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Chaotic Differential Evolution Optimization

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Abstract: In this paper, a hybrid differential evolution (DE) algorithm based on chaos is proposed. In this algorithm, Chaos Search gives more perturbations, which provides more opportunities for the algorithm to find the global optimum. Two test functions are employed for experiments. The simulation results show that the proposed algorithm is efficient.

Keywords: Chaos; Differential Evolution Algorithm; Evolutionary Algorithms, Multi-modal functions.

1. Introduction

Classical methods often face great difficulties in solving optimization problems that abound in the real world. In order to overcome the shortcomings of traditional mathematical techniques, nature-inspired soft computing algorithms have been introduced. Several evolutionary or meta-heuristic algorithms have since been developed which combine rules and randomness mimicking natural phenomena. Many researchers have recently studied these meta-heuristic algorithms to solve various optimization problems. However, new heuristic algorithms are needed to solve difficult and complicated real-world problems.

In recent years, the theories and applications of nonlinear dynamics, especially of chaos, have attracted more and more attention in many fields. One is chaos controlling and synchronization. Another field is the potential applications of chaos in various disciplines including optimization (Yang, 2007).

Differential Evolution (DE) is an effective robust optimization algorithm which was proposed by Rainer Storn and Kenneth Price in 1995 (Storn and Price, 1995). It became one of the fastest stochastic algorithms quickly because of the simpler evolutionary operator and fewer control parameters. However, it also has some shortcomings, the slower convergence rate in latter periods, even failing to local extremes. Its search performance depends on balancing the ability of global exploration and local development.

In this paper, an enhanced Differential Evolution algorithm is introduced. This proposed method is based on combining chaos search to the original DE algorithm. Two well known benchmark Multi-modal functions are adopted to validate the proposed method. This paper is structured as following: Section 2 is made for Chaos, section 3 is devoted to Differential Evolution approach, the proposed algorithm is illustrated in section 4, experiments and simulation results are shown in section 5, and finally in section 6 conclusion is presented.

2. Chaos

Chaos is a characteristic of nonlinear systems and it has been extensively studied and applied in many fields. Although it appears to be stochastic, it occurs in a deterministic nonlinear system under deterministic conditions. Chaos has been extended to various optimization areas like in El-Santawy and Ahmed (2012), El-Santawy and Ahmed (2011), Zhang et al. (1999), and Li and Jiang (1998) because it can more easily escape from local minima than other stochastic optimization algorithms. Recently, chaotic sequences have been adopted instead of random sequences and very interesting and somewhat good results have been shown in many applications.

Mathematically, chaos is randomness of a simple deterministic dynamical system and chaotic system may be considered as sources of randomness (Alatas, 2010). A chaotic map is a discrete-time dynamical system

\[ x_{k+1} = f(x_k), \quad 0 < x_k < 1, \quad k = 0,1,2,\ldots \]  

running in the chaotic state. The chaotic sequence \( \{x_k : k = 0,1,2,\ldots\} \) can be used as spread-spectrum sequence and as a random number sequence.

One-dimensional noninvertible maps are the simplest systems with capability of generating
chaotic motion (Ott, 2002). Here, two well-known one-dimensional maps are introduced. Later on, these maps are used in the chaotic searches.

The Logistic map: In 1976, Robert May pointed out that the logistic map led to chaotic dynamics (May, 1976). A logistic map is a polynomial map. It is often cited as an example of how complex behavior can arise from a very simple nonlinear dynamical equation (Ott, 2002). This map is defined by

$$z_{k+1} = \mu z_k (1-z_k)$$  \hspace{1cm} (2)

Obviously, $z_k \in [0,1]$ under the conditions that the initial $z_0 \in [0,1]$, where $k$ is the iteration number and $\mu = 4$.

The Circle map: The circle map is represented by

$$\frac{1}{\pi} \sin(2\pi z) \mod(1) = c + d \cdot z_n \quad \text{mod}(1)$$

where $c = 0.5$, $d = 0.2$, and $z_0 \in [0,1]$ generates chaotic sequence in $[0,1]$ (Zheng, 1994).

3. Differential Evolution Algorithm

Differential evolution (DE) is a population based stochastic search algorithm (Storn and Price, 1995), and has been successfully applied to solve complex problems including linear and nonlinear, Uni-modal and Multi-modal functions. Over the recent years, DE has been successfully applied to different subjects such as reservoir system optimization (Reddy and Kumar, 2007), optimal design of shell and tube heat exchangers (Babu and Munawar, 2007), beef property model optimization problems (Mayer et al., 2005), generation planning problems (Kannan et al., 2003).

The key idea behind DE is a scheme for generating trial parameter vectors. Mutation and crossover are used to generate new vectors (trial vectors), and selection then determines which of the vectors will survive the next generation. A set of $D$ optimization parameters is called an individual, which is represented by a $D$-dimensional parameter vector. A population consists of $NP$ parameter vectors $X_{i,G}$ ($i = 1,2,\ldots, NP$ for each generation $G$). According to Storn and Price, DE’s basic strategy can be described as follows.

3.1. Mutation

For each target vector $X_{i,G}$ ($i = 1,2,\ldots, NP$), a mutant vector $V_{i,G+1}$ is generated according to

$$V_{i,G+1} = X_{i,G} + F \cdot \left( X_{r1,G} - X_{r3,G} \right), \quad r1 \neq r2 \neq r3 \neq i. \hspace{1cm} (4)$$

where $r1$, $r2$, $r3$ belong to $\{1, 2,\ldots, NP\}$ and are randomly chosen integer indexes. Note that indexes have to be different from each other and from the running index. $F$ is called mutation factor between $[0,1]$ which controls the amplification of the differential variation ($X_{r2,G} - X_{r3,G}$).

3.2. Crossover

In order to increase the diversity of the perturbed parameter vectors, crossover is introduced. The target vector is mixed with the mutated vector, using the following scheme, to yield the trial vector $U_{i,G+1} = (u_{1,i,G+1}, u_{2,i,G+1}, \ldots, u_{D,i,G+1})$, that is

$$u_{j,G+1} = \begin{cases} V_{j,G+1} & \text{if rand(j) } \leq CR \text{ or } j = nrb(i) \\ X_{j,G} & \text{otherwise} \end{cases} \hspace{1cm} (5)$$

where rand(j) is the $j$th evaluation of a uniform random number generator between $[0,1]$. $CR$ is the crossover constant between $[0,1]$ which has to be determined by the user. $nrb(i)$ is a randomly chosen index from $1,2,\ldots,D$ which ensures that $U_{i,G+1}$ gets at least one parameter from $V_{i,G+1}$. Otherwise, no new parent vector would be produced and the population would not alter.

3.3. Selection

To decide whether or not it should become a member of the next generation $G + 1$, the trial vector $U_{i,G+1}$ is compared to the target vector $X_{i,G}$. Assume that the objective function is to be minimized, according to the following rule:

$$X_{i,G+1} = \begin{cases} U_{i,G+1} & \text{if } f(U_{i,G+1}) < f(X_{i,G}) \\ X_{i,G} & \text{otherwise} \end{cases} \hspace{1cm} (6)$$

That is, if vector $U_{i,G+1}$ yields a better evaluation function value than $X_{i,G}$, then $X_{i,G+1}$ is set to $U_{i,G+1}$; otherwise, the old value $X_{i,G}$ is retained. As a result, all the individuals of the next generation are as good as or better than their counterparts in the current generation.

4. Chaotic Differential Evolution Algorithm

The new method so-called Chaotic Differential Evolution (CDE) combines chaotic search to DE. Some modifications are done in order to hybridize chaos search DE. The main aim is to have better exploration during search, and so speed up the standalone algorithm. Through the
rest of this section, the modifications done will be illustrated.

In the proposed algorithm, when a random number is needed by the classical DE algorithm, it is generated by iterating one step of the chosen chaotic map that has been started from a random initial condition at the first iteration. Also, both constants $F$ and $CR$ are updated chaotically as shown follows:

$$F_{G+1} = f(F_G), \quad F_{\min} \leq F_G \leq F_{\max} \quad (7)$$
$$CR_{G+1} = f(CR_G), \quad CR_{\min} \leq CR_G \leq CR_{\max}, \quad G = 1, 2, \ldots \quad (8)$$

where the values of $F_{\min}$, $F_{\max}$, $CR_{\min}$, and $CR_{\max}$ are user defined.

5. Experiments and Results

Well-defined benchmark functions which are based on mathematical functions can be used as objective functions to measure and test the performance of optimization methods. From the standard set of benchmark problems available in the literature, two important functions which are Multi-modal (containing many local optima, but only one global optimum) are considered to test the efficiency of the proposed methods.

The two selected benchmark functions are Griewangk and Rastrigin functions defined in Eq.(9) and Eq.(10), respectively. Table 1 shows the main properties of the selected benchmark functions used in the experiments, where $lb$ indicates lower bound, $ub$ indicates upper bound, and $opt$ indicates optimal point.

$$f_1(x) = \sum_{i=1}^{N} \left( \frac{x_i^2}{4000} - \prod_{i=1}^{N} \cos \left( \frac{x_i}{\sqrt{i}} \right) \right) + 1 \quad (9)$$

$$f_2(x) = 10 \times N + \sum_{i=1}^{N} \left( x_i^2 - 10 \cdot \cos (2\pi x_i) \right) \quad (10)$$

Table 1: Selected benchmark functions

<table>
<thead>
<tr>
<th>No.</th>
<th>Function</th>
<th>$lb$</th>
<th>$ub$</th>
<th>$opt$</th>
<th>property</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Griewangk</td>
<td>-50</td>
<td>50</td>
<td>0</td>
<td>Multi-modal</td>
</tr>
<tr>
<td>2</td>
<td>Rastrigin</td>
<td>-5.12</td>
<td>5.12</td>
<td>0</td>
<td>Multi-modal</td>
</tr>
</tbody>
</table>

In this experiment, The algorithm was run 100 times for each function to catch its stochastic properties. The goal is not to find the global optimum values but to find out the potential of the proposed algorithm. Algorithm success rate defined in Eq.(11) has been used for comparison of the results obtained from both functions.

$$S = 100 \frac{N_{\text{successful}}}{N_{\text{all}}} |Q_{\text{level}}| \quad (11)$$

where $N_{\text{successful}}$ is the number of trials, which found the solution on the $Q_{\text{level}}$ in the allowable maximum iteration. $N_{\text{all}}$ is the number of all trials. $Q_{\text{level}}$ is the end condition to stop the algorithm, when it converges into $Q_{\text{level}}$ tolerance (Alatas, 2010).

The initial parameters are set at $NP = 50$, $G = 500$, $CR_{\min} = 0.7$, $CR_{\max} = 0.9$, $F_{\min} = 0.3$, and $F_{\max} = 0.6$. The logistic map is used to update $F$ and $CR$ values, while the circle map is employed to generate chaotic generations used during search. Table 2 depicts the success rates of the proposed algorithm for both functions for $(N = 2)$.

<table>
<thead>
<tr>
<th>$Q_{\text{level}}$</th>
<th>Griewangk</th>
<th>Rastrigin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.e-5</td>
<td>56</td>
<td>45</td>
</tr>
<tr>
<td>1.e-6</td>
<td>42</td>
<td>23</td>
</tr>
</tbody>
</table>

6. Conclusion

In this paper, we try to develop an enhanced DE version for global optimization by embedding chaos search. The proposed technique employs chaos in an efficient manner for better search. Results of the two experiments show that the proposed technique is promising and efficient in optimizing Multi-modal functions.

