p-Democracy a Pervasive Majority Rule

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Abstract. Today, group decision making in our democratic society uses the non-ranked method. What we need is an improved method that allows decision makers to indicate not only their chosen alternative, but also their order of preference by which all alternatives will be placed. We classify this as a particular Social Choice Function, where choice is a group decision-making methodology in an ideal democratic society that gives the expression of the will of the majority. We use the Eigenvector Function to obtain individual priorities of preferences and Borda's Function to obtain the Ranking or otherwise, the Group Choice. Our conclusions give rise to new directions for pervasive democracy with an innovative degenerative quantum scale to allow even for strong to very strong preferences.

Key words: Multi Criteria Group Decision Support Systems, Analytic Hierarchy Process, Pervasive Context Aware Activity Based Computing, e-Government, Everyware Development

Introduction

Decision support systems are nowadays becoming a widespread set of tools for the decision analyst and decision maker, utilized in an ever-increasing number of public and private organizations. Furthermore, today's evolution that come from extensive use of pervasive computing systems, ubiquitous services and ambient intelligence, makes it even more attractive to deploy group decision-aid techniques to achieve democratic operational environments on the productive and social activities that take place in an organization. In addition, we can optimize results by taking into account as many possible views coming from as many different fields of studies and interests. Finally, we can keep up to date to the recent needs of the knowledge age, where specialization of each decision maker involved in the decision-making process play an active role. This paper presents the design, development and implementation of a pervasive multi criteria group decision support system based on the Analytic Hierarchy Process [1] to obtain individual priorities of preferences for each decision maker, whom gives pair wise comparisons of the alternatives in question. We utilize a modified Saaty's scale [2], namely a degenerative quantum scale, which eventually allows us to obtain strong and absolute preferences. Thereafter, we aggregate individual priorities and using Borda's Social Choice Function [3], we obtain the ranking or the group choice for all decision makers participating in the decision process to obtain an expression of the will of the majority.

Background and Current Trends

Our main research activities are generally concerned with the effects of human computer interactions with pervasive computing systems as in analogy with electricity for example [1], which we occasionally use but not pay too much attention of its presence. Rick Belluzo [2], general manager of Hewlett-Packard called it “the stage when we take computing for granted. We only notice its absence, rather than its presence”. Louis V. Gerstner [3], Jr., of IBM had also said “Picture a day when billion of people will interact with million of e-businesses via a trillion interconnected devices”. Mark Weiser [4] at the Computer Science Lab at Xerox PARC only just recently coined the idea of pervasive computing in 1988. MIT Project Oxygen [5], Sun [6], Microsoft [7] Adobe [8] and Oracle [9] have also contributed significant research into this field. In addition, there appears to be a growing list of institutions [10] that focus in ubiquitous computing research and development.

The primary research unit in question involves the paradigm of a pervasive information and communication system technologically mediated for collaborative practices in order to aid decision-making. Interdisciplinary areas include Pervasive or Ubiquitous Computing (UbiComp) [11], Everyware Distributed Engineering (EWDE) [12], Computer Supported Cooperative Work (CSCW) [13], Human Computer Interaction (HCI) [14], Multi Criteria Group Decision Support Systems (MCGDSS) [15], Analytic Hierarchy Process (AHP), and e-Participation / e-Government [16]. We accept in the CSCW matrix of location and collaboration that MCGDSS are co-located and synchronous. The purpose is therefore, to extend that notion so they may also become remote and asynchronous. Major research is thus concentrated in the design development and implementation of a Context Aware (CA) Activity Based Computing (ABC) [17] framework based on server-to-server distributed network architecture, relying on Java Enterprise Edition (JEE) [18] to provide the pervasive and persistent platform. Thereafter we design, develop and implement our MCGDSS an embedded platform application, which we call “p-Democracy” [19] as utilized from both decision analysts and decision makers.

Initially, we address the issue of developing user authentication and authorization and device concepts (fingerprint, eye recognition) for identity management in the ABC framework. Security is of outmost important here, so we use Java Authentication and Authorization Services (JAAS) [20], enable Secure Sockets Layer (SSL) and obtain 128-bit Encryption Certificates on the server, to protect the identity of the decision maker. Anonymity is the primordial essence here and not compromised at any costs, assuring privacy, and trust and dependability conditions in order to avoid cyber crime. Specifically, we provide ubiquitous decision support services using our ambient intelligent component, p-Democracy embedded into our ABC framework. We deem that the success of our application lies in the modified Saaty’s scale, which eventually allows decision makers to make strong to absolute preferences in their pair wise comparisons of the alternatives in question.

