Human Linguistic Perception of Distances: Examining Intrapersonal & Interpersonal Perceptions

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***Abstract*— Human navigation systems implemented on mobile devices often define distances or localization relative **to landmarks using quantitative metrics. However, human minds abstract and articulate distances in linguistic forms using words rather than numeric distances, hence the current locations descriptions are not completely in tune with human cognition. The proposal in this work is to further evaluate the challenges inherent in linguistic description of distances, specifically by examining the intrapersonal & interpersonal perceptions variations. A general challenge in location referencing is the impossibility of adequately estimating distances accurately from landmarks and also due to the fact that human minds, that is, majority of the people, cannot adequately grasp or perceive quantitative distances, but rather reprocess the quantitative distances into linguistic articulations. This work focuses how best qualitative or linguistic descriptions of distances can be accomplished. The overall aim of the research in this direction is to fashion out the best approach to building models that reprocess quantitative distances in indoor environment into linguistic form suitable for different groups of users such as old, young, handicapped, blind, etc. The results from the study demonstrated that there are no significant variations in the intrapersonal perceptions while there exist considerable significant differences in interpersonal perceptions among the various subject groups examined. It is hoped that the results may provide further guidance in the modelling of quantitative distances for mobile gadgets such as PDAs, firemen localisation devices.**

***Keywords*—** put your keywords here, keywords are separated by comma.

I. Introduction

Current navigation devices implement localisation systems that describe locations from landmarks in crisp quantitative terms. Location reference or authority are term used to describe any set of referents for location references [1] in location-based computing or navigation systems. The notations or schemes are often expressed in geometrical, topological or hybrid forms. The term linguistic reference is used to describe qualitative description of location references in natural language rather than using quantitative descriptions. Using the current quantitative location references is quite sufficient for robots, machines, cars and to a great extent for humans, in spite of the uncertainties in the computations of distances to landmarks. However, this is not completely in line with human natural cognition, abstraction of distances and human intuition in dealing with location referencing. Human mind, often times, do not really reckon with the precise quantitative distance but rather internalize and articulate a linguistic abstraction of such quantitative distances. Localization gadgets and systems such as GPS, Uber etc give direction information such as "in 100m, turn to the right". Likewise, personal digital assistants such as Siri, Alexa, Cortana etc provide services in linguistic forms but however describe distances in quantitative terms, such as 100 metres. Human mind in this instance, does not necessarily grasp what the precise quantitative distance 100m means. What is done generally is to linguistically approximate the distance to something like move a little bit further, then turn to the right.

To further understand the importance and inevitability of linguistic location reference, let's take the case of a person stranded in a building in an emergency situation such as fire. In these kind of emergency situations, people may not have the time or opportunity to type their locations on a mobile gadget but rather hurriedly use verbal descriptions of where they are located to make it easier for rescue workers to locate them. Hence, to describe their distances from a landmark found around them, they would most probably say "I am close to the staircase" rather than "3 meters to the staircase". This is the general human intuition and difficult to act otherwise.

Hence, text inputs under situation of emergency or duress may not be feasible thereby making the present systems inadequate.

Previous work has established that several factors have effects on how people perceive distances. Human perception, in general, is known to be influenced by emotions such as sadness, happiness, fear. Other factors that have equally be shown to play critical roles in perceptions include benefits as well as costs of an anticipated action [2]. Furthermore, Alter and Balcetis [3] have established that having fondness with respect to traversing a given distance makes perceiving the distance to be shorter, whereas in the case of a given unappealing distance, people tend to have unoptimistic estimate of such distance. Accordingly, desired locations often seem nearer due to being motivated and energized to traverse the distance in order to reach the destination as quickly as possible. Clementini et al [4] classified efforts into four forms, viz; spatial (metric distance), temporal (travel time), economic (cost to be invested) and perpetual (spatial perception). Barrett, Mesquita and Gendron, [5] on the other hand, underscore familiarity with the distance to greatly affect how distances are perceived. This reflects that a considerable understanding of the conceptual map of the desired location may aid a more realistic perception. This is also corroborated by the findings from Olowolayemo & Mantoro [6] that people perceive distances between points in familiar environment to be shorter than when given quantitative values of the distances. It is also known that people's perception varies from one person to another while even the same person may perceive the same length of distance differently depending on the situation or scenarios. The first instance is often referred to as interpersonal uncertainty while the latter is regarded as the intrapersonal uncertainty [7-8]. Again, it may even be difficult to reach a common perception between a speaker and the receiver, since all linguistic representations are vague to certain degree in the perceptions of the originators and in that of the receivers [8]. A unanimous understanding of words is often elusive due to the fact that the meaning of words is not the same in the minds of all people while people may describe identical situations using different expressions of uncertainty [7-8].

