A Dynamic and Customisable Layered Serious Game Design Framework for Improving the Physical and Mental Health of the Aged and the Infirm

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***Abstract*— This paper proposes a dynamic and customizable layered serious game design framework for improving the physical and mental health of the aged after presenting the results obtained from a study with mainstream and alternative/complimentary health professionals concerning the usage of interactive games as a tool to improve both physical and mental well-being of the elderly. This study reports on the commonality of design and health factors regarding the usability of video games for the aged to ensure the elderly benefit from traditional and alternative healthcare professionals' perspectives.**

Keywords-healthcare; elderly; serious games; game design; interactive games; usability; balance.

I. INTRODUCTION

According to recent studies, the majority of the developed countries are dealing with a dramatic increase of the aged population which could result in a crisis, if the problem is not addressed effectively and in a timely fashion [1]. As a result of this predicted crisis, there has been a huge increase in the development of systems to improve the well-being and quality of life of seniors looking for the prevention of diseases and injuries related to ageing. The usage of some interactive technologies such as video games, has shown a positive impact in health outcomes for the elderly [2]. Research has been applied to find feasible methods to encourage and engage seniors with the use of these games [3], [4]. The strategy of using game technology and game design principles for a primary purpose other than pure entertainment is referred as "serious games". The definition of serious games according to [5] is "a mental contest, played with a computer in accordance with specific rules that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives.". From the aforementioned description it could be inferred that the more aligned these game design rules and usability factors are to the ultimate objective of a serious game the more effective this serious game results in achieving its primary goal. The primary goal of utilising game technology in this preliminary study is that of improving the mental and physical health of the elderly.

This paper reports and comments on a study regarding the suitability of four Nintendo Wii balance games under the observation of six experts in health and wellbeing techniques [6][7]. This study presents a further analysis and discussion over the results gathered from the observations of health professionals from traditional and alternative healthcare professionals' perspectives. Finally this paper proposes a dynamic and customizable layered serious same design framework with the purpose of aligning and targeting game design rules and usability factors for the enhancement of the physical and mental health of the user.

This study was performed via a series of recorded and transcribed semi-structured interviews where health design factors and the suitability of the games for the elderly users were assessed [6][7]. The authors present the emerging factors from the observations of the games and results of the interviews and a discussion concerning the findings followed by the proposed framework and the conclusion.

II. METHODOLOGY

In order to identify the barriers, drivers and usability factors of the use of the assessed interactive technologies, the authors utilized the following two (2) combined methodologies:

1) the modified Analytic Framework used by Jamieson et al [8] in their landmark study on Consumer Health Information Technologies used by the elderly, chronically ill and underserved (see Figure 1). The modifications limited the technologies to Interactive Game Technologies, in this case, four (4) Wii games that concentrate on balance.

2) a heuristic based evaluation technique for the identification and categorization of the interactive technology usability factors. This video games heuristic evaluation technique was selected due to its flexibility and adaptable nature [9].

Figure 1 below sets out the Analytical Framework which served as a basis for our semi-structured interviews and demonstrations.

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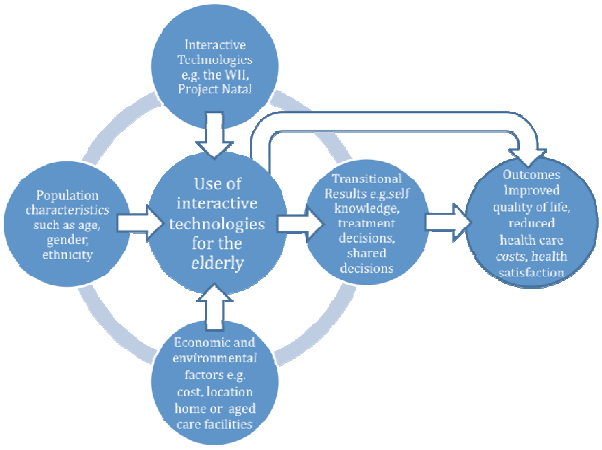

Figure 1. Jimison's Analytic Framework [8].

The Analytic Framework followed by an heuristic evaluation technique were applied to evaluate of the usability of the video games by interviewing health professionals who had experience with elderly patients [6][7]. The researchers did not run experiments with older users at this preliminary stage due to the risks inherent in this practice.

During July and August 2010, the authors evaluated four Wii balance games (see Table 2) with the cooperation of six health professionals, three of them representing alternative health techniques, and the other three representing traditional medicine (see Table 1).

TABLE I. GAMES' DESCRIPTION [11]

	Objective	Procedures[1]	Rules[2]	Conflict[3]
Balance Bubble	Navigate it along a river to the rainbow finish line.	Shift weight to propel the bubble along the river.	Hazards such as rocks and river banks, and bees.	Reach the goal avoiding hazards and respecting the time limit.
Table Tilt	Tilt the tables so that the balls drop into the hole(s).	Shift weight to tilt the table. The table could have at least one hole in it; the balls must be guided into the hole(s).	Hazards such as: unguarded edges, slopes, blocks.	Dropping balls could lose more balls as well as causing delays, time limit.
Tightrope Walk	Walk a rope strung between two buildings.	Walk across the rope, jump when biting machines appear.	Biting machines, obscured view, wind.	Leaning, falling off the rope, unbalanced jumps, time limit.
Skateboard Arena	Show off your technique with a skateboard.	Turn the balance board through 90 degrees clockwise, push off with your back foot to start and jump when obstacles.	Ramps, half-pipes, etc.	The scoring depends on your tricks on ramps or half-pipe.

[1] According to the game design theory, *Procedure* is everything that player can do respecting the rules.
[2] The *Rules* describe objects and behaviours.
[3] *Conflict* is everything which does not let you reach the goal directly. [12] T. Fullerton, *Game Design Workshop*, Second Edition ed. Burlington, MA: Elsevier Inc., 2008.

Overall, the sessions were conducted by following three stages: (1) One semi structured interview with each health professional concerning the procedures which each one performed with the patients over 65yrs, as well as their experience, if any, involving interactive technologies within their practices (see Table 2).

(2) A demonstration of the four Wii balance games, namely Skate Board Arena, Tightrope Walk, Balance Bubble, and Table Tilt; all of them part of the Wii Fit Plus suite (see Table 1). These demonstrations were performed by one of our researchers. In one interview, the interviewee offered to perform the activity. During all the demonstrations, the interviewee was providing oral feedback by remarking on the strengths and weaknesses of the video games. They offered suggestions to make the games more enjoyable and suitable for their elderly patients.(3) This material was transcribed and analyzed using Leximancer, a specialist analytics technology for unstructured, qualitative, textual data [10].

TABLE II. INTERVIEWEES' DETAILS AND PSEUDONYMS [7]

Traditional Medicine	**Expert 1:** Professor Aged Care, Sydney Hospital Researcher and director of Health and the Aged Centre.
	Expert 2: Physiotherapist at an large Aged Care Facility in Sydney
	Expert 3: Associate Professor Chronic Care at a Sydney university.
Alternative Health Techniques	**Expert 4:** Certified Feldenkrais Movement Practitioner in Sydney.
	Expert 5: Certified Alexander Technique Practitioner in Sydney. Own Practice.
	Expert 6: Expressive Arts & Music Therapy Specialist at a university in Sydney as well as having a Sydney private practice.

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III. CATEGORISATION OF USABILITY FACTORS

In order to identify and categorize usability factors a modified version of the Heuristic Evaluation was utilized. This methodology was slightly modified in order to adapt to Jamieson's framework.

The term Heuristic Evaluation is an inspection technique where a set of usability principles is established and used by evaluators to explore an interface. These principles are called heuristics.

The heuristic evaluation [8] was applied by following the following five (5) stages: (1) the identification of usability problems as well as their categorization; in order to be able to identify not only the 'problems' or barriers, but also the drivers mentioned in Jamieson et al [8]. The scope of the term 'problems' was expanded to a more generic neutral term that we refer to as 'factors' in this paper; these factors can be of a positive or negative nature; (2) the observation of players while interacting with the videogames under the observation of evaluators; recording facial expressions, verbal reactions, etc; looking for new factors which could be missed from the first stage; (3) the re-categorization of usability factors; (4) the description of the ways to resolve problems encountered previously by the creation of heuristics; (5) the testing of heuristics applying the methodology of user logging combining the thinking aloud protocol.

The list below describes the final categorization of the appeared usability factors [7]:

I. Provide training phases: The game should have training phases before the real game starts, allowing the users to become familiar with the technology. Additionally, these training stages must be easy to skip when they are not required anymore.

II. Create feasible goals: The goals must be reachable by adapting the difficulty of hazards to take into account the physical abilities of the aged cohort.

III. Establish appropriate relations between movements and display: The game must respond according to the user movements.

IV. Provide rules, information and instructions in an adequate way: The information regarding rules, suggestions and instruction should be given before and during the game, so the user does not have to read instructions and operate at the same time. Also, this information should be provided by audio.

V. Consider the mental condition of the player: The player should not feel frustrated and upset because of hard goals. The objective of a game is to entertain the player, so practices such as the ones involving excessive memorizing or unnecessary cognitive complexity to understand the game must be avoided.

VI. Consider the physical condition of the player: Avoid unnecessary requirements for workouts involving coordination and flexibility outcomes. If possible, preclude the need for complex movements so the elderly users, if at all possible, do not require frames to maintain balance.

VII. Engage the user: The thematic of the video game must be in accordance with the audience's interest to avoid lack of commitment.

Tables 3 illustrates the frequency and total number of usability factors found with each heuristic as identified by the alternative and mainstream practitioners. Table 4 shows the frequency and total number of positive and negatives for the heuristics.

TABLE III. NUMBER OF USABILITY FACTORS FOUND WITH EACH HEURISTIC BY ALTERNATIVVE AND MAINSTREAM PRACTITIONERS.

Count of Categrory (Stage1)	Medical Approach		
Categrory (Stage1)	Alternative / C	Traditional / M	Grand Total
Physical Health	11	8	19
Engagement	1	12	13
Providing Rules, information and Instructions	6	2	8
Co-relation between movements and display	6		6
Difficulty to reach the goal	1	4	5
Mental Health	2	2	4
Requirement of Support (e.g. Rollator)		3	3
Training		2	2
Grand Total	**27**	**33**	**60**

TABLE IV. TOTAL NUMBER OF POSITIVE AND NEGATIVES FOUND WITH EACH HEURISTIC

Count of Categrory (Stage1)	Column Labels				
Row Labels	Comment	Negative	Positive	Suggestions	Grand Total
Co-relation between movements and display		2	4		6
Difficulty to reach the goal	1	2	2		5
Engagement	2	4	6	1	13
Mental Health		3	1		4
Physical Health	1	6	12		19
Providing Rules, information and Instructions		6		2	8
Requirement of Support (e.g. Rollator)				3	3
Training	1		1		2
Grand Total	**5**	**23**	**26**	**6**	**60**

IV. RESULTS

After running the evaluation and categorizing the problems, the total number of unique usability factors was 60. The distribution of the total number of occurrences per medical approach was 45 % (27 occurrences out of 60) for the "Alternative/Complementary" group against 55 % of the "Traditional/Mainstream" (33 occurrences out of 60) respectively.

Figure 2 provides a graphical representation of the frequency trends of the two (2) medical approaches per usability category. Factors such as Physical Health had the major number of occurrences for the two medical approaches whereas Engagement seemed to present a large discrepancy between the two.

Figure 3 presents the total granular frequency of usability factors (positive or negative) found for each usability factors' category. The major numbers of negative occurrences were related to the Physical Health category followed by the Provision of Rules, Information and Instructions.

Table 5 presents a subset of the pre-processed results with detailed occurrences related to Physical and Mental Health usability factors.

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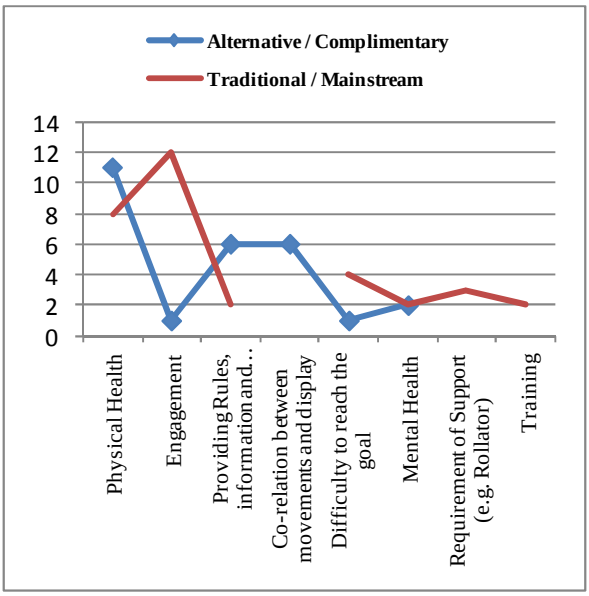

Figure 2. Frequency trends of the two (2) medical approaches per usability category.

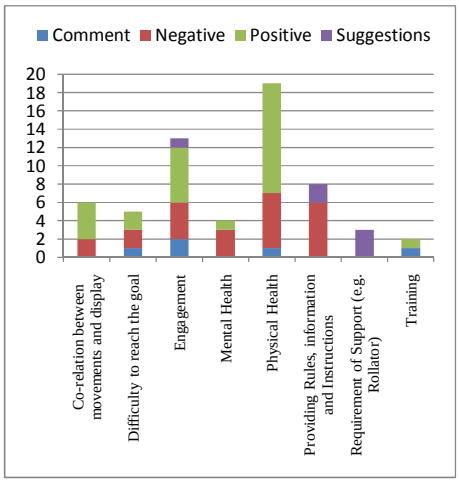

Figure 3. Frequency trends of the two (2) medical approaches per usability category.

TABLE V. LIST OF MENTAL AND HEALTH USABILITY FACTORS (BARRIERS AND DRIVERS)

Categrory (Stage1)	*Impact*	*Detail (Level2)*	*Game*
Mental Health	Negative	Upsetting particulary if the avatar fail	Tightrope
	Negative	Anxiety producing stimulus makes people tighten their necks and shoulders and sabotages their balance reflex	Tightrope
	Negative	Hitting the side the whole time could be frustrating, worrying	Bubble
	Positive	Good for concentration	TableTilt
Physical Health	Negative	Patients could have issues with putting the foot on and off	SkateBoard
	Negative	Encouraged patients to tense up and lose balance instead of relaxing and loosening up	TableTilt
	Negative	Potential dangerous for the elderly (learning unwanted movement patterns)	Bubble
	Negative	Backward lean may be tricky for the elderly	SkateBoard
	Positive	Good for balance and weight shifting	Tightrope
	Positive	Allows movement forwards and backwards and side to side, which is a good strategy	Bubble
	Positive	Good for counterbalance	SkateBoard
	Positive	Good for locomotion practice	SkateBoard
	Positive	Good exercise and suitable	TableTilt
	Positive	Good for counterbalance	TableTilt
	Positive	Good for stimulating body awarness of weight distribution on the feet	Bubble
	Comment	Use of quads and bit of his core	Tightrope
	Negative	Not useful for cardiac rehabilitation patients as it did not raise their heart rate sufficiently	Bubble
	Negative	Useful for younger and more able patients (Coordination and flexibility are needed)	SkateBoard
	Positive	Useful exercise for balance and shifting weight	Tightrope
	Positive	Gentle and safe	Bubble
	Positive	Better workout, Expert likes it	SkateBoard
	Positive	Not a problem for stroke patients if able to walk independently	Tightrope
	Positive	Relevant fine balance movements	TableTilt

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V. DISCUSSION

As explained earlier in this paper, the use of videogames among the aged population requires a deep inspection to guarantee optimum results on health practices. Thanks to the use of methods like the heuristic evaluation to assess the usability of interactive video games as well as the co-operation of health specialists, we found that there are some characteristics, which could bring out unexpected results regarding the mental and physical health of the elderly. Problems such as the lack of relation between what it is supposed you do and what you see on the screen, could cause confusion for the player giving as a result a feeling of anxiety and frustration affecting, at the same time, the balance reflex and mental satisfaction. Also, it is important to mention that due to the changes which the human body suffers in advanced ages, the users could lose the accuracy of senses such as sight and hearing, making it complicated for the elderly to read or listen to instructions while the game is running.

VI. FRAMEWORK

The majority of the barriers in this preliminary study were related to the physical and mental conditions of the elderly (e.g. muscle strength, balance, memorization or cognitive capacity to perform concurrent activities). Another major factor was the lack of alignment in between the game rules or goals which in many cases lead to undesirable physical and/or mental user behaviors and the primary goal of improving the health of the user. These game rules should be not only aligned to the user health condition profile, but also customizable and automatically adjustable to the user's progress. Granularity for specific user health conditions should be specifically targeted, measurable and adjustable to multivariate skill progress during the evolution of the game.

The proposed Dynamic and Customizable Layered Serious Game Design Framework in Figure 4 is proposed as an aid to serious game design for health purposes. This framework attempts to align to Jamison's major positive user effect instigators which should provide a complete feedback loop that includes:

(a) monitoring of current patient status, (b) interpretation of this data in light of established, often individualized, treatment goals, (c) adjustment of the management plan as needed, (d) communication back to the patient with tailored recommendations or advice, and (e) repetition of this cycle at appropriate intervals. Systems that provided only one or a subset of these functions were less consistently effective [8].

The proposed framework aims to alleviate design customizable problems improving the Physical and Mental Health of the Aged.

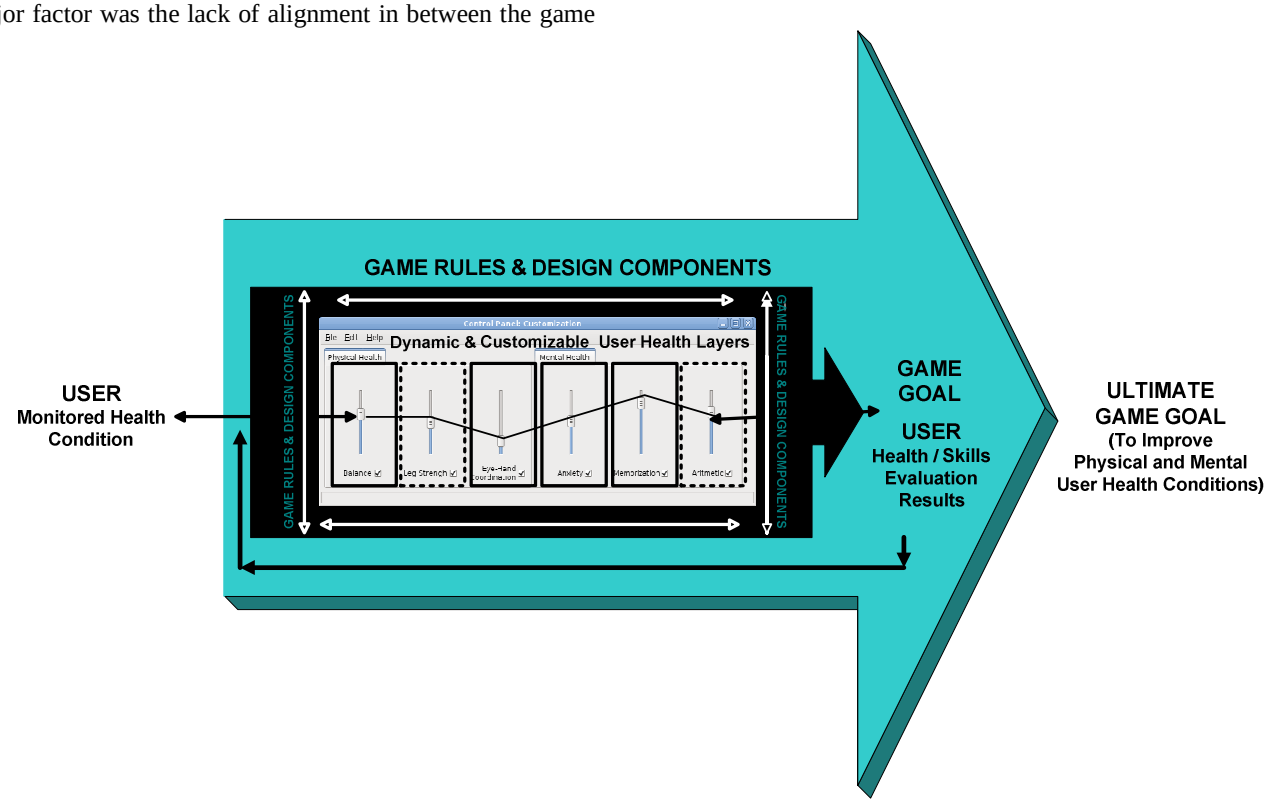

Figure 4. The Dynamic and Customisable Layered Serious Game Design Framework for Improving the Physical and Mental Health of the Aged.

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VII. CONCLUSION

Previous research has shown that the usage of video games for health purposes provides some positive outcomes for the elderly. This is evidenced by the successful result of research which treated diseases related with getting older by using video games and interactive technologies. Despite this, these practices could result in drawbacks for the elderly when their mental and physical conditions before playing video games are not considered. Furthermore, testing the usability and suitability of videogames is crucial to obtain the improvements expected. Consequently, in order to identify the barriers, drivers and usability factors of the use of the assessed interactive technologies, the authors utilized the modified Analytic Framework used by Jamieson et al [8] in their landmark study on Consumer Health Information Technologies used by the elderly, chronically ill and underserved (see Figure 1), as well as a heuristic based evaluation technique for the identification and categorization of the interactive technology usability factors. This video games heuristic evaluation technique was selected due to its flexibility and adaptable nature [9].

The use of an extended heuristic evaluation and the interviews with six healthcare experts have shown effective results in assessing the usability of videogames; this flexibility has allowed the researchers to discover and categorize hidden usability factors regarding the suitability of Nintendo Wii games for aged users.

The analysis of the results obtained during this study led the researchers to the proposed dynamic and customizable layered serious game design framework for improving the physical and mental health of the aged.

Although this topic is currently being researched world wide, the complexity in the alignment of the game design components with the granularity and dynamics of the targeted, measurable and customized user health conditions locates this multidisciplinary area of research at the beginning of a long road ahead of discoveries in disciplines of game design, health and behavioral sciences among others.

REFERENCES

[1] G. Hugo, "Contextualising the 'Crisis in Aged Care' in Australia :: A Demographic Perspective," Australian Journal of Social Issues, The, vol. 42, pp. 169-182, Winter 2007 2007.

[2] S. T. Smith, et al., "Electronic Games for Aged Care and Rehabilitation," in e-Health Networking, Applications and Services, 2009. Healthcom 2009. 11th International Conference on, 2009, pp. 42-47.

[3] H. Sugarman, et al., "Use of the Wii Fit system for the treatment of balance problems in the elderly: A feasibility study," in Virtual Rehabilitation International Conference, 2009, 2009, pp. 111-116.

[4] C. Neufeldt, "Wii play with elderly people," International Reports in Socio-Informatics, vol. 6, 2009 2009.

[5] Zyda, M. (September 2005). "From visual simulation to virtual reality to games". IEEE Computer.

[6] E. Lawrence, et al., "Healthcare Professionals' Perspectives on Interactive Games for the Aged," Under review, 2010.

[7] Garcia Marin, et al., " Heuristic Evaluation for Interactive Games within Elderly Users," presented at the Under review, 2010.

[8] Jimison H, Gorman P, Woods S, Nygren P, Walker M, Norris S, Hersh W. Barriers and Drivers of Health Information Technology Use for the Elderly, Chronically Ill, and Underserved.Evidence Report/Technology Assessment No. 175 (Prepared by the Oregon Evidence-based Practice Center under Contract No. 290-02-0024). AHRQ Publication No. 09-E004. Rockville, MD: Agency for Healthcare Research and Quality. November 2008.

[9] D. Pinelle, et al., "Heuristic evaluation for games: usability principles for video game design," presented at the Proceeding of the twenty-sixth annual SIGCHI conference on Human factors in computing systems, Florence, Italy, 2008.

[10] Anonymous. (2010, October 14, 2010). What is Leximancer. Available: www.leximancer.com

[11] (2010, October 4, 2010). Wii Fit and Wii Fit Plus. Available: http://www.fitgameforum.com/wiki/index.php/Main_Page

[12] T. Fullerton, Game Design Workshop, Second Edition ed. Burlington, MA: Elsevier Inc., 2008.

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