Contrary to today’s practice and strategy, ubiquitous computers will not just run applications but will elicit them as context aware activities in portable server distributed network architectures to provide simultaneously co-located, remote, synchronous and asynchronous multimodal interactions. It is the dawn of the next generation society of ubiquitous citizens in the “Internet of Things”.

Everyware, a Pervasive Platform

Everyware Development first coined by Adam Greenfield [1] in 2006 in which he envisages when "million of people will interact with multitude of devices in a single space at a single time". It is the evolution from Software Development. What we seek is an open source, cross-platform portable, scalable and extensible programming environment. Sun's Java Enterprise Edition (JEE) [2] and Java Mobile Edition (JME) [3] with Eclipse [4] as an Interface Development Environment (IDE) provide such a repository. We use Apache Tomcat [5] as the web application server for p-Democracy and a pervasive system project lifecycle with an automated contingency plan namely subversion supported on Java's HTTP server [6] which can be also used for digital surveillance, tracking and monitoring of user sessions. Tom Taylor's [7] in "Everyware: the future is already here, it is just not well distributed yet" sums our efforts.

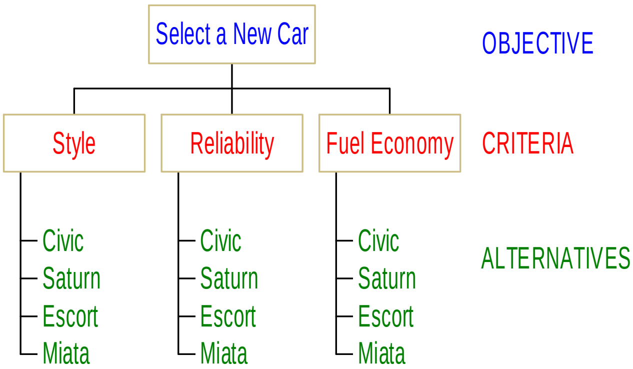
The initial goal of this research is therefore concentrated in the design, development and implementation of an ABC framework, that is, a pervasive platform based on Java's Remote Method Invocation (RMI) [8] a hybrid server to server and server to client distributed architecture. Thereafter, primary effort is concentrated into designing, developing and implementing collective user authentication and authorization interfaces with multi modal context aware interactions [9] and thence, extend the security context aware prototype to new user and authentication mechanisms that will allow both multi touch and multi person interactive interfaces. Secondary research focuses on embedding into the framework a set of collective user evaluation interfaces with multimodal interactions using AHP with our innovative degenerative quantum scale that allows strong to absolute preferences in our MCGDSS component. We run field studies of our Application Protocol Interface (API) deployment with examples from both the public and private sector [10].

Everyware Application: p-Democracy

We demonstrate group decision-making using the AHP by a simple five-step method. 1. The Decision Analyst is constrained to structure Hierarchons [1] based only on three level hierarchies, where each level can have no more than 3 or 4 decision elements. We pay particular attention for rank reversal and preservation as to the choice of mode of synthesis i.e. distributive or ideal. 2. The Decision Maker inputs pairwise comparisons of criteria and alternatives using basically, the fundamental scale, considering homogeneity and clustering as to extend or reduce the fundamental scale if required. 3. The Class defined, calculates and outputs relative weights (ranking) of criteria and alternatives, using the eigenvector, estimating consistency in each case. Sensitivity of the principal right eigenvector is ignored as the number of criteria and alternatives are kept to a minimum. 4. The relative weights are areggregated to obtain each individual's overall rankings. 5. The individual overall rankings are thereafter aggregated in order to obtain an overall group ranking

1. Structure the hierarchy into interrelated decision elements

This is the most important step of decision-making and that is the structuring of the hierarchy itself. The decision analyst develops the hierarchical representation of the problem. At the top of the hierarchy are the overall objective and the decision alternatives are at the bottom. Between the top and bottom, levels are the relevant criteria. We assign each Hierarchon to specific decision maker or group of decision makers. Example, defining the hierarchy: Objective: Select new car / Criteria: Style, Reliability, Economy / Alternatives: Civic, Saturn, Escort, Miata.



2. Collect pair wise comparisons of the decision elements

This step generates relational data for comparing the criteria and alternatives. This requires the decision-maker to make pair wise comparisons of homogeneous elements at each level. In the AHP, the fundamental scale of real numbers from 1 to 9 is used to systematically assign preferences in terms of intensity judgments as shown below

Intensity	Definition	Explanation
1	**Equal importance**	**contribute equally**
2	Weak	
3	**Moderate importance**	**slightly favor**
4	Moderate plus	
5	**Strong importance**	**strongly favored**
6	Strong plus	
7	**Very strong**	**strongly dominant**
8	Very, very strong	
9	**Extreme importance**	**favored affirmation**
Reciprocals of above	**If element *i* has one of the above nonzero numbers assigned to it when compared with activity j, the *j* has the reciprocal value when compared to *i***	**reasonable assumption**
Rationales	**Ratio arising from the scale**	**consistency**

3. Calculate the relative weights of the decision elements using the eigenvector and check for consistency.

Utilizing the pair wise comparisons of step 2 an eigenvector method is used to determine the relative priority of each criteria and alternatives in the hierarchy. In addition, a consistency ratio is calculated, using the Eigenvalue and displayed. According to Saaty, small consistency ratios (less than 0.1, that is, 10%) does not drastically affect the rankings. The user has the option of redoing the comparison matrix should the consistency ratio be larger than 10%. If the decision maker knows the actual relative weights of n decision elements, the pair wise comparison matrix would be depicted as shown for matrix A. Assuming we are given **n** stones, $\mathbf{A_1,\ldots,A_n}$, whith weights $\mathbf{w_1,\ldots,w_n}$, respectively, the matrix will contain the ratios of the weights of each ratio with respect to all others. The smaller of each pair of ratios is used as the unit and the larger one is measured in terms of multiples of that unit:

$$A = \begin{array}{c} 1 \\ 2 \\ 3 \\ \cdot \\ \cdot \\ \cdot \\ n \end{array} \begin{bmatrix} w_1/w_1 & w_1/w_2 & w_1/w_3 & \ldots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & w_2/w_3 & \ldots & w_2/w_n \\ w_3/w_1 & w_3/w_2 & w_3/w_3 & \ldots & w_3/w_n \\ . & . & . & . & . \\ . & . & . & . & . \\ . & . & . & . & . \\ w_n/w_1 & w_n/w_2 & w_n/w_3 & \ldots & w_n/w_n \end{bmatrix}$$

This leads to the eigenvalue equation:

$$\begin{bmatrix} w_1/w_1 & w_1/w_2 & w_1/w_3 & \ldots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & w_2/w_3 & \ldots & w_2/w_n \\ w_3/w_1 & w_3/w_2 & w_3/w_3 & \ldots & w_3/w_n \\ . & . & . & & \\ . & . & . & & \\ . & . & . & & \\ w_n/w_1 & w_n/w_2 & w_n/w_3 & \ldots & w_n/w_n \end{bmatrix} * \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ . \\ . \\ . \\ w_n \end{bmatrix} = n * \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ . \\ . \\ . \\ w_n \end{bmatrix}$$

$$\boldsymbol{A} \cdot \boldsymbol{W} = n \cdot \boldsymbol{W}$$

The solution of the above called the principal eigenvector of **A** which is the normalization of any column of **A**. Where,

$$\sum_{i=1}^{n} w_i = 1$$

$\boldsymbol{A}$ → vector comparison matrix

$\boldsymbol{W}$ → $(w_1,w_2,w_3,\ldots,w_n)^{\mathbf{T}}$ vector of relative weights. The right eigenvector of matrix **A**

n → scalar eigenvalue (principal maximum)of matrix **A**

The matrix

$$\boldsymbol{A = a_{ij},\ a_{ij} = w_i/w_j,\ i,j = 1,\ldots,n,}$$

Satisfies the reciprocal property if *a* is twice more preferable than *b*, *b* is twice more preferable than *c*, then *a* is four times more preferable than *c* (*cardinal scale*).

$$a_{ji} = 1/a_{ij}$$

Is *consistent* provided the following condition is satisfied:

$$a_{jk} = a_{ik}/a_{ij},\ i, j, k = 1,\dots,n.$$

4. Aggregate the relative weights of the decision elements to arrive at an overall individual ranking.

In this step, the priorities of the lowest level alternatives relative to the top most objective are determined and displayed, which serves as a ratings of decision alternatives in achieving the objective. The final output from is the relative priorities of the bottom most (in the hierarchy) alternatives relative to the overall objective (top level of hierarchy). The composite relative weight vector of elements at the kth level w.r.t. the first computed by :

$$C[1,k] = \prod_{i=2}^{k} B_i$$

Where:

$C[1,k] \rightarrow$ vector of composite weights of elements at level k w.r.t. element on level 1.