From the foregoing, linguistic articulation of distances is riddled with uncertainties. Approaches employed are intended primarily to address the two types of linguistic uncertainties – intrapersonal and interpersonal uncertainties. Earlier authors have tried to distinguish different intrapersonal perceptions using three levels [9]. This was further explored in Olowolayemo et al. [10], classifying the three levels as the "Most Likely", "Next Likely" and "Least but Likely" perceptions.

This study focuses on examining the variations that are inherent in people's perception of distances; specifically intrapersonal and interpersonal perception variations. The approach adopted uses a case indoor environment and collecting subjective interval distance perception references from selected subjects. The data were thereafter analysed using exploratory and inferential statistics of the two highlighted perceptions which was subsequently followed by a discussion of the results as well as further recommendations for future work.

II. Related Work

In the following sections, a brief background of the related work is presented.

A. Closed Area Navigation

Generally, there are inherent vagueness and uncertainties in linguistic articulations among people when describing locations, relative to landmarks. For navigation means, landmarks, are "any features of the environment which are relatively stable and conspicuous" [11] and often used as references depending on the scale or the environment.

Human navigations have been said to be in four levels of representation based on psychology. These levels of cognitive maps are schemata, landmarks, routes and surveys [12-13]. Human mind is said to function by utilising cognitive map to internalize the schema of the physical layout of the environment. The human mind employing intuition often works over and elaborates abstraction as well as understanding of the environment. Firstly, a tentative cognitive-like map of the environment indicating routes, paths and environmental relationships is conceptualized. This is persistently reinforced until a considerable conceptual cognitive map is achieved and internalised [14].

A new environment is often scanned in exploratory fashion identifying the landmarks, the routes and survey knowledge of the environment persistently, and continuously reinforced until the mind becomes conversant with the environment forming a familiar cognition in the mind. Using landmark knowledge, a primary skeletal framework is sketched in the human mind resulting in clear cognitive maps. The second form of knowledge, route knowledge, is the knowledge requisite to navigating from a point in a path to other points relative to landmark within the environment to get to the desired destination. The route knowledge is often used to provide route descriptions by someone familiar with the environment to others less familiar with a new environment, or someone who might be confused about locating some points within an environment.

B. *Indoor Environment*

Despite the potentials of expressing distance information in linguistic form, it is not unambiguous. This is because a number of factors affect perception of distance. These factors include perspectives and circumstance, especially that which account for the effort required to transverse the distance; spatial (metric distance), temporal (travel time), economic (cost to be invested) and perpetual (spatial perception) [4].

Owing to the aforementioned, in an attempt to present distances from landmarks in linguistic form, there is the need for a painstaking approach to gain insight into the best way to model distances taking into consideration the factors highlighted.