References


ENGAGING CONSUMERS THROUGH COMPANY SOCIAL MEDIA WEBSITES

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ABSTRACT
The purpose of this research is to investigate how companies can effectively engage with consumers through their social media websites. The reasons why companies create social media websites and why consumers join the websites are identified. In addition, the relationship between consumer demographics and the degree of participation in company social media websites are examined. The study adopted a quantitative approach involving hypotheses testing. Primary data were obtained via an online questionnaire. The results suggest no significant correlation between the demographics and the degree of consumers’ involvement or activity in company social media websites. The reasons for creating the websites and for consumers joining sites are presented. Based on the findings, insights are developed for businesses to engage more effectively with consumers through the company social media websites.

Keywords: Consumers, Company, Social media, Websites, Marketing

INTRODUCTION
‘Social media is no longer a trend for marketers: it is a reality’ (Williamson, 2010). It has become of increasing importance for brands to have a strong presence within social media. Social media websites allow organisations to engage in conversations with consumers through unique interactive features. These features such as feedback mechanisms, news feeds and quizzes can enhance promotional and marketing activities by engaging consumers and encouraging their repeat use of social media websites (Hyojung et al. 2011). Consumers are increasingly turning to social media such as Facebook to see what others are saying about the organisation rather than using search engines to find the company website and read what the company has written about itself (Dougherty 2011).

Despite the growth in social media, managers are still unclear as to how it can be used to benefit their organisations (Ang 2011). Social media marketing has become of increasing importance to businesses as a marketing platform. It can be used to positively influence businesses and yield lucrative results. The findings of our study are relevant to organisations especially in enabling them to make the most out of the tools that social media has to offer to engage with consumers and thus benefit their business.

Shneiderman et al. (2011) claim that social media research can have a profound impact on every discipline. The field of social media is constantly changing and developing and thereby providing wide opportunities for further research. Stankov et al. (2010) examine consumer content on company Facebook pages. The factors that drive consumers to contribute in the social pages are yet to be thoroughly investigated.

Despite the fact that many businesses have created their own Facebook pages, most of them get little traffic and fail to engage consumers in genuine dialogue (SĂVulescu 2011). Genuine dialogue with consumers can help to increase a company’s trustworthiness and goodwill and in turn, improve credibility. It also creates the opportunity for companies to receive feedback about the products and services they provide and potentially gain insights into how they can improve their product offering. Some commentators see social media as having the potential means for economic revitalisation through business innovation (ibid). This will provide added value and insights to organisations as to how they can engage with consumers through their social media page.

The aim of this research is to investigate how companies can effectively engage with consumers through their social media page. We use company Facebook page as a representative of company social media page.
The reasons why companies use or create social media pages are identified. The factors that motivate consumers to join and engage in company social media pages are also identified. The study further examines the relationship between demographic characteristics of consumers that join a company social media page and the degree of their participation in the website.

In terms of the structure of the paper, the next section describes the growth of social media marketing and this is followed by a discussion on the use of Facebook in marketing. An overview of studies that have tended to link social media with marketing is then presented followed by a description of the methodology that was adopted in this study. The results of the study are then presented and discussed. Lastly, the conclusions of the paper and the implications of the findings are presented.

THE GROWTH OF SOCIAL MEDIA MARKETING

Social media is a collection of Internet-based applications that build on the ideological and technological foundations of Web 2.0 and allow the creation and exchange of user-generated content (Andreas and Michael 2010). Web 2.0 is a platform whereby content and applications are continuously modified by all users in a participatory and collaborative fashion (ibid). Web 2.0 sites allow users to interact with each other in social media dialogue as opposed to websites where users are limited to the passive viewing of content that was created for them. Web 2.0 is not about centralized control and static web pages, rather, it sees users as co-developers and co-creators (Ward 2011).

The development of social media has substantially changed the way organizations, communities, and individuals communicate. Although primarily social media allows individuals to communicate with each other, it has also made it much easier for companies to develop relations with consumers that transcend age, race, culture and geographical differences (Stankov et al. 2010).

Social media marketing is growing rapidly and has gained considerable attention in global general-interest media (Colliander and Dahlén 2011). In today’s online landscape, consumers are increasingly turning to virtual communities to express opinions and exchange information, making these communities an idea tool for marketers to build relationships with consumers (Shu-Chuan 2011).

Recent trends show that consumers are shifting from seeking information from company websites to reading consumer-generated content on social media websites. Previous studies have found that consumers tend to trust user-generated messages, such as peer recommendations or consumer reviews on social media more than messages from traditional mass media or what organization’s say about themselves (Chung and Austria 2010).

The expansion of social media has influenced the development of a new type of consumer who is more interactive and engages in communication with businesses and even creates content for marketers to use (SâVulescu 2011).

Despite the growth in social media, managers are still unclear how it can be best used to benefit their organizations. Managing a community of online users is quite different from the norm. Ang (2011) developed the 4Cs model of community relationship management (CoRM) which suggests that an organization should connect, converse, create and collaborate with the online community. This theory provides an important framework for businesses to consider when managing their social media platforms.

The use of social media requires marketers to take a step back from traditional campaign thinking and focus more on relationship building (Colliander and Dahlén 2011). It is imperative that social media marketing is incorporated into the organisation’s marketing strategy. It is also important that organisations have a presence across a range of social media platforms.

THE USE OF FACEBOOK IN MARKETING

Organisations can create their own company pages on Facebook which users or consumers can ‘like.’ Companies must conform to the Facebook page terms, promotions guidelines and advertising guidelines set out by Facebook. These are continually revised as the website develops. If an individual joins a company’s page on Facebook it ‘allows them to receive messages about forthcoming events, special offers, and other useful information’ (Minerof 2010).
Once a consumer ‘likes’ a company page on Facebook, their brand perceptions and purchasing decisions could be influenced by mobilising information they receive from other consumers. Therefore, brand managers should focus their efforts more on encouraging consumers who already have favourable attitudes toward advertising in social media and in general to share viral advertising with their contacts, because these consumers are more likely to engage actively in viral advertising through group applications (Shu-Chuan 2011).

This study focuses specifically on companies’ Facebook pages. Company Facebook pages have become an essential aspect of a brand’s presence online. They can provide marketers interactive communication environments with opportunities to enhance existing relationships with consumers (Chung and Austria 2010). In engaging consumers via social media pages, organisations should aim to avoid ‘brandalism.’ This is a portmanteau that refers to brands exhibiting similar behaviour to vandals (SAVulescu 2011). The concept explains that excessive activity on a company Facebook page by the organisation could be regarded as spam.

SOCIAL MEDIA AND MARKETING: OVERVIEW OF PAST STUDIES

There are a number of studies that have been done around in the field of social media marketing. Details about them including their aim, methods used, key findings and limitations are shown in Table 1.
<table>
<thead>
<tr>
<th>Author</th>
<th>Study</th>
<th>Research Aim</th>
<th>Research Method</th>
<th>Key Findings</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-Jenaibi (2011)</td>
<td>The Use of Social Media in the United Arab Emirates – An Initial Study</td>
<td>Which kind of social media are used by people in the United Arab Emirates (UAE)?</td>
<td>Combined qualitative and quantitative methods. The quantitative component consisted of the use of 200 surveys. Qualitative component consisted of the use of a focus group session involving nine individuals</td>
<td>The most popular types of social media in UAE are Facebook, video sharing sites such as YouTube, and micro-blogging sites like Twitter. In the UAE, social media has earned a place in the society. It serves as a vital source of news and information.</td>
<td>Region specific-United Arab Emirates Opinions of social media</td>
</tr>
<tr>
<td>Ang (2010)</td>
<td>Community relationship management and social media</td>
<td>How Facebook can be used to benefit organisations using a community relationship management approach</td>
<td>A comprehensive search of literature to develop theory</td>
<td>Examples of how organisations can benefit from the use of Social Media. It also criticises why the term ‘social CRM’ is misleading and instead suggests the term CoRM be used because it more accurately reflects the notion of people interacting with each other in a community. advantage of these</td>
<td>No primary research Not specific to Facebook</td>
</tr>
<tr>
<td>Baird and Parasnis (2011)</td>
<td>From social media to social customer relationship management</td>
<td>What triggers a customer to seek out a company or brand via social media? What would make a customer reluctant to interact and engage?</td>
<td>Survey of more than 1,000 consumers worldwide. Survey 350 executives to tell us why they think customers are interacting with their organisations</td>
<td>Companies assume consumers are seeking them out to feel connected to their brand. Consumers are far more interested in obtaining tangible value. Businesses may be confusing their own desire for customer intimacy with consumers’ motivations for engaging.</td>
<td>Research methods not feasible for our study</td>
</tr>
<tr>
<td>Dubose (2011)</td>
<td>The Social Media Revolution</td>
<td>To investigate popular social media sites and their effect on radiologic technology education and business practices.</td>
<td>A comprehensive search of literature using the research database EBSCOhost was performed to examine social media and its applications in education, health care, and business</td>
<td>Social media use is on the rise, affecting all aspects of mainstream society. Leaders in the radiologic sciences should be familiar with social media and aware of its risks.</td>
<td>This literature review covered a mere fraction of the available social media platforms available. Further research is needed to determine the methods and frequency of social media use, as well as reasons it is not being incorporated.</td>
</tr>
<tr>
<td>Hyleggard (2011)</td>
<td>An exploratory study of college</td>
<td>This study examined the factors that predict</td>
<td>Survey approach was used to collect data from a sample of</td>
<td>Consumers may view the use of Facebook and the act of fanning as a means by which to not</td>
<td>Based upon analyses of data collected from</td>
</tr>
<tr>
<td>Study Title</td>
<td>Research Question</td>
<td>Methodological Details</td>
<td>Region/Industry/Speciality</td>
<td></td>
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<tr>
<td>----------------------------------------------------------------------------</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>students fanning behaviour on Facebook</td>
<td>college students' motives to use Facebook as well as to fan consumer goods companies on Facebook</td>
<td>150 college student Facebook users. Focus group with 11 college students who had Facebook experience was conducted to explore motives for using Facebook and for fanning consumer goods companies. Questionnaire contained demographic questions.</td>
<td>college students, and thus, cannot be generalized to the broader consumer population USA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hyojung (2011)</td>
<td>Health organisations use of Facebook for health advertising and promotion</td>
<td>Examine how health organisations use interactive features on Facebook for advertising purposes</td>
<td>Region- USA Industry specific Content analysis Constant development of technology-soon out of date. Does not draw on causal connections</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Junco (2012)</td>
<td>The relationship between frequency of Facebook use, participation in Facebook activities, and student engagement</td>
<td>Is there a relationship between frequency of Facebook use and student engagement? Is there a relationship between frequency of Facebook activities and student engagement?</td>
<td>Cross-sectional and correlational in nature, Doesn’t determine the causal mechanisms between Facebook use and engagement. Students only Region- USA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nga Ling, Chan (2011)</td>
<td>Investigation of Social Media Marketing: How Does the Hotel Industry in Hong Kong Perform in Marketing on Social Media Websites?</td>
<td>Investigate the extent to which social media marketing is being utilized in the Hong Kong hotel industry</td>
<td>Only looks at one industry Specific to Hong Kong Firstly, only 67 hotels were selected as the sample. In this respect, the results may not be representative of the entire hotel industry in Hong Kong. This is a cross-sectional study which can only</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Shu-Chuan Chu (2011)</strong></td>
<td><strong>Viral advertising in social media: participation in Facebook groups and responses among college age users.</strong></td>
<td><strong>This study investigates how Facebook group members and non-members differ on selected psychological variables and their subsequent forwarding behaviour in viral advertising settings. An online survey served to gather the data to answer the research questions.</strong></td>
<td><strong>Online survey was conducted to collect data to answer research question. E-mail invitations sent to students with FB accounts. Survey duration 15 minutes 2 week data collection period 359 participants</strong></td>
<td><strong>It is imperative for advertisers to gain a more comprehensive understanding of consumers' characteristics. To make Facebook groups more cohesive and powerful, advertisers should send out more personalized and customized messages to members' inboxes to announce upcoming promotions or provide incentives to encourage them to pass on messages. Brand managers' advertising efforts also should focus more on encouraging Facebook group members who already have favourable attitudes toward advertising in social media and in general to share viral advertising with their contacts, because these consumers are more likely to engage actively in viral advertising through group applications.</strong></td>
<td><strong>The findings cannot necessarily be generalized to the entire Facebook user population. This exploratory study only focuses on self-disclosure and attitude-related variables in relation to participation in Facebook groups.</strong></td>
</tr>
<tr>
<td><strong>Stankov (2010)</strong></td>
<td><strong>The extent of use of basic Facebook user-generated content by the national tourism organizations in Europe</strong></td>
<td><strong>Identify how many NTOs in Europe have an official presence on Facebook and to determine the extent of the use of basic Facebook user-generated content (Pages and Groups).</strong></td>
<td><strong>For the research, the researchers used data on all 39 NTOs that are members of the European Travel Commission (ETC). Data collection and analysis was conducted in June and July 2009.</strong></td>
<td><strong>Insignificant Facebook presence, NTOs do not use all the advantages that are offered by user-generated content. All trends show that Facebook community will continue to grow. NTOs should consider using Facebook in the next couple of years, as an effective marketing strategy.</strong></td>
<td><strong>Cross sectional Specific industry-Tourism Content analysis Out-dated due to Facebook developments</strong></td>
</tr>
</tbody>
</table>
Despite the growing popularity of social media or Facebook Company pages, Table 1 shows not significant studies that have addressed fully how consumers could be engaged via the social media websites. Specifically, studies on social media in relation to consumer demographics are very limited, hence revealing scope for more research. A key focus of our study is in analysis of the correlation between Facebook activity and consumer demographics.