$B_i \rightarrow$ $\mathbf{n_{i-1} \times n_i}$ matrix of vector $\boldsymbol{W}$

5. Aggregate the overall individual rankings for each hierarchon to obtain group ranking.

After having obtained the individual rankings for a particular hierarchon, we can then aggregate these results for all decision makers to obtain the group ranking. The simplest way to do this is to use Borda's positional method. The basic idea is to add the individual ranking matrix for every decision maker. For each individual ranking, we assign one point for lowest ranked, two for the second lowest, three for the third an so forth. The Group Ranking, *Rg*, is obtained by adding all the points assigned for each of the individual rankings and ranking highest, this time, the rank with the most points, second with the next most points and so forth.
Given k individual rankings we choose Borda's coefficients, $r_1, r_2, r_3, \dots, r_k$ such that, $r_1 > r_2 > r_3 > \dots > r_k$,,For each decision maker, $c \in S$ list r_i, Score $B_i(c)$ *with* a total Borda Score, $B(c)$ defined as:

$$B(c) = \sum_{i=1}^{k} B_i(c)$$

The Scale Solution

Considering Saaty's 1 – 9 linear scale we observe that it yields correct results provided that the comparison of pair wise matrices show moderate importance (weak preference). For example, if:

A = 2xB
B = 3xC
Then,
C = 1/6xA

In order to be consistent and is applicable on this scale. Assuming 10 % acceptable inconsistency, then the range of acceptable values occur when:

C= 1/7xA	3.2%
C= 1/5xA	0.4%
C= 1/4xA	2.0%
C= 1/3xA	5.6%

However, if:

A = 3xB
B = 4xC
Then,
C = 1/12xA

We cannot be consistent; unfortunately, this is not applicable, as we exceed the original scale. Considering even:

A = 9xB
B = 9xC
Then,
C = 1/81xA

The scale in this case squares. Here, we seek methods to overcome this constraint. Assuming that decision making lends itself to quantized preferences, then a statistical approach for, say, a decision that comprises of two elements and one member would be analogous to throwing a coin once, whereas the elements represent combinations and the members represent permutations. Therefore, if the number of members were increased it would be the same as if we increased the number of throws. For example, a decision comprising two elements and one member **(e = 2, i = 1):**

e-number of elements = 2
(i.e. a combination of 2 probabilities, e.g. Heads or Tails)

i-number of members = 1
(possible permutations)

Where,

e = {1, 2}

Assuming that the events are:

$$\mathbf{p(1 \cap 2) = p(1) \times p(2)} \text{ i.e. independent}$$

And

$$\mathbf{p(1 \cup 2) = p(1) + p(2)} \text{ i.e. mutually exclusive}$$

For a decision comprising of three elements and one member, it would be analogous to a throw of a dice. As the number of members increase, so would the number of throws. In case that a decision comprises of four elements and one member, this would be analogous to a twenty-four faced dice thrown once; increasing the members, increases the number of throws. Therefore, if we use:

$$\mathbf{{}^{\mathit{i}}p_e = e!^{\mathit{i}}}$$

We end up with a dual parity degenerative quantum scale[1]. This translates to, when a pair of comparison matrixes are in the same preference direction then the resulting reciprocal matrix derives from the multiplication of the previous pairs. For example, if:

A = 9xB
B = 9xC
Then,
C = 1/81xA

When the pair of comparison matrixes is in the opposite preference directions then the resulting reciprocal matrix derives from the addition of the previous pairs. For example, if:

A = 9xB
B = 1/3xC
Then,
C = 6xA

Conclusions

We extended the design, development and implementation of collective user interfaces with multi modal interactions. We provided innovative techniques, methods and mechanisms for evaluating these interfaces and interactions. We obtained empirical data from real life situations coming from both the public and private sector. Most of all, this research was perceived as a methodology for facilitating human contact, building knowledge and skills for improving conditions and quality of work, formalizing international research collaboration for business and overall societal related quality and relevance. Community orientated, it will be an end for cultural enhancement of ubiquitous citizens whom their choices and opinions will provide consistency, sustainability and autonomy to the system itself.

[1] To be published.

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