The location referencing techniques implemented in the present navigation system are insufficient intrinsically for humans, especially people that may rely on voice recognition or text to speech (and vice versa) systems in special situations or needs. These sets of people include the visually impaired, physically challenged, the elderly or rescue workers that may not have sufficient time or are too preoccupied to conveniently use their hands to enter input. Examples of current systems geared towards helping the disabled, visually impaired or the blind have been proposed or examined by studies such as [15-19]. Most of these systems rely entirely on audio input and output for all activities. However, in all these systems, quantitative distances are used in situations that require location referencing. Therefore, this state of the present location referencing techniques demands development of new opportunities for location referencing to make it more user-friendly and intuitive especially for the class of users highlighted above. This requires proper evaluation particularly making it more human-centric to develop the possibility of a new perception-based location reference that accommodates the systematic co-existence of human-centric variations. It is therefore necessary to explore an approach towards making location referencing more meaningful in line with human cognition.

In the case of inputs in the current systems, it is either the user pins the location on a map or types the name of a landmark or input using voice message or describing location through call which is more appropriate and realistic to humans, especially for blind, physically challenges or in emergency situation. Hence, the proposal in this work is to examine whether it is possible to present location references in a linguistic form and allowing appropriate consideration for human natural understanding [10]. This work can be extended to all scales in different environment – indoors or outdoors, but the focus of present work is indoor environment since the applications are more relevant and probably currently required.

III. Methodology

This study focuses the challenges in reconciling distance perceptions between different categories of users in the efforts to develop a linguistic location references anchored on user perception and natural linguistic approximation of distances between a given pair of points in indoors environment. Previous work described in Olowolayemo and Mantoro [6] explored the disparities that arise in the perceptions of distance given in numerical values compared with that of pairs of points whose distances' quantitative values are not revealed to the respondents. The previous work demonstrates that there is significant difference between the perceptions in these two scenarios.

The ultimate aim of the work in this direction is to model distances in linguistic forms rather than the current quantitative forms with a view to making location references more intuitive in line with natural human cognition. The approach intended in the eventual modelling is the enhanced interval (EIA) approach, based on computing with words (CWW) [7], [20], which is then reprocessed into linguistic perception of distances based on several fuzzy logic models [6]. The descriptions of fuzzy models namely the α-cut, Gaussian, and ANFIS for enhanced interval approach for the linguistic approximation with treatment of the underlying uncertainty have been elaborately elucidated in Olowolayemo and Mantoro [6].

However, this current work examines an extension of the challenges and the varying complexities inherent in achieving a harmonious model that best suit the entire categories of users and thereby proposes a few solutions that may be further explored to actualise the idea.

This section is divided into two subsections, viz.: data collection approach and subjects' descriptions.

The overall aim is to provide linguistic representation of distances between a user and other entities in the environment for location references. Entities in the environment of the user could be other users, relevant landmarks, as well as other nearby objects or devices.

To realize this idea, the first most vital consideration is to understand people's perception about distances in indoor environment, using different but adequate approaches to acquire information from various categories of users. Subsequently, an evaluation of the differences in the perceptions among the categories of users is carried out. Here, any significant differences as well as likely reasons responsible for these are noted. Thereby, it is intended that an approach is proposed to either normalize the differences by modeling a consensus of the differences while noting the uncertainties possible or separate models appropriate for each category of users are adopted.

A. Population, Sample, and Data Collection Approach

The population essentially is the overall users of navigation systems. However, indoor environment setting has been adopted in the present study. In a typical indoor space, different categories of users are found which may include able bodied users as well as people with special needs – handicapped, blind, young as well as old. The work was situated in a campus building to provide an environment that can be utilised for the purpose of the research. Unfortunately, the old, young as well as the handicapped have not been included in this work due to limited number of respondents in these categories that are found. The users considered in the present study are broadly divided into three types: the normal users, the expert users and the blind. The next subsection describes the need for each of the categories of users. The sampling technique adopted is purposeful sampling due to the limited number of participants. Eight experts out of a population of about 50 staff of the faculty of building engineering responded, however, only five were usable due to incomplete responses. Three of the responses were inconsistent. On the other hand, 78 ordinary subjects were sampled while, 22 blind responses were sampled.

B. Subjects

This work is an attempt to model distances relative to landmarks in linguistic forms suitable for computing devices, e.g. mobile gadgets, especially which may be used by the blind and other physically challenged people as well as normal people such as emergency or rescue workers. The idea is especially useful for voice input where it is difficult to type into mobile phones. This could be due to an emergency or dangerous situation where typing on the mobile gadgets' keypads may not be feasible.

The subjects were classified into three groups, tagged the general users, the experts and the blind. It was thought to include users that were well experienced in building management, as "expert subjects'. This group of respondents is chosen from people with building or construction engineering background. Based on previous work such as [21-22], blind subjects were included to provide their perspectives on cognitive approximation of distances. This is especially intuitive for the blind when the distances were presented in the form of number of steps. The third and the largest group is the ordinary users' group that are familiar with the case location.

The data collection part consists of two parts, namely demographic and quantitative distance between pairs of known locations. The demographic part was intended to determine whether demographic differences, specifically; category – experts, general & blind; plays significant roles. This is required so that different requirements may be included in the eventual implementation on navigation devices. The majority of the respondents were students, both undergraduates and postgraduate students of the faculty of computer science. The other set of respondents were the blind at YMCA sampled, most of whom were considerably educated. Several of them are employed as administrative staffs in different companies while some others work in massage and other related centres. They easily compared the distances presented to them to other familiar measurements such as the length of a swimming pool and were able to respond, while the researcher filled the questionnaires on their behalf.

IV. Discussion

This section presents the discussion on the results of analysis of perceptions of the respondents. There were three categories of subjects considered. The ordinary users, the blind and some selected experts. The method adopted for the elicitation of interval data in subjective form from subjects was through online survey for the general and expert users. In the case of the blind however, the questions were read to them while the researcher entered responses on their behalf. The perception analysis is divided into two types, namely; the intrapersonal and interpersonal perceptions. The intrapersonal perception analysis focuses on the likely differences a particular person may have regarding their own perception of the linguistic distances. Interpersonal perception analysis on the other hand is intended to evaluate the variations in perceptions among different subjects. Owning to the complexity and uncertainty inherent in accurately estimating distances linguistically, an absolute right or wrong answer may not be feasible. Consequently, a given distance may have several meaning to even a particular person, hence, intrapersonal perception variations may exist. Likewise, it is expected that a certain distance should necessarily have different meanings among different individuals (interpersonal perception variations).

C. Intrapersonal perception analysis

For every intended perception question, three levels of data were elicited from the participants to evaluate any differences that may exist in the mind of the individual respondent. This is based on the notion that subjective opinions may not be precise, and may have varying meanings in the mind of a particular user. Hence, a particular distance may be considered a "Close", "Intermediate" and "Far" at the same time by the same person with varying degrees. Thereby, the three levels of the data were designated as "Most Likely", "Next Likely" and "Least but Likely". The multilevel notion was first proposed by Jong [23] and further explored by Olowolayemo and Mantoro [6].

This work focuses indoor building spaces and from the general understanding of the indoor environment, respondents should have an intuitive understanding of distances to which they considered very close, close, intermediate, far and very far. These five linguistic labels were chosen in the present study in agreement with five Likert's scale, even though, other linguistic words that are articulated by users to describe localisation distances exist. The subjective elicitation questions were laid out in three forms for every numerical distance as explained previously.

Examples of the questions in this category are given thus:

"Indicate how BEST you can describe this distance – about 2.5m (~ 8 feet or about 10 steps) distance in indoor environment?"

"Indicate how NEXT LIKELY you can describe this distance – about 2.5m (~ 8 feet or about 10 steps) distance in indoor environment?"

"Indicate how LEAST BUT LIKELY you can describe this distance – about 2.5m (~ 8 feet or about 10 steps) distance in indoor environment?"

The responses were analyzed using significant test at 5% level of confidence, presented in table 1. From the results, it can be seen that there is no significant difference between the perceptions of the three levels of data acquired – Best, Next, Least, in most of the cases, especially for distances higher than 15m. This signifies that a level of the data might be sufficient to approximate the linguistic model of the data for the general users. Hence, it can be concluded that intrapersonal perception variations are not significant enough to call for different models for a particular individual. As can be seen clearly, shorter distance interpersonal perceptions among the groups are significantly different. This is due to the fact that the amount of effort to traverse the distances is less demanding, hence respondents tend to be flexible in their responses to accommodate the three level of variations. This situation drastically changed when compared with distances beyond 15m, since the users have started to perceive unconsciously that the distances are somewhat far, hence, far or longest choices in those categories were selected.

TABLE I COMPARISON BETWEEN THE THREE LEVELS OF ELICITATION

Distance(in metres)	P-Value (ANOVA)
2.5	0.1
5	0.002
7.5	0.04
10	0.02
12.5	0.023
15	0.012
17.5	0.23
20	0.987
22.5	0.332
25	0.209
27.5	0.256
30	0.518
32.5	0.805
35	0.415
37.5	0.056
40	0.097

A. *Interpersonal Perception Analysis*

This subsection presents analysis of results of interpersonal (person to person) perceptions. Firstly, perception analysis was carried out to determine whether there is agreement in the perceptions of the various groups within the groups themselves, as well as with the selected experts. It is also necessary to find out if there is unanimous agreement regarding each quantitative distance among the users on one hand and the selected experts on the other.

TABLE II DESCRIPTIVE DATA OF THE INDOOR DISTANCE (EXPERTS & USERS)

Distance (in metres)	Range	Mean (Very Close (5) – Very Far (1)	Std Dev
2.5	2	4.88	0.43
5	2	4.51	0.6
7.5	3	4.23	0.55
10	3	4.01	0.61
12.5	2	3.87	0.63
15	3	3.64	0.6
17.5	2	3.12	0.56
20	2	2.9	0.44
22.5	2	2.73	0.53
25	2	2.65	0.58
27.5	2	2.45	0.54
30	2	2.32	0.59
32.5	2	2.11	0.46
35	2	1.97	0.62
37.5	2	1.86	0.52
40	2	1.77	0.6

*Linguistic labels for distances range from Very Close (5) – Very Far (1)

The final comparisons were done between the responses of the users and the blind with respect to their linguistic articulations of the distances presented to them within a given indoor environment. The descriptive analysis of the experts and ordinary users is presented in Table 2.

The hypothesis test in Table 3 shows that there is no significant difference between the perception of the experts and the ordinary subjects, despite the fact that the mean responses from the expert groups are slightly higher than that of the general users, and there is more variability in response of the experts, except in a few cases where there seem to be somewhat level of agreement. This result signifies that there is no complete agreement among the experts themselves within their group as well as among the general users and much more between the two groups. Specifically, as should be expected, the results suggest that modelling distances is subjective and there exists a clear complexity in how people perceive distance linguistic approximations within an indoor space.

As can be seen from the results in table 3, all the subjects agree to the gradual linear variation of the linguistic variables, however, the subjects do not agree on the boundaries of each of the linguistic values in the scale.

TABLE III HYPOTHESIS TEST BETWEEN EXPERTS AND ORDINARY USERS

Distance (in metres)	Mean Response (Total Experts - 5)	Mean Response (General Users - 78)	P-Value Sig. (2-tailed)
	Very Close (5) – Very Far (1)		
2.5	4.6	4.81	0.455
5	4.6	4.47	0.648
7.5	4.6	4.32	0.752
10	4.4	4.01	0.393
12.5	4.3	3.85	0.452
15	4.2	3.67	0.23
17.5	4.04	3.28	0.245
20	3	2.94	0.852
22.5	3	2.82	0.152
25	3	2.72	0.452
27.5	2.6	2.55	0.554
30	2.4	2.44	0.896
32.5	2.4	2.23	0.436
35	2.4	2.12	0.329
37.5	2.25	2.02	0.222
40	2.2	1.88	0.205

*Linguistic labels for distances range from Very Close (5) – Very Far (1)

The blind subjects included due to their unique cognitive approach to distances compared to normal subjects provided better guidance to modeling the linguistic location reference.

TABLE IV BLIND RESPONDENTS

Distance (in meter)	Mean
2.5	5
5	5
7.5	5
10	5
12.5	5
15	4.9
17.5	4.7
20	4.6
22.5	4.5
25	4.4
27.5	4.2
30	4.1
32.5	4
35	4
37.5	4
40	4

***Linguistic labels for distances range from Very Close (5) – Very Far (1)**

In fact, for instance, a distance of 2.5m which was almost unanimously considered close among the 78 students (4.81 ~5: Very Close) was less agreed upon by the 5 experts (4.60 ~ 5: Very Close). This was surprising when the blind respondents interviewed considered a distance of 20m, Very Close in a familiar environment.

TABLE V SIGNIFICANT DIFFERENCE ANALYSIS BASED ON STUDY SUBJECTS

	Hypothesis	P-Value	Decision
1	2.5	.057*	Not Significant
2	5	.049*	Not Significant
3	7.5	.026**	Significant
4	10	.027**	Significant
5	12.5	.013**	Significant
6	15	.029**	Significant
7	17.5	.016**	Significant
8	20	.022**	Significant
9	22.5	.034**	Significant
10	25	.025**	Significant
11	27.5	.021**	Significant
12	30	.027**	Significant
13	32.5	.015**	Significant
14	35	.010**	Significant
15	37.5	.024**	Significant
16	40	.015**	Significant

P= 0.000, ** - significant at 0.05 level (2- tailed))

The blind generally considered distances in familiar environment relatively shorter compared to that of unfamiliar environment as well as environments where they feel under threat or conscious of damaging things by accident such as breakables – cups, plates etc.

From the perception analysis above, it can be seen that for small distances such as 2.5m and 5m, there is slightly no significant difference between the perception of general users (since 0.057 and 0.049 are considerably close to 0.05) and the blind group while from 7.5m onward there exist considerably significant differences between the two groups.

V. Conclusion

The overall work in this direction is focused on approaches to reprocess quantitative distances from landmarks into linguistic articulations suitable for use on the current mobile devices. The approaches are perception based employing procedures used in computing with words (CWW).

This particular study however expresses some of the impediments in the way of achieving linguistic approximations of quantitative distances to landmarks in indoor environment suitable for implementation on mobile devices, specifically focusing on the intrapersonal and interpersonal perception variations. Achieving this would be particularly useful for use in situation of emergency such as fire where it might be difficult or not practicable to enter inputs on keypads of mobile gadgets.

This work specifically examines intrapersonal and interpersonal perception variations of distances for indoor linguistic referencing. From the results of the perception analysis carried out, it is safe to conclude that for a given distance, intrapersonal perception variations may not count significantly in the models unlike interpersonal perception variations.

Reconciling interpersonal perception variations, on the other hand, proves complex. There is significant variation within ordinary users' group, as well as within expert group. Furthermore, there exists significant variation between expert group when compared with ordinary group as well as when compared with the blind group.

Probable work that could be examined as a future work is the likelihood of incorporating modified models suitable for different groups such as old, young, handicap as well as designing systems that provide opportunities for individuals to personalise settings that enable adjusting the systems to his or her understanding to further improve the results without compromising efficiency.

A further work which may prove quite useful is to collate and re-evaluate all distance code words used by people and attempt to determine their intervals using this approach to generate a complete computing with words (CWW) for distances. The present work though evaluated a wide range of the words in the preliminary stage, however, singled out only five to ensure an initial framework. It is believed that further comprehensive exploration of the words will enable adequate user friendly choices to be relayed to users of the systems.

It is also vital that all distance linguistic code words for different languages be evaluated in the same way the few English words have been evaluated. This will be necessary to implement on mobile gadgets that are able to process several of the world languages.

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