the users to interact with a system that was almost similar to the final prototype. The second prototype, covering the same four tasks during the first prototype, was evaluated by 12 patrons in terms of user satisfaction, effectiveness and efficiency. On table 3, patrons evaluated the tasks in terms of efficiency which was measured in terms of time required to execute the task compared to the target time to execute it. Surprisingly, the first task was executed (88.92 s) faster than the target time (90 s) even though it was the only task lacking the effectiveness. It could only mean that the use of RFID for check-in and checkout process streamlined the circulation process. Unfortunately, the remaining three tasks were executed slower than the target time, which could only mean that there were still revisions to be made even though it passed the effectiveness criteria.

TABLE II. USABILITY EVALUATION FOR THE FIRST PROTOTYPE

Task	Successful	Failed
Self-Service Circulation	50%	50%
Holdings Locator	20%	80%
Multimodal Search Facility	40%	60%
Patron Engagement	90%	10%

TABLE III. EFFICIENCY EVALUATION FOR THE SECOND PROTOTYPE

Participant	Task 1	Task 2	Task 3	Task 4
P1	56	88	45	48
P2	77	79	67	68
P3	56	64	54	58
P4	115	78	79	87
P5	120	98	67	78
P6	88	77	59	67
P7	90	72	58	59
P8	92	85	72	71
P9	100	89	87	75
P10	98	82	82	69
P11	76	78	54	62
P12	99	88	65	61
Average	**88.92**	**81.50**	**65.75**	**66.92**
Target Time	**90**	**70**	**60**	**60**

TABLE IV. EFFECTIVENESS EVALUATION FOR THE SECOND PROTOTYPE

Participant	Task 1	Task 2	Task 3	Task 4
P1	✓	✓	✓	✓
P2	×	✓	✓	✓
P3	✓	✓	✓	✓
P4	✓	✓	✓	✓
P5	✓	✓	✓	✓
P6	✓	✓	✓	✓
P7	✓	✓	✓	✓
P8	✓	✓	✓	✓
P9	×	✓	✓	✓
P10	✓	✓	✓	✓
P11	✓	✓	✓	✓
P12	✓	✓	✓	✓
Successful Tasks	10	12	12	12
%	**83.33**	**100**	**100**	**100**

Note: A tick mark means that the patron could perform the task while a cross mark means that the patron could not.

As can be seen on Table 5, the average score of user satisfaction evaluation was 84.34 which indicate a high acceptance (above the mean of related usability studies) as it exceeded the threshold of 80.3. With this usability score average, users are more likely to recommend the system to other potential users of the system. Based on the results of the second evaluation, furthermore, the following changes were performed as improvements for the last prototype: (1) make the generation of metadata information such as Library of Congress classification and author cutter as automatic in the cataloging section of the system to reduce the clerical works of librarians, (2) add a book recommendation in case the library does not have the holdings as searched by patrons, (3) allow patrons to vote the holdings requested by other patrons, (4) redesign the patron profile page by making it more social-

friendly. Include a section for the list of books reviewed, and history of borrowed holdings, and (5) include a notification message for overdue items in email and SMS.

TABLE V. USER SATISFACTION SCORES FOR THE SECOND PROTOTYPE

Participants	Total Score	SUS Score
P1	30	75
P2	38	95
P3	40	100
P4	38	95
P5	25	62.5
P6	21	52.5
P7	25	62.5
P8	40	100
P9	40	100
P10	34	85
P11	34	85
P12	40	100
Average SUS Score (P1-P12)		**84.34**

3) Evaluation of the third prototype

After the second evaluation, enhancements were made to improve the prototype in preparation for the final assessment. At this stage, a sample of system interactivity and experience of the self-service LMS that will be offered to users was built using different programming languages. The third prototype, covering the whole system, was evaluated by four librarians, 120 students, 24 teachers, and five software developers using the metrics defined in the ISO/IEC 25022 standard. At this stage of the project cycle, the system modules are already working properly, hence, participants achieved the tasks successfully which results to 100% in the effectiveness metric in all tasks. It could only mean that the interventions made specifically on the Task 1, during the second prototype were able to refine the next version of the prototype. Moreover, patrons were able to perform the tasks faster than the second prototype and the improvement in terms of speed can be seen dramatically. Finally, the average score of user satisfaction had improved as well from 84.34 on the second prototype to 89.01 on the last prototype. Though minimal, it can also be perceived as an improvement of the system.

TABLE VI. EVALUATION OF THE THIRD PROTOTYPE

Task	Effectiveness	Efficiency	Satisfaction
Task 1	100%	85.24 s	**89.01**
Task 2	100%	65.42 s	
Task 3	100%	58.24 s	
Task 4	100%	54.23 s	

V. CONCLUSION

In this paper, a new generation of library management system with the introduction of Human-Library Interaction was developed to renovate the house of dusty books and card files, and transform it into a center of research, collaboration, and creativity through the fusion of traditional librarianship, self-service solutions, and human-computer interaction. By strictly following HCSDLC as the software methodology and ISO 9241-210 international specification on human-centered design for interactive systems as the main guidelines and foundation all throughout the project life cycle, the final self-service library system was created as a system-centered and user-centered information system. Early and continuous feedback to all prototypes created pointed the right direction to a more usable and functional LMS. Apart from this, UCD activities from ISO 9241-210 that match the HCSDLC phases contributed to the success of integrating different technologies and modalities such as kiosk terminal with the inclusion of built-in camera, speaker, microphone, lights and touch-assisted monitor screen, RFID, content-based image retrieval, and Automatic Speech Recognition as evident on the usability evaluation based from ISO/IEC 25022 with a final SUS score of 89.01 points. The use of a sequential modality has been proven effective, yet, parallel modality warrants a further investigation to determine if it has the same impact value based from the perception of its users. Albeit HLI was briefly discussed, the author will create a separate paper that will thoroughly cover the concept. On the other hand, a library management system with a multimodal interface should be put into consideration first by academic libraries as it requires more resources and funding. Since the implementation of an e-learning system is widely accepted in the Philippines [17], seeing it as an additional feature in the patron profile page does make sense. Libraries are, and can still be relevant in the digital age especially with the right technology at its side. At the end of the day, technology, when used properly, could aid libraries to be a better source of information and knowledge.

REFERENCES

[1] A. R. Haris. (2016, May 23). *The 21st Century Library*.

[2] ISO. (2010, May 23). *Ergonomics of Human-System Interaction – Part 210: Human-Centred Design for Interactive Systems*. Available: https://www.iso.org/standard/52075.html

[3] K. Maclay. (2003, May 23). *Clay cuneiform tablets from ancient Mesopotamia to be placed online*.

[4] M. Breeding, "Next Generation Library Automation: Its Impact on the Serials Community," *The Serials Librarian,* vol. 56, pp. 55-64, 2009.

[5] R. S. Buwule and S. R. Ponelis, "Perspectives on university library automation and national development in Uganda," *IFLA*, 2017.

[6] D. Kolokotsas. (2013). *Creating the Library of the Future in Greece*.

[7] V. V. Kumar and S. Jasimudeen, "Adoption and User Perceptions of Koha Library Management System in India," *Annals of Library and Information Studies,* vol. 59, pp. 223-230, 2012.

[8] A. M. Yunus, M. R. A. Kadir, A. N. Mansor, and I. Kadir, "Library Management System (LMS): Impact on Library Environments," *Proceedings of the 29th International Business Information Management Association Conference,* 2017.

[9] S. Tabusum, A. S. Saleem, and S. Batcha, "Impact of Library Automation in the Development Era," *IOSR Journal of Humanities and Social Science (IOSR-JHSS),* vol. 17, 2013.

[10] B. Dumas, D. Lalanne, and S. Oviatt, "Multimodal Interfaces: A Survey of Principles, Models and Frameworks," in *Human Machine Interaction: Research Results of the MMI Program*, Springer.

[11] M. Turk, "Multimodal interaction: A review," *Pattern Recognition Letters,* vol. 36, pp. 189-195, 2014/01/15/ 2014.

[12] R. C. Richey, "Developmental Research: The Definition and Scope," *ERIC Clearinghouse on Information and Technology,* 1994.

[13] P. Zhang, J. Carey, D. Te'eni, and M. Tremaine, "Integrating Human-Computer Interaction Development into the Systems Development Life Cycle: A Methodology," *Communications of the Association for Information Systems,* vol. 15, 2005.

[14] W. C. Note. (2003). *W3C Multimodal Interaction Framework*. Available: https://www.w3.org/TR/mmi-framework

[15] ISO. (2016, May 23). *ISO/IEC DIS 25022 - Systems and software engineering - Systems and software quality requirements and evaluation (SQuaRE) - Measurement of quality in use*. Available: https://www.iso.org/standard/35746.html

[16] Usability.gov. (2015, May 23). *System Usability Scale (SUS)*. Available: https://www.usability.gov/how-to-and-tools/methods/system-usability-scale.html

[17] M. B. Garcia, "E-Learning Technology Adoption in the Philippines: An Investigation of Factors Affecting Filipino College Students' Acceptance of Learning Management Systems," *The International Journal of E-Learning and Educational Technologies in the Digital Media* vol. 3, pp. 118-130, 2017