METHODS

Data types and sources
Both primary and secondary data were used in this study. Secondary sources were relevant in addressing the study’s first objective of identifying the reasons why companies create their social media pages. This was achieved through a thorough review of literature. Primary data were relevant in addressing the other objectives of this study including why consumers join company social media pages and the analysis of the relationship between consumer demographics and degree of participation in the websites.

Sampling and data collection
A non-probability sampling technique was adopted in this research. In non-probability sampling, the researcher systematically and purposefully selects units from the population (Maylor and Blackmon 2005). Specifically, snowball sampling technique was employed. This is helpful in identifying appropriate participants and the costs are relatively low. Maylor and Blackmon (2005) advise researchers to get as large a sample as possible within time and cost constraints. Considering such factors, 100 respondents were included in this study. This is not much different from 150 respondents that participated in Hyllegard et al.’s (2011) study on ‘fanning’ behaviour in relation to social media.

We adopted a survey strategy and this is especially useful in capturing facts, opinions, behaviours and attitudes (Maylor and Blackmon 2005). A questionnaire was prepared to guide the data collection. In a survey, each respondent is asked to respond to the same set of questions and this provides an efficient way of collecting responses from a large sample prior to quantitative analysis (Saunders et al. 2009). The questionnaire was self-administered via a survey monkey. Surveymonkey is a private company that enables users to create their own web-survey. Other studies have used Surveymonkey as the host for their questionnaire, for instance Junco (2012) used this in a study exploring the relationship between frequency of Facebook use and engagement though this was limited to student population. This survey software is usually preferred as it is free and simple to use. Survey invitations in our study were distributed via the University e-mail system, Facebook and personal e-mails. In other words, respondents were sent a link to the online questionnaire via a range of communication channels and completed the survey electronically via the internet. This approach of collecting data has several advantages including; cheap and quick to administer, respondents can fill out the questionnaire at their own convenience, less likely to exhibit social desirability bias, and no interviewer variability.

The structure of the questionnaire was that the first half asked respondents’ background questions. This was relevant in eliciting demographic and socio-economic information of the consumers. The other half asked respondents attitudinal questions regarding their activities and interests surrounding company Facebook pages (Remenyi 1998).

All questions had clear instructions about how to respond, for instance whether the question required single or multiple responses (Bryman and Bell 2007). The key considerations in designing the questionnaire were; clarity, simplicity, brevity and neutrality (Maylor and Blackmon 2005). As stated earlier, the data used in the study were collected through a survey. This was carried out during the month of January 2012. This period nearly corresponds that of Shu-Chuan (2011) who assumed less than month in conducting an online survey about Facebook groups.

Data management and analysis
Firstly, an inspection of the questionnaire responses for conflicting information was conducted (Ghauri and Gronhaug 2005). A data file in SPSS was then prepared so that it was ready to enter the survey data. This involved defining variables,
assigning appropriate numeric codes to alphanumeric data and coding missing data (Coakes and Steed 2001). The data were then input from Survey Monkey into the analysis software and checked for errors. This was done by checking if there were any illegitimate codes, illogical relationships between individual respondent’s answers, and that rules were followed correctly in filter questions (Saunders et al. 2009). This paved way for statistical analysis. SPSS is relatively straightforward to use (Bryman and Bell 2007) and it is widely used in the sort of analysis that characterise this study.

Frequency counts from the survey were presented using bar charts and pie charts. Pie charts were used to show percentages among categories of nominal variables by displaying the categories as segments of a circle. Bar charts were used to display nominal data from multiple response questions (Ghauri and Grønhaug 2005). Frequency counts are a useful way of presenting information in a summary form so that conclusions can start to be drawn (Maylor and Blackmon 2005).

Descriptive statistical analysis was run to calculate the mean and standard deviations especially in regards to the profile of the consumers. Spearman’s correlation analysis was done to establish the relationship between relevant variables. This analysis assisted in testing the hypotheses. Hypotheses were tested to determine whether assumed relationships and co-variations between variables hold ‘true’ (Ghauri and Grønhaug 2005). The analysis was then interpreted in order to understand the meaning and implications.

For the purpose of the analysis, for the gender variable, females were coded as zero while a male assumed a value of one. The education level had seven categories, namely: Degree or higher degree; Higher educational qualification below degree; A levels or Higher; ONC/BTEC; O level/GCSE (A-C) or CSE (1) or standard grade (1-3); GCSE (D-G) or CSE (2-5) or Standard grade (4-6); No formal qualifications. For analysis, the highest level, degree or higher degree, assumed a value of seven and decreased in the listed order, with ‘no formal qualification’ coded as one.

In classification along social grades, Grade A represents Higher managerial/professional/administrative, B Intermediate managerial/professional/administrative, C1 Supervisory or clerical/junior managerial/professional/administrative, C2 Skilled manual worker, D Semi or unskilled manual work, E Casual or lowest grade workers, pensioners and others who depend on the welfare state for their income. In the analysis, current working status was coded from 1-6 where one represented the lowest social grade (E).

RESULTS AND DISCUSSION

Descriptive analysis

Table 2 presents the descriptive statistics related to the demographics of this research’s participants.

<table>
<thead>
<tr>
<th>Gender of Respondent</th>
<th>Age of Respondent</th>
<th>Highest Level of Education Completed</th>
<th>Current Working Status of Respondent</th>
</tr>
</thead>
<tbody>
<tr>
<td>N Valid</td>
<td>98</td>
<td>98</td>
<td>98</td>
</tr>
<tr>
<td>Missing</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mean</td>
<td>0.29</td>
<td>1.26</td>
<td>2.60</td>
</tr>
<tr>
<td>Median</td>
<td>0.00</td>
<td>1.00</td>
<td>3.00</td>
</tr>
<tr>
<td>Mode</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>0.454</td>
<td>0.597</td>
<td>1.292</td>
</tr>
<tr>
<td>Variance</td>
<td>0.206</td>
<td>0.357</td>
<td>1.644</td>
</tr>
<tr>
<td>Range</td>
<td>1</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Minimum</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Maximum</td>
<td>1</td>
<td>3</td>
<td>7</td>
</tr>
</tbody>
</table>
The mean scores for the demographics of the respondents were: gender- female; Age-25 or under; highest level of education completed - A-levels or Highers; current working status - semi or unskilled manual work. Mode and median scores revealed that the most common and middle value was casual or lowest grade workers, pensioners, students and others who depend on the welfare state for their income.

Standard deviation measures how spread out the results are. Education and social grade have a high standard deviation which signifies that the consumers were not clustered around the average. Gender of respondents has a low standard deviation meaning that most of the data points are centered around the average.

There were a larger proportion of females (72%) that completed the survey than males (28%). This disparity is not uncommon. Many surveys have substantially more female than male respondents (often 60/40) although there are often more males in the population (Population Research Institute 2008).

The majority of respondents (81%) were of age 25 or younger. Statistics show that in 2011, around half of Facebook users fell into this age bracket (Inside Facebook 2011). A small percentage of respondents fell into the 26-40 and 41-55 age brackets. No respondents in this survey were 56 or older.

The most respondents were of A-levels or Highers level of education (45%). 25% had degree or higher postgraduate qualifications while 17% had qualifications higher than A levels or Highers and below degree level. A large proportion of respondents (58%) were of social grade E. This is predominantly because they are still in education. Twenty-one percent of respondents were in social grade C1. There were no respondents that were in the highest social grade.

Of all the respondents that were contacted, 84% of them had ‘liked’ a company Facebook page. This large proportion provides a larger base size of data to identify the demographic characteristics of consumers that ‘like’ company Facebook pages and to answer the objectives about Facebook activity and engagement.

**Reasons why companies use Facebook pages**

This study identified by a thorough review of literature five key reasons why companies use Facebook pages. These reasons were: A) Increase trustworthiness and goodwill - Two-way communication helps to build good customer relations and increase credibility. B) Lead generation - Facebook allows organisations to reach out to targeted consumers to try generate interest into products or services that they provide. C) Ability to engage with consumers - Company Facebook pages allow businesses and consumers the flexibility to engage with each other with no geographical or time boundaries. D) Access to customer’s feedback - Finding out customers opinions can help the organisations improve the products/services it provides. By knowing target consumers preferences, it is easier to enhance products in line with consumer demand and plan marketing campaigns more effectively. E) Cheap form of advertising - Businesses can advertise and market their products and services through a virtually free channel. It is a cheap way to announce new products or services. Social media also makes it easier to spread information virally.

**Factors that motivate consumers to join and engage in company Facebook pages**

Table 3 shows the reasons that motivate consumers to join or like a company Facebook page. Respondents were allowed to select as many factors as were applicable.
The respondents that had joined a company Facebook page were asked to state why they ‘like’ the page. Out of the 100 respondents that participated in the research, 80 answered this question while 20 skipped it. The main reason respondents ‘liked’ a company page was because they literally ‘liked’ the product or service the company provides. Secondary to this, 58% of respondents ‘like’ pages to receive special offers on products or services. This is consistent with findings by Baird and Parasnis (2011) that shows that in seeking out companies via social media, consumers are far more interested in obtaining tangible value.

Large proportions of the consumers also like the company Facebook pages to receive the latest information and to enter competitions. A greater proportion of respondents ‘liked’ a page to read feedback that is given by other consumers (10%) than give feedback themselves (5%). 10% of respondents were influence by their piers to ‘like a company page’. In addition to the reasons that are identified here, it is useful to note that some consumers may participate in the company social media pages with the motive of making a statement about their self emage (Hyleggard 2011). The study finds that consumers view the act of ‘fanning’ Facebook pages as a way to connect with organisations and to make identity announcements to others about themselves.

On asking respondents that had 'liked' company Facebook page whether they ever posted a comment on their wall or photos, only 25% indicate to have done this while a massive 75% had not. This concurs with past studies that have found that the majority of Facebook users do not actively comment on company Facebook walls (Hyojung et al. 2011).

**Demographic characteristics of consumers that ‘like’ company Facebook pages**

A typical respondent was female, 25 years old or under, completed A-levels or Highers, social grade E. 90% of respondents who ‘liked’ a company Facebook page had completed a-levels or some form of further education. Seventy percent of respondents were in social grade E.

---

**Table 3: Reasons for liking a company Facebook page**

<table>
<thead>
<tr>
<th>Reason</th>
<th>%</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discounts and special offers on products or services</td>
<td>58%</td>
<td>46</td>
</tr>
<tr>
<td>Competitions</td>
<td>34%</td>
<td>27</td>
</tr>
<tr>
<td>Curiosity</td>
<td>19%</td>
<td>15</td>
</tr>
<tr>
<td>like the product/service</td>
<td>60%</td>
<td>48</td>
</tr>
<tr>
<td>latest information</td>
<td>39%</td>
<td>31</td>
</tr>
<tr>
<td>give consumer feedback</td>
<td>5%</td>
<td>4</td>
</tr>
<tr>
<td>read other consumer feedback</td>
<td>10%</td>
<td>8</td>
</tr>
<tr>
<td>Recommended by a friend</td>
<td>10%</td>
<td>8</td>
</tr>
<tr>
<td>Work for the company</td>
<td>5%</td>
<td>4</td>
</tr>
<tr>
<td>Other (please specify)</td>
<td>10%</td>
<td>8</td>
</tr>
</tbody>
</table>
Relationship between consumer demographics and Facebook activity

Table 4 shows that majority of the females visited company Facebook pages after more than a month's period. Most males visited only on the occasion they liked the page. Surprisingly, most consumers that had joined company Facebook pages (32%) and aged 25 or under visited the website after a period of more than a month had elapsed, a higher proportion compared to 25% which represent those of the same age that visited the websites daily. Older people aged 41-55 tended to visit the websites once a month.
The consumers who had completed O-levels or GCSEs (grades A-C) were the most frequent visitors to the company Facebook pages. Most consumers did not visit the websites in a month or they only did so on the occasion they liked the page. A small proportion of respondents with a higher educational qualification, though below degree level, visited more regularly either daily or once a week.

There were no distinct patterns between social grade and frequency of visiting the company social pages. The consumers who were classified as social grade E had dispersed results but the majority of them visited the websites after more than a month's time.

**Relationship between consumer demographics and Facebook activity**

A Spearman correlation analysis was conducted to identify and test statistically the relationship between consumer demographics and their degree of participation in the company Facebook pages. Table 4 shows the estimated correlation coefficients.

### Table 4: Frequencies related to demographics and Facebook activity

<table>
<thead>
<tr>
<th>How often respondents visit company pages</th>
<th>Daily</th>
<th>Once a week</th>
<th>Once a fortnight</th>
<th>Once a month</th>
<th>Visited after</th>
<th>more than a month</th>
<th>Other</th>
<th>No response</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender of Respondent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>14</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>2</td>
<td>13</td>
<td>2</td>
<td>70</td>
</tr>
<tr>
<td>Male</td>
<td>22</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>8</td>
<td>1</td>
<td>6</td>
<td>25</td>
</tr>
<tr>
<td>Total</td>
<td>36</td>
<td>1</td>
<td>5</td>
<td>7</td>
<td>14</td>
<td>2</td>
<td>13</td>
<td>8</td>
<td>95</td>
</tr>
<tr>
<td>Age of Respondent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 or under</td>
<td>20</td>
<td>0</td>
<td>3</td>
<td>7</td>
<td>8</td>
<td>22</td>
<td>1</td>
<td>1</td>
<td>81</td>
</tr>
<tr>
<td>26-40</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>6</td>
<td>8</td>
<td>0</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>41-55</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>1</td>
<td>5</td>
<td>7</td>
<td>16</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>98</td>
</tr>
<tr>
<td>Highest Level of Education Completed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Degree or Higher Degree</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td>2</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>Higher educational qualification below degree</td>
<td>12</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>6</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>A levels or Higher</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ONC/ITEC</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Degree or Higher Degree</td>
<td>13</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>14</td>
<td>1</td>
<td>9</td>
<td>45</td>
</tr>
<tr>
<td>Higher educational qualification below degree</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Degree or Higher Degree</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>1</td>
<td>5</td>
<td>7</td>
<td>16</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>98</td>
</tr>
<tr>
<td>Social class</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Casual or low grade workers, pensioners and others who depend on the welfare state for their income</td>
<td>16</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>22</td>
<td>2</td>
<td>4</td>
<td>11</td>
<td>68</td>
</tr>
<tr>
<td>Semi or unskilled manual worker</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Skilled manual worker</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Registered professional administrators</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>1</td>
<td>5</td>
<td>7</td>
<td>16</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>98</td>
</tr>
</tbody>
</table>

The consumers who had completed O-levels or GCSEs (grades A-C) were the most frequent visitors to the company Facebook pages. Most consumers did not visit the websites in a month or they only did so on the occasion they liked the page. A small proportion of respondents with a higher educational qualification, though below degree level, visited more regularly either daily or once a week.

There were no distinct patterns between social grade and frequency of visiting the company social pages. The consumers who were classified as social grade E had dispersed results but the majority of them visited the websites after more than a month's time.

**Relationship between consumer demographics and Facebook activity**

A Spearman correlation analysis was conducted to identify and test statistically the relationship between consumer demographics and their degree of participation in the company Facebook pages. Table 4 shows the estimated correlation coefficients.
In conclusion, the findings suggest no significant relationships between consumer demographics and Facebook activity. Correlation analysis showed that there was no statistically significant relationship between the reason for 'liking' a company page and the frequency of visits to the company page.

Figure 2: Proportion of respondents visiting company Facebook page at different frequencies
The study enquired about the frequency of visits to company Facebook pages once the respondent has ‘liked’ the page. Visits to the company page are mostly infrequent with 40% of respondents visiting after more than a month’s period has elapsed. 28% of respondents only visit the company page on the occasion that they ‘like’ it. Only 1% of the respondents that like a company Facebook page visited it daily. Some respondents stated that in some instances they ‘unliked’ pages that they had previously ‘liked’.

The consumers who visited most frequently, daily, did so to obtain discounts or enter competitions. Weekly visitors to company pages mainly did so to give feedback on products or services. Consumers were less frequent in visiting company pages when they ‘liked’ it out of curiosity. Respondents whose reason for ‘liking’ was because the page was recommended by a friend were least likely to visit the page again after the occasion they ‘liked’ it.

CONCLUSIONS

This study set forth to identify reasons for companies to use Facebook pages, factors that motivate consumers to join and engage in company Facebook pages, demographic characteristics of the consumers and to examine the relationship between Facebook activity and consumer demographics.

The reasons why companies use Facebook pages were found to be: increase trustworthiness and goodwill, lead generation, engage with consumers, access customer’s feedback, and that this is a cheap form of advertising.

Primary data obtained from the online survey showed that the main factors that motivate consumers to join a company Facebook page were because they liked the company, to find out more information about the company and to receive discounts and special offers.

The findings suggest that a ‘typical’ respondent who ‘liked’ a company Facebook page was a female, 25 or under, completed A-levels or Highers, social grade E and white British. The results shows that that males tended to visit only on the occasion they ‘liked’ the page whereas females visited more frequently. Older respondents visited more frequently than younger respondents. Respondents who had completed O-levels or GCSEs (grades A-C) were the most frequent visitors and there was no distinct relationship between social grade and frequency of visits.
The results of this study generally found that there was no relationship between consumer demographics and Facebook activity or motivations for liking company pages. In other words, there was no statistical significance between consumer demographics and: ‘liking’ of Facebook pages; frequency of visits to company Facebook pages; and activity (posting on the wall or on photos) on company Facebook pages. Also, there was no statistical significance between the reason for ’liking’ a company page and the frequency of visits to the company page.

**IMPLICATIONS**

**BIOGRAPHY**

All the three authors of this paper are affiliated to Bournemouth University in the UK. Hannah Leach is a final year Business Studies Student at the University. Lilian Komo graduated recently with MBA Degree from the University. Isaac Ngugi (PhD) is a Lecturer in Marketing, in the Business School, Bournemouth University.

**References**


For organisations to improve their engagement with consumers through their social media pages, it would be useful for them to: provide clear information about the product or service that they provide - consumer’s main reason for ‘liking’ the page is to gain information; give discounts and/or special offers on products or services to reward consumers as this can increase loyalty; hold competitions in order to increase traffic on the social media page; carefully read and respond to consumer feedback as potential customers often consider other consumer opinions when making a purchasing decisions.


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Chaotic Harmony Search Optimizer for Solving Numerical Integration

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Abstract: In this paper, a new method is developed based on Harmony Search algorithm combined with Chaos theory to solve numerical integration. The simulation results show that the proposed algorithm is efficient and precise. The proposed algorithm produces better segmentation points and adaptation which is reflected in better accuracy. Several numerical simulation results show the superiority of the proposed algorithm over traditional methods.

Keywords: Chaos; Harmony Search algorithm; Numerical integration; Optimization.

1. Introduction
Numerical integration plays a very important and critical role in various research areas. A formula for the integrand may be known, but it may be difficult or impossible to find an anti-derivative which is an elementary function. It may be possible to find an anti-derivative symbolically, but it may be easier to compute a numerical approximation than to compute the anti-derivative. There are some traditional methods such as Newton method, Gauss method, Romberg method, and Simpson’s method (Mi, 1991), but they have many limitations like complexity in calculations, low precision, and their convergence is not guaranteed for higher order (Qu, 2010).

The Harmony Search (HS) algorithm originally came from the analogy between music improvisation and optimization process (Geem, 2001). This algorithm has been successfully applied to various discrete optimization problems such as traveling salesperson problem (Geem, 2001), tour routing (Geem, 2005), music composition (Geem, 2007), and water network design (Geem, 2006). A new method is developed based on Harmony Search algorithm combined with Chaos theory to solve numerical integration. The main idea behind this new method is to make adaptive optimization of the segmentations which are represented by harmony vectors generated randomly in the integral interval.

This paper is structured as following: section 2 is made for harmony search approach, section 3 is devoted to Chaos, the proposed algorithm is illustrated in section 4, experiments and simulation results are shown in section 5, and finally in section 6 conclusion is presented.

2. Harmony Search Algorithm
The HS algorithm was originally developed by Geem et al. in 2001, and is based on natural musical performance processes that occur when a musician searches for a better state of harmony, such as during jazz improvisation. Jazz improvisation seeks to find musically pleasing harmony (a perfect state) as determined by an aesthetic standard, just as the optimization process seeks to find a global solution (a perfect state) as determined by an objective function. The pitch of each musical instrument determines the aesthetic quality, just as the objective function value is determined by the set of values assigned to each design variable (Lee, 2005). The HS algorithm optimization procedure which is shown below consists of the following five steps.

Step 1: Problem and algorithm parameter initialization
The optimization problem is specified as follows:
Minimize $f(x)$ subject to $x_j \in X_j = 1,2,\ldots,N$
where $f(x)$ is an objective function; $x$ is the set of each decision variable $x_j$; $N$ is the number of decision variables, $X_j$ is the set of the possible range of values for each decision variable, that is $x_j^{\text{min}}$ and $x_j^{\text{max}}$ are the lower and upper boundaries of the $j$th decision parameter respectively. The HS algorithm parameters are also specified in this step. These are the harmony memory size (HMS), or the number of
solution vectors in the harmony memory; harmony memory considering rate (HMCR); pitch adjusting rate (PAR); bandwidth distance (bw); and the number of improvisations (NI), or stopping criterion. The harmony memory (HM) is a memory location where all the solution vectors (sets of decision variables) are stored.

Step 2: Harmony memory initialization and evaluation

The HM matrix is randomly generated as shown in Eq. (1)

\[
x_{i,j}^0 = x_j^{\min} + r_j \times (x_j^{\max} - x_j^{\min})
\]

\[i = 1,2,...,\text{HMS}; j = 1,2,...,N\]

and \(r_j [0,1] \) is a uniformly distributed random number generated new for each value of \(j\). Solution vectors in HM are analyzed, and their objective function values are calculated.

Step 3: New harmony improvisation

In this step, a new harmony vector is generated based on three rules. They are memory consideration, pitch adjustment, and random selection. The value of a design variable can be selected from the values stored in HM with a probability of harmony memory considering rate (HMCR). It can be further adjusted by moving to a neighbor value of a selected value from the HM with a probability of pitch adjusting rate (PAR). Or, it can be selected randomly from the set of all candidate values without considering the stored values in HM, with the probability of \((1 - \text{HMCR})\).

Step 4: Harmony memory update

The new better harmony vector is included in the HM and the worst harmony is excluded.

Step 5: Termination criterion check

The HS algorithm is terminated when the termination criterion (e.g. maximum number of improvisations) has been met. Otherwise, steps 3 and 4 are repeated.

3. Chaos

In recent years, the theories and applications of nonlinear dynamics, especially of chaos, have drawn more and more attention in many fields. One is chaos controlling, and synchronization. Another field is the potential applications of chaos in various disciplines including optimization (Yang, 2007).

Chaos is a deterministic, random-like process found in nonlinear, dynamical system, which is non-period, non-converging and bounded. Moreover, it has a very sensitive dependence upon its initial condition and parameter. The nature of chaos is apparently random and unpredictable and it also possesses an element of regularity. Mathematically, chaos is randomness of a simple deterministic dynamical system and chaotic system may be considered as sources of randomness (Alatas, 2010). A chaotic map is a discrete-time dynamical system

\[ x_{k+1} = f(x_k), \quad 0 < x_k < 1, \quad k = 0,1,2,... \]

running in the chaotic state. The chaotic sequence \(\{x_k : k = 0,1,2,...\} \) can be used as spread-spectrum sequence and as a random number sequence.

Some new searching algorithms called Chaos Optimization Algorithms (COAs) use the properties of chaos like ergodicity as in Li (1998) and Zhang (1999). Recently Chaos is extended to various optimization areas, for example Multi-Objective Optimization (El-Santawy, 2011) because it can more easily escape from local minima than other stochastic optimization algorithms. The use of chaotic sequences in HS can be helpful to improve the global convergence, and to prevent sticking on a local solution than the classical HS algorithm which uses fixed values for HMCR, PAR and bw. In the chaotic HS algorithm, when a random number is needed by the classical HS algorithm, it is generated by iterating one step of the chosen chaotic map that has been started from a random initial condition at the first iteration of the HS (Alatas, 2010).

4. Chaotic harmony Search for Solving Numerical Integrals

Suppose that segmentation T splits an integral interval \([a,b]\) into \(n\)-subintervals:

\[ [x_0,x_1], [x_1,x_2], ..., [x_{n+1},x_n], \]

where \(x_j < x_{j+1}\) for \(j = 1,2,...,n-1\); \(x_0 = a\), and \(x_n = b\), also define \(\Delta x_k = x_k - x_{k-1}\) for \(k = 1,2,...,n\). Using this notation, the integral \(f(x)\) in \([a,b]\) can be approximated as in Eq. (3) (Qu, 2010):

\[
\int_a^b f(x)\,dx = \sum_{k=1}^{n} [f(x_{k-1}) + 4f((x_{k-1} + x_k)/2) + f(x_k)]\Delta x_k \quad (3)
\]

The steps of the Chaotic Harmony Search algorithm for calculating numerical value of definite Integral (CHSINT) are as follows:
Step 1: setting the HS algorithm parameters {HMS,HMCR,NI}.

Step 2: initializing HM by iterating the selected chaotic maps until if reaches the HMS. This process produces HMS segmentations randomly in \([a,b]\). Determining the fitness of each harmony vector as in Eq.(3) is done after.

Step 3: generating new harmony improvisations based on the three updating rules as illustrated in section 2. In this algorithm PAR and bw values have not been fixed in HS and they have been modified by the selected chaotic maps as follows

\[
\text{PAR}(t+1) = f(\text{PAR}(t)), \quad 0 < \text{PAR}(t) < 1, \quad t = 1,2,\ldots
\]

\[
\text{bw}(t+1) = f(\text{bw}(t)), \quad 0 < \text{bw}(t) < 1, \quad t = 1,2,\ldots
\]

Step 4: updating Harmony memory after evaluating all harmony vectors in Eq.(3).

Step 5: checking to ensure the termination criterion has been met. Otherwise, steps 3 and 4 are repeated.

5. Experiments and Results

Several experiments have been done to verify the validity of the proposed algorithm. The initial parameters set at HMS = 40, HMCR = 0.9, and NI = 50. The selected chaotic map for all experiments is the Logistic map, whose equation is given in Eq. (6). It has been brought to the attention of scientists by Robert May (May, 1976).

\[
z_{k+1} = \mu z_k (1-z_k)
\]

Obviously, \(z_k \in [0,1]\) under the conditions that the initial \(z_0 \in [0,1]\), where \(k\) is the iteration number and \(\mu = 4\). The programs are realized in Matlab 7.0. The integral values of functions \(1/(1+x)\) in \([0,2]\), \(e^x\) in \([0,2]\), and \(e^{-x^2}\) in \([0,1]\) are selected for experiments. The results of CHSINT algorithm are conducted from 30 independent runs for each integrand, while the results of other techniques are found in Burden (2001) and Wang (2004). As shown in Table 1 the results of CHSINT algorithm are superior compared to the results of Trapezoidal method, Simpson’s method, and Fourth order Newton-Cotes method.

<table>
<thead>
<tr>
<th>CHSINT</th>
<th>1.0986</th>
<th>6.3891</th>
<th>0.74682</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trapezoidal method</td>
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<td>0.74621</td>
</tr>
<tr>
<td>Simpson's method</td>
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<td>Newton-Cotes method</td>
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<td>6.3892</td>
<td>0.74683</td>
</tr>
<tr>
<td>Accurate value</td>
<td>1.0986</td>
<td>6.3891</td>
<td>0.74682</td>
</tr>
</tbody>
</table>

6. Conclusion

In this paper, a novel algorithm based on Harmony search and Chaos for calculating the numerical value of definite integrals is presented. This algorithm has the ability to overcome the shortage that the segmentation points are uniform in traditional methods. The simulation examples of numerical integration validated the algorithm as effective and enforceable. Experimental results show that the algorithm can converge to the best solution, and it has high accuracy which makes it easily usable in engineering.

References


A Dictionary-Based Integrated Development Environment for Programming Java in an Indigenous Nigerian Language

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Abstract
In an effort to localize and encourage computer programming activities in an indigenous language, an Integrated Development Environment (IDE) that aids the compilation of Java code in a local Nigeria language (Yoruba) was developed and implemented. The IDE provides the code-behind-file language Graphical User Interface (GUI) that is used to render the application. Consoles and window-based platform for programming activities applications are also presented. This is supported by a dictionary-based user friendly environment that allows programmers to interact with the computer in an indigenous target language. Programming is made more understandable by providing a glossary of Java keywords in local languages, such that the programming concepts are captured in as much details as possible. Preliminary usage of the NaijaJava Platform showed very promising results and provided feedbacks for improvements.

Keywords: IDE, Localization, Java, Yoruba, GUI

Introduction
Since the introduction of the Java programming language in the mid 1990s, it has gained much acceptance within programming circles as a programming language of choice for developing scalable applications using the object oriented paradigm. Today, Java has almost become the defacto programming language for teaching introductory computer programming all over the world (Yong, 2010). As a result of the fact that most programming languages emanated from English speaking countries such as America, Britain, Canada and Australia (Adegbola, 2009), most developing nations run programming courses and program development in English language. The fact that programming like other courses are taught in English has been a subject surrounded with arguments bordering around knowledge retention and academic performance in so many countries. In the programming domain in Nigeria, tutors and students conform to this monopolistic approach to be relevant in the ever dynamic world of ICT.

The journey of self-realization and relevance in the programming domain requires the creation of indigenous programming languages as well as porting existing languages into indigenous platforms. This will assist in contributing to internationalization of indigenous languages thereby helping quantifiable and non-English literate portion of the entire population to benefit from the dividends of ICT.

Research has suggested that using indigenous languages (mother tongue) makes it easy to grasp complex ideas which might be more difficult to assimilate in a second language (Buttzukamm, 2003; Olopade, 2009). Studies have also shown that countries in which education is delivered in the mother tongue have consistently higher values of Human Development Index (HDI) than those in which education is delivered in a foreign language. The HDI is a normalized aggregate of a vector of indicators such as life expectancy, literacy, education, standard of living and per capita gross domestic product (Subba, 2008; Langford, 2011).

Considering the quest in some academic quarters that teaching programming language in indigenous languages in Africa can assist in developing a new generation of programmers with the ability to build
computer applications and software to solve indigenous local problems, the interest to localize an important programming language such as Java is not unfounded. We attempt to do this by developing a dictionary-based Integrated Development Environment (IDE) that will enable the programming of Java in local languages other than its native language i.e. English language. In particular, we experiment with programming Java in a native Nigeria language, Yoruba, which is spoken by over 40 million people across the world (Longe, 2012).

The remaining part of this paper is organized as follows. Section 2 discusses relevant literature in the domain of localization and indigenous language programming. In section 3, we present system design and conceptualization. System development and implementation is the focus of Section 4. We conclude in Section 5 with directions for future works.

2. RELATED WORKS

The need to conduct academic activities in indigenous language has been suggested and reported in several studies. In a cross-country and cross-cultural studies conducted by Adegbola (2009), a compelling level of correlation between the use of indigenous languages and development was reported. Localization of scientific contents and technology activities has become a new and exciting domain study among linguistics as the world becomes a global village and goods and services can be delivered at the speed of light through the internet. Localization adapts products and services and in this context software program, to specific languages, culture and norms as well as to the needs and expectations of a specific target market (Souya et al, 1991; Heugen, 1996). Localization in the context of this discourse involves translating codes and application languages from English into other target languages since most software that are being used in most developing nations are originally developed using the English language.

These efforts throw a challenge that can only be solved at the nexus of computing and linguistics. Of course the two fields share a commonality from history. The Chomsky hierarchy which drives computational languages came from Noam Chomsky, a linguist at the MIT in the USA who formalized the language theory in 1956 (Wikipedia, 2012). While localization and translation are used interchangeably since the localization process entails translation, it must be stressed however that translation is just a process (subset) of the localization process (Pen, 1997). Localization cannot be complete without other intermediate phases that takes into consideration culture, content, context, and other socio-technical issues that must be considered in order to converse effectively in a target language. With respect so software localization, it is worthy to note that many Asian, Arab and European countries have localized programming languages with great success and impact on national development and productivity (Gross, 2006, Adams, 2009; GDC, 2012).

For instance, winDev from France, Python from Netherland, Chinese Basic, Hindawi from India and Arlogo from Arab are successful representations to localized software systems. The Yoruba language is the language of choice due to the fact that it is the native language of this immediate environment in this part of Nigeria. It is by over 40 million people with 21 million of them living in the original homeland in southwest of Nigeria (Events Destination, 2011; Longe, 2012).

The rest are in Republic of Benin, Togo, the U.S., and Brazil It remains the 29th largest spoken language in the world and the first in Africa. It is considered as a minority language, but it has matured orthography. For instance, the first Yoruba Bible Translation from the English King James Bible was done as early as 1850 (Ade-Ajayi, 1999).

In its written form, the Yoruba language contains seven oral vowels (a, e, ë, i, ï, o, ò, u), five nasal vowels (an, en, in, on, un), three tones: the acute low tone (‘), the middle tone (‘) and the grave tone (‘).

The Yoruba orthography does not use the letters c, q, v, x, and z. (Olopade, 2009). Yoruba is a tonal language that employs the use of a
combination of diacritics and Roman alphabets to make up for the full representation of the entire Yoruba alphabets on any keyboard. A minimum of 31 keys on the keyboards will be required to fully recognize and represent the entire alphabet. Luckily, extensive research has been done by the African Languages Technology Initiative (Alt-i) which resulted in the development of the Alt-i Version 2 Yoruba keyboard (Adegbola, 2009). The Alt-i version 2 Yoruba keyboard modifies the QWERTY layout of the Standard English keyboard. It is made available for use as the Konyin keyboard, the Wazobia keyboard, the NITDA keyboard and the ABD keyboard.

3. SYSTEM CONCEPTUALIZATION

Existing Java system are Java IDEs that allow interaction with it interface in English language. Although this interaction is made possible, the system does not allow alteration that makes the Java platform location or language-specific, thereby limiting the localization of the major software development process. Numerous existing IDEs built on the Java platform such as NetBeans, JCreator, and Eclipse do not also support localization of Java.

The challenge therefore is to look into the possibility of improving the existing IDEs by the inclusion of additional features that can enhance the existing IDEs to allow/support localization on one of the major software development process; in this context, software coding. To do this we modeled the system in view and then add a dictionary component that allows translation of code from English to the target language.

This enables the IDE to have a base which allows for translation of the keywords and other resources that users or programmers interacted with during the software development process. To sharpen the linguistic contents, linguists were consulted on knowledge acquisition, proper translation of English keywords and language representation for the target dictionary.

![Dictionary-Based IDE for JAVA](image)

**Fig. 1- UML Used-Case Diagram for the Proposed System**

The system is conceptualized as an IDE with an
integration of a dictionary base to allow for a lookup that permits it to function as a database. This database provides a platform for the translation of existing Java platform's keywords to that of a target language (in this case the Yoruba language). In addition to this dictionary look up, it also creates room for a proper translation of the resources that are interacted with during the process of software development. The system is able to edit, compile and execute localized source code, given as a base a glossary which the IDE can use as a backbone to handle translation from the target language to that of the original specification required by the Java's platform.

Fig. 2a - UML Package Activities Diagram
The platform also handles a properly captured translated version of the resources that are to be encountered during the interaction with the IDE, when the target language is selected as the mode of operation. The UML models depicted below are obtained by analyzing functional requirements of the system and defining the system processes that require both system and human input. Use cases are used primarily to describe the functional requirements of the system and to list the human interactions with the system in the order in which they occur. These diagrams are shown in the figures below.

Fig. 2b - UML Package Activities [EDIT] Diagram

Fig. 2c - UML Package Activities [COMPILE SOURCE CODE] Diagram
4. SYSTEM DEVELOPMENT AND IMPLEMENTATION

The programming language of choice for coding (add-on development) is Java. Since objects will be compiled into machine-independent bytecodes, Java application can be distributed more easily with Java WebStart software which allows users to launch the applications with a single click of the mouse. NetBeans 6.5, an IDE developed by Sun Microsystems, was used in the development of the application for this project. It provides basic functionalities of an IDE and other features that enhance rapid application development.

Java makes use of a Graphical User interface (GUI) and drag and drop features to enhance the development of an application’s interface. One of its major features is code generation, which aided the development of this application (NaiJava). Our application’s Dictionary-based IDE made use of batch filing (a DOS programming concept) to handle directory operations and Java’s Desktop Application Programming Interface (API), to handle all compilation and execution process required by the system.

To install and run the new platform, the zip file that holds the compiled application can be unpacked into a folder. In the folder the application can be found with the name NAIJava.jar. The application runs on double-clicking the NAIJava.jar file. The dictionary-based IDE application is codenamed NAIJava™. Its front-end is the interface where users (i.e. application programmers) can edit, compile and execute their Java application written in an English based environment or its equivalent Yoruba Environment (Fig. 3(a) and 3(b) below). The back-end, which makes use of the file system to hold all required data, can be accessed after a security test is passed by the user. Below are screenshots showing the English and Yoruba based Environment for opening text files (Fig. 4(a), 4(b), 5(a) and 5(b). The front-end part of the solution has been developed with consideration for new computer programmers that are proficient in either English or Yoruba languages. The user is however required to be skilled in interacting with the command prompt should programming require error correction during compilation. Tool tips are provided to guide users on the functions of each of the features provided on the Naijava platform. The compile, run and other features are provided under the MENU tool. The dictionary structure is shown in Fig. 6(a) and 6(b).
Fig. 4(a) English Language-based Environment for opening text files

Fig. 4(a) Yoruba Language-based Environment for opening text files

Fig. 5 (a) The compile, update dictionary, run and select features for the English language interface
Fig. 5 (b) The compile, update dictionary, run and select features for Yoruba-language based Interface

A typical tool-tip Message that guides user on easily interacting with the system with the mouse is on the exit menu item IN THE Yoruba Environment

Fig. 6 (a) The IDE Based Dictionary Showing Equivalent Buttons for Yoruba Output

Prints table contents in Yoruba
Reset table contents to default
Save table contents to file
5. CONCLUSION AND FUTURE WORKS

In a world of immense evolution and over-dependence on industrial technology, computer science, has become an instrument of growth and presented itself as a tool for localization and indigenization. Through collaboration with experts from linguistics, computer science can contribute to localization of software product. We developed an add-on tagged NaiJava to the Java platform with the capability for localizing and indigenizing computer programming using the Java programming language For the Yoruba user the system made use of string manipulation to search and replace task with the aid of a target language dictionary built into the system.

Future work will be directed at making the system user-friendly. The knowledge base used in the project will also be further expanded in conjunction with linguists in order to enhance the translation of the Java keywords and other resources into the target

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A Chaos Embedded Differential Evolution Algorithm for Multi-Objective Optimization

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Abstract: In Multi-Objective Optimization, the problem of identifying the whole pareto-optimal set is very crucial. In this paper, we developed a new Multi-Objective Evolutionary technique. The new method incorporates Differential Evolution algorithm to Chaos search for better exploration, and so better quality of solution. In order to obtain more diversified solution set we used the well known Fitness Sharing method to adopt the size of the external archive maintained by the technique during search. Several test functions are employed for experiments. The simulation results show that the proposed algorithm is efficient.

Keywords: Chaos; Differential Evolution Algorithm; Multi-Objective Optimization.

1. Introduction

Decision situations often involve multiple criteria or objectives. In many cases, objectives are incommensurable, meaning they are not comparable with respect to magnitude and value, and conflicting, meaning that the different objectives cannot be arbitrarily improved without decreasing the value of another. Multi-Objective programming is a part of mathematical programming dealing with decision problems characterized by multiple and conflicting objective functions that are to be optimized over a feasible set of decisions. Such problems, referred to as Multi-Objective Programs (MOPs), are commonly encountered in many areas of human activity including engineering, management, and others (Ehrgott and Ruzika, 2008).

Differential evolution (DE), proposed initially by Price and Storn in 1995, is a population based stochastic search algorithm (Storn and Price, 1995), and has been successfully applied to solve complex problems including linear and nonlinear, unimodal and multimodal functions. Over the recent years, DE has been successfully applied to different subjects such as reservoir system optimization (Reddy and Kumar, 2007), optimal design of shell and tube heat exchangers (Babu and Munawar, 2007), beef property model optimization problems (Mayer et al., 2005), generation planning problems (Kannan et al., 2003).

Chaos is a kind of characteristic of nonlinear systems and it has been extensively studied and applied in many fields. Although it appears to be stochastic, it occurs in a deterministic nonlinear system under deterministic conditions. Chaos has been extended to various optimization areas like in El-Santawy and Ahmed (2012), El-Santawy and Ahmed (2011), Zhang et al. (1999), and Li and Jiang (1998) because it can more easily escape from local minima than other stochastic optimization algorithms. Recently, chaotic sequences have been adopted instead of random sequences and very interesting and somewhat good results have been shown in many applications.

In this paper, a new method based on chaos search and Differential Evolution technique is constructed to solve Multi-Objective problems efficiently. Several experiments are done to validate the proposed method. This paper is structured as following: Multi-Objective Optimization is briefly presented in section 2, section 3 is made for Differential Evolution approach, section 4 is devoted to Chaos, the proposed algorithm is illustrated in section 5, experiments and simulation results are shown in section 6, and finally in section 7 conclusion is presented.
2. Multi-Objective Optimization

In general, a $k$-objective minimization problem can be formulated as:

$$\min \{f_i(x), \ldots, f_k(x) : x \in X\} \tag{1}$$

It is usually assumed that the set $X$ is given implicitly in the form of constraints resulting in the feasible region in the decision space (Deb, 2001).

$$X = \{x \in \mathbb{R}^n : g_i(x) \leq 0, j = 1, \ldots, s; h_j(x) = 0, j = 1, \ldots, m\} \tag{2}$$

One of the main differences between single objective and Multi-Objective Optimization is that in multi-objective optimization the objective functions constitute a multi-dimensional space, in addition to the usual variable space. For each solution $x$ in the variable space, there exists a point in the objective space, denoted by $f(x) = z = (z_1, z_2, \ldots, z_k)^T$.

**Definition 1 (Pareto Dominance):** Without loss of generality in a minimization problem, a decision vector $x_i \in X$ is said to dominate a decision vector $x_2 \in X$ iff the following two conditions are satisfied:

1. The decision vector $x_1$ is not worse than $x_2$ in all objectives, or $\forall i \in \{1,2,\ldots,k\} : f_i(x_1) \leq f_i(x_2)$.
2. The decision vector $x_1$ is strictly better than $x_2$ in at least one objective, or $\exists i \in \{1,2,\ldots,k\} : f_i(x_1) < f_i(x_2)$.

If any of the above conditions is violated, then $x_1$ does not dominate $x_2$. A decision vector $x_j \in X$ is called Pareto-optimal if there is no other $x_j \in X$ that dominates it and in this case $x_j$ is called non-dominated with respect to $X$; also an objective vector is called Pareto-optimal if the corresponding decision vector is Pareto-optimal (Deb, 2001).

**Definition 2 (Pareto Optimal Set):** The Pareto Optimal Set $P^*$ is defined by:

$$P^* = \{x \in X | x \text{ is pareto-optimal}\} \tag{3}$$

Many researchers had developed a lot of mathematical programming techniques to solve Multi-Objective Optimization problems, some representatives of this class of techniques are the weighting method, the $\varepsilon$-constraint method, and the goal programming; also some authors had adopted the Evolutionary Algorithms (EAs), Simulated Annealing (SA), Genetic Algorithms (GA), as well as Swarm Intelligence (SI) techniques to deal with Multi-Objective Problems (El-Santawy, 2009).

3. Differential Evolution Algorithm

The key idea behind DE is a scheme for generating trial parameter vectors. Mutation and crossover are used to generate new vectors (trial vectors), and selection then determines which of the vectors will survive the next generation.

A set of $D$ optimization parameters is called an individual, which is represented by a $D$-dimensional parameter vector. A population consists of $NP$ parameter vectors $X_{i,G}$, $(i = 1,2,\ldots, NP$ for each generation $G$). According to Storn and Price, DE’s basic strategy can be described as follows.

3.1. Mutation

For each target vector $X_{i,G}$ ($i = 1,2,\ldots, NP$), a mutant vector $V_{i,G+1}$ is generated according to

$$V_{i,G+1} = X_{i,G} + F \cdot (X_{2,G} - X_{3,G}). \tag{4}$$

where $r_1 \neq r_2 \neq r_3 \neq i$. Note that randomly chosen integer indexes have to be different from each other and from the running index. $F$ is called mutation factor between $[0,1]$ which controls the amplification of the differential variation ($X_{2,G} - X_{3,G}$).

3.2. Crossover

In order to increase the diversity of the perturbed parameter vectors, crossover is introduced. The target vector is mixed with the mutated vector, using the following scheme, to yield the trial vector $U_{i,G+1} = (u_{i1,G+1}, u_{i2,G+1}, \ldots, u_{iD,G+1})$, that is

$$u_{ij,G+1} = \begin{cases} v_{ij,G+1} & \text{if rand} (j) \leq CR \text{ or } j = \text{rmb}(i) \\ X_{ij,G} & \text{otherwise} \\ \end{cases} \tag{5}$$

where rand($j$) is the $j$th evaluation of a uniform random number generator between $[0,1]$. $CR$ is the crossover constant between $[0,1]$ which has to be determined by the user. $\text{rmb}(i)$ is a randomly chosen index from $1,2,\ldots,D$ which ensures that $U_{i,G+1}$ gets at least one parameter from $V_{i,G+1}$. Otherwise, no new parent vector would be produced and the population would not alter.

3.3. Selection

To decide whether or not it should become a member of the next generation $G+1$, the trial vector $U_{i,G+1}$ is compared to the target vector
Assume that the objective function is to be minimized, according to the following rule:

\[ X_{G+1} = \begin{cases} U_{i,G+1} & \text{if } f(U_{i,G+1}) \leq f(X_{i,G}) \\ X_{i,G} & \text{otherwise} \end{cases} \]  

(6)

That is, if vector \( U_{i,G+1} \) yields a better evaluation function value than \( X_{i,G} \), then \( X_{i,G+1} \) is set to \( U_{i,G+1} \); otherwise, the old value \( X_{i,G} \) is retained.

As a result, all the individuals of the next generation are as good as or better than their counterparts in the current generation.

4. Chaos

In recent years, the theories and applications of nonlinear dynamics, especially of chaos, have attracted more and more attention in many fields. One is chaos controlling, and synchronization. Another field is the potential applications of chaos in various disciplines including optimization (Yang, 2007).

Mathematically, chaos is randomness of a simple deterministic dynamical system and chaotic system may be considered as sources of randomness (Alatas, 2010). A chaotic map is a discrete-time dynamical system

\[ x_{k+1} = f(x_k), \quad 0 < x_k < 1, \quad k = 0,1,2,\ldots \]  

(7)

running in the chaotic state. The chaotic sequence \( \{x_k : k = 0,1,2,\ldots\} \) can be used as spread-spectrum sequence and as a random number sequence.

One-dimensional noninvertible maps are the simplest systems with capability of generating chaotic motion (Ott, 2002). Here, two well-known one-dimensional maps are introduced. Later on, these maps are used in the chaotic searches.

**The Logistic map:** In 1976, Robert May pointed out that the logistic map led to chaotic dynamics (May, 1976). A logistic map is a polynomial map. It is often cited as an example of how complex behavior can arise from a very simple nonlinear dynamical equation (Ott, 2002). This map is defined by

\[ z_{k+1} = \mu z_k (1 - z_k) \]  

(8)

Obviously, \( z_k \in [0,1] \) under the conditions that the initial \( z_0 \in [0,1] \), where \( k \) is the iteration number and \( \mu = 4 \).

**The Circle map:** The circle map is represented by

\[ z_{n+1} = z_n + d - (c / 2\pi) \sin(2\pi z_n) \mod(1) \]  

(9)

where \( c = 0.5, \ d = 0.2, \) and \( z_0 \in [0,1] \) generates chaotic sequence in \([0,1]\) (Zheng, 1994).

5. Multi-Objective Chaotic Differential Evolution Technique

In Multi-Objective Optimization, we aim to find a set of different solutions (the so-called Pareto optimal set). It is obvious that the original scheme has to be modified in order to be extended to the Multi-Objective version. The solutions obtained during search are usually kept in a different place from the population, which is called external archive: This is a repository in which the nondominated solutions found so far are stored (Sierra and Coello, 2006). The solutions contained in the external archive are used in the updating process. Furthermore, the contents of the external archive are also usually reported as the final output of the algorithm.

In this proposal, two modifications are introduced in order to enhance the performance of DE to be able to explore Multi-Objective Optimization. The new method so-called Multi-Objective Chaotic Differential Evolution (MOCDE) combines an external archive and chaotic search to DE. We will illustrate the two mechanisms along the rest of this section.

**Fitness sharing:** The main idea of fitness sharing is to distribute a population of individuals along a set of resources (Lechuga and Rowe, 2005). When an individual \( i \) is sharing resources with other individuals, its fitness \( f_i \) is degraded in proportion to the number and closeness to individuals that surround it, and in this way promoting and maintaining diversity. In general Fitness sharing for an individual \( i \) is defined as:

\[ f_{\text{share}}(i) = f_i \sum_{j=0}^{n} \text{sharing}_i \]  

(10)

where \( n \) is the number of individuals in the population.

**Chaos search:** In this algorithm, when a random number is needed by the classical DE algorithm, it is generated by iterating one step of the chosen chaotic map that has been started from a random initial condition at the first iteration. Also, we suggest updating the mutation constant \( F \) chaotically as follows

\[ F_{G+1} = f(F_G), \quad F_{\min} \leq F_G \leq F_{\max}, \]  

(11)

\[ G = 1,2,\ldots \]
where the values of $F_{\min}$ and $F_{\max}$ are user defined. Along this paper, the initial parameters are set at $NP = 50$, $G = 100$, $CR = 0.8$, $F_{\min} = 0.3$, and $F_{\max} = 0.6$. The logistic map is used to update $F$, while the circle map is employed to generate chaotic generations used during search. The external archive is set to keep 100 nondominated solutions.

6. Experiments and Results

In order to validate the proposed approach, some quantitative (adopting two performance measures) and qualitative comparisons (plotting the Pareto fronts produced) are performed. The two measures of performance done are:

**Success Counting (SCC):** This measure counts the number of vectors (in the current set of nondominated vectors available) that are members of the Pareto optimal set:

$$ SCC = \sum_i S_i $$

where $n$ is the number of vectors in the current set of nondominated vectors available; $S_i = 1$ if vector is a member of the Pareto optimal set, and $S_i = 0$ otherwise. The SCC values vary from 0 to 100 in the experiment (Sierra and Coello, 2005).

**Inverted Generational Distance (IGD):** In this measure, the true Pareto front is used as a reference, and each of its elements is compared with respect to the front produced by the considered algorithm. This measure is defined as: $IGD = \sqrt{\sum_i d_i^2 / n}$ where $n$ is the number of elements in the true Pareto front and $d_i$ is the Euclidean distance (measured in objective space) between each of these and the nearest member of the set of nondominated vectors found by the algorithm. It should be clear that a value of $IGD = 0$ indicates that all the elements generated are in the true Pareto front of the problem (Sierra and Coello, 2005).

As shown in Table 1, the measures [average, median, worst, best, and standard deviation] are computed from 30 independent runs done for each test function. Obviously, the proposed method obtains quite efficient results. The proposed technique success to explore the pareto front in the three experiments as shown in the Figures 1, 2, and 3.

<table>
<thead>
<tr>
<th>Table 1: Results of experiments</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th></th>
<th>ZDT1</th>
<th>ZDT2</th>
<th>ZDT4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCC</td>
<td>70</td>
<td>69</td>
<td>60</td>
</tr>
<tr>
<td>IGD</td>
<td>0.009</td>
<td>0.008</td>
<td>0.0143</td>
</tr>
<tr>
<td>Median</td>
<td>60.00143</td>
<td>60.0096</td>
<td>55.0019</td>
</tr>
<tr>
<td>Worst</td>
<td>50</td>
<td>55.0056</td>
<td>55.0013</td>
</tr>
<tr>
<td>Average</td>
<td>68.4</td>
<td>65.00044</td>
<td>56.00019</td>
</tr>
<tr>
<td>Std. dev.</td>
<td>6.3</td>
<td>8.4</td>
<td>6.4</td>
</tr>
</tbody>
</table>

Three test functions ZDT1, ZDT2, and ZDT4 are adopted for experiments. The three test functions are well known in the specialized literature, and used widely in Multi-Objective Evolutionary Algorithms area (Zitzler, 1999).

ZDT1 (2-objective, 30 decision variables):

$$
\begin{align*}
    f_1(x_i) &= x_i \\
    f_2(x) &= g(x_2,\ldots,x_n)h(f_1, g) \\
    g(x_2,\ldots,x_n) &= 1 + \sum_{i=2}^{n} \frac{x_i}{(n-1)} \\
    h(f_1, g) &= 1 - \sqrt{f_1} / g \\
    x_i \in [0,1], & n = 30, i = 1,\ldots,n
\end{align*}
$$

ZDT2 (2-objective, 30 decision variables):

$$
\begin{align*}
    f_1(x_i) &= x_i \\
    f_2(x) &= g(x_2,\ldots,x_n)h(f_1, g) \\
    g(x_2,\ldots,x_n) &= 1 + \sum_{i=2}^{n} \frac{x_i}{(n-1)} \\
    h(f_1, g) &= 1 - (f_1 / g)^2 \\
    x_i \in [0,1], & n = 30, i = 1,\ldots,n
\end{align*}
$$

ZDT4 (2-objective, 10 decision variables):

$$
\begin{align*}
    f_1(x_i) &= x_i \\
    f_2(x) &= g(x_2,\ldots,x_n)h(f_1, g) \\
    g(x_2,\ldots,x_n) &= 1 + 10(n-1) + \sum_{i=2}^{n} (x_i^2 - 10\cos(4\pi x_i)) \\
    h(f_1, g) &= 1 - \sqrt{f_1} / g \\
    n = 10, x_i \in [0,1], & x_n \in [-5,5]
\end{align*}
$$

![Figure 1. Pareto front obtained for ZDT1](image)
7. Conclusion

In this paper, we try to incorporate chaos search to Multi-Objective Evolutionary Algorithms (MOEAs) by developing a new method. The proposed technique explores the search space in an efficient manner referring to the chaotic perturbations. We combined an external archive to the new method to keep solutions found along search. The fitness sharing method is employed to fix the archive's size. Results show that the proposed technique is promising and efficient.

References


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VIRTUAL COMMUNITIES IN MODERN BUSINESS ORGANISATIONS: THE CHALLENGE OF PROLIFERATION AND CONVERGENCE

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Abstract
With the emergence of the Internet and its growth in the middle 1990s, the structure and relationships in business has drastically changed. Customer relationship and supply chain are examples of relationships that have been redefined and better supported. The same information and communication technology that supports these electronic business structures enables the creation of virtual communities for customers, employees, suppliers and other stakeholders. While these communities can be variously classified, there is a noticeable convergence of them thereby presenting challenges to business organisations on how to structure and manage them. These challenges seem not to be treated in existing literature. This brief paper discusses the developments assisted by Web 2.0 in these communities and is a first attempt at trying to tease out the challenge of how to manage their proliferation and convergence.

Keywords: virtual communities, e-commerce, social networking, collaboration

Introduction
Information and communications technologies have bridged the geographical distance between businesses and their customers. It has even made small business become ‘big’ using Web presence. The same technologies that have enabled the boom of electronic commerce have encouraged the springing up and maintenance of virtual communities. These communities extend existing structures and concepts like customer relationship and supply chain. However, these communities do not end at business levels but also include social elements especially with the emergence of Web 2.0 social networking capabilities. Businesses (and individuals) are now inundated with many virtual communities that it should be challenging how to optimally manage and utilise them to business benefits. This paper will discuss the role of these communities and the challenge that is presented to businesses. The rest of this paper is organised under (a) e-commerce; (b) technology support for existing structures; (c) virtual communities; (d) convergence and business challenge.

E-commerce
Electronic commerce and its applications predate the modern Internet. From electronic funds transfer (EFT) in the early 1970s to electronic data interchange (EDI) that enabled both financial and non-financial documents to be transferred, some commercial use of Internet was set. The Internet, itself as well published in literature, was originally for non-commercial, technical audience of governmental agencies and academic researchers and scientists. The great change came in the early 1990s with the invention of the World Wide Web and Internet browsers. This development encouraged the Internet presence with texts and pictures and when it became commercialised, birth was given to electronic commerce (EC). Beginning from the Business to Consumer (B2C) business structure, EC has progressed to B2B, B2B to B2E (Business to Employees), C2B, C2C, G2C (government to citizens) and other types which describe the participants in the electronic commerce. Other terms which tend to portray the mode, and sometimes the content, of operation have been formulated. Examples are c-commerce (collaborative commerce), e-government, e-learning and m-commerce. In 2005, social networks emerged on the EC technologies and started to receive much attention.

New wine in old wineskin?
Are the EC structures inventing new ways of doing business? The answer can be “yes” and “no”. In terms of commerce, the basic transaction of exchanging goods or services
for money has not changed. This process is kept the same on EC though it might be more instant and has succeeded in breaking the barriers of geographical distance and language differences. The same can be said of the basic customer relationship management (CRM). However, there have been tremendous improvements with regards to the ease of getting customer information and also individualising products and services to each customer based on the information obtained. Besides, it has become possible for the customer to be very actively involved in providing and managing her information as well as being proactive not only to service delivery but also product design. For instance, IKEA product designs are said to be wholly invented by its customers. It is therefore not surprising to see the emergence of the CKM (customer knowledge management) discipline which emphasises that there is significant amount of useful knowledge to be acquired not only about but from customers.

Sometimes though, the EC phenomenon is such a new wine that it cannot contain in an old wineskin. For instance, though the basic idea of supply chains are transferred to EC, their structure often change from that of a chain to a star, where an EC technology stands in the centre of various suppliers and companies that seek supplies. Though sometimes, a customer can use an intermediary to get to a merchant, for example when booking a KLM flight at Thomas Cook travel agency, EC enables disintermediation. Thus, a customer can also directly book from the KLM web site or portal. Most large and medium organisations currently have web portals each of which consists of hundreds of pages in many cases. Re-intermediation also occurs when some of the portal owners are using them to aggregate demand or supply, for example in the travel and tourism industry. Such portals provide a one-stop site for consumers who want to shop for flights. The same is experienced in the insurance industry such as http://www.gocompare.com/ where people can shop for car insurance companies.

With the development in Web 2.0, the users eg customers are given great powers to contribute to content thereby enhancing the formation and running of Web or virtual communities that are discussed in the next section.

**Virtual Communities**

Humans being social animals have always tended to group for purposes that range from religion to business and leisure. Internet technologies have only supported this habit. According to Turban et al (2010, p 36), EC is about technology, commerce and people. The people brought together by EC include employees of different organisations and customers. The original sole interest was profit making through commerce. Also, before Web 2.0, content was primarily provided by the web site owner. O’Reilly Media in 2004 coined the term Web 2.0 to represent second generation Internet capabilities that enables people to more easily contribute content, share information and collaborate in innovative ways. Example of its applications is the common Facebook and Twitter. The initial use of Web 2.0 facilities was for leisure – sharing personal diaries and exchanging of pictures for instance. Now the facilities have matured and are being incorporated into EC. The common capabilities of blogging, chatting and running forums are used in EC environments to enhance communities that were running on mostly only emails and chats.
A virtual community is also referred to as a Web or an online community and describes the gathering or people and businesses without a physical meeting location (Rheingold, 1993; Schneider, 2009). Virtual communities in the EC context were originally to directly generate revenue, for instance when distributing products over the internet using viral marketing (Flavián and Guinalíu, 2005). Thus, referring to the categorisation of virtual communities in Figure, EC communities would mainly fall within the Business category (such as amazon.com for business transactions) and perhaps the Research Community for R&D. However, modern businesses do not turn their back virtual communities with much social content because they realise that besides fulfilling social needs, virtual communities constitute a good platform for companies, their customers, and their suppliers to “plan, collaborate, transact business, and interact in ways that benefit all of them (Schneider, 2009, p 6). The incorporation of Web 2.0 as already discussed, makes it easy for customers and other users who are not owners of the system to easily contribute to the community.

Schubert and Ginsburg (1999) classification of virtual communities is not exhaustive and some classifications cut across the groupings. A significant one that is not clearly represented on the diagram but is receiving much research attention is community of practice (CoP) which often traverses organisational boundaries (Borzillo and Kaminska-Labbé, 2011; Majewski et al, 2011; Retna and Ng, 2011; Usoro et al, 2007, Usoro et al, 2011). Research indicates that businesses should encourage them because by knowledge sharing in these communities, valuable knowledge flows into organisations (Laycock, 2005). However, the aim of this paper is to necessarily to produce a complete listing but to highlight the challenge that the increasing numbers of this communities has posed.

**Business challenge of proliferation and convergence**

Figure has presented a classification of virtual communities, but they can also be classified in terms of the groupings of customers, employees (of different types and at different levels such as managers and sales personnel, supply chain and so on. They may also be
simply classified into internal and the inter-organisational ones eg professional communities. What is witnessed with the current growth in Web 2.0 and social networking is that individuals and organisations are bombarded with plenty of virtual communities with overlapping functionalities. The professional virtual communities, for instance, are adding social aspects to their provisions which are not negative. Some communities that started as merely social, eg Facebook, are also providing a platform for serious business.

Another good example of the convergence is YouTube (http://www.youtube.com/) that contain both trivial as well as serous business information. The likes of YouTube and the Internet generally perhaps are bearable as they are not waiting for one to approach them and with the use of their search engines, useful desired information can be obtained. The situation is a bit different with virtual communities that organisations or their members have to be enrolled into and engage in. Their content and activities undoubtedly can add business value but with very many ‘songs’ at the same time, a business or its managers may be confused which ones to ‘listen to’ and when they find a number of them desirable, their wish would be some simplification of filtering so that they can get the best out of most of them. This is the challenge that this paper presents. It does not appear that research has been done to first of all survey the problem in terms of establishing how organisations and its members react to the surge of virtual communities.

The author’s observation is that some businesses, like Cisco, are themselves building social networks into which customers (their students) and organisational members 1 (including teachers and administrators) irrespective of their hierarchical positions are encouraged to belong. The virtual community thus becomes a common playing ground where each member is free to express opinion and is thus a useful tool for knowing the customers’ minds. Because the customers can easily use blogs and uploading of files to contribute content, they can contribute their intellectual capital into product development and improvements.

It is also possible to sub-divide the virtual community to provide a space for special interest groups or for only some members. This possibility should be available not only to a central controller but be distributed among users. While this may appear a pragmatic way forward, does the approach of a business establishing its own virtual community and inviting all stakeholders to join sufficient to ensure they can get the best of existing virtual communities? The community established by a business will only be one of the many that may still provide good business use. It may be that a supplier also has its large community. How best can useful information from the suppliers’ communities be easily collected to complement an organisation’s virtual community so that such information can be incorporated into the knowledge base of the organisation? Yes, technology may be a key component to the answer but it is likely to be only one of the several key components of the strategic solution (Gadman and Cooper, 2005). These are the challenges that this paper poses.

Conclusions and Implications

The increasing ability to create and join virtual communities can enable businesses to quickly access the minds and creativity of customers and employees as well as employees’ links to external professional bodies which operate under communities of practice. Businesses can also individually create their own virtual communities of employees, customers and other stakeholders. However, the mere proliferation and convergence of these communities may pose decision challenge to business managers. They may need to decide the best approach to tap into this business asset.

The implication of this paper is that while the business benefits of virtual communities should be recognised, there is need to research into the nature of the proliferation and convergence problem. It is time to evaluate how managers cope with the increasing virtual communities offered to them. Such an evaluation should be a first step towards proffering a solution strategy.

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1 The business benefits of implementing even a social network system in the workplace are established in research (Bennett et al, 2010).
References:


Appreciation

I appreciate Prof Sam McKinstry for inviting me to present at the Beijing Business Conference of June 2011 at BCBUU, China. The invitation motivated the development of this paper.
Abstract: Many organizations want to expand their operations through allocating new facilities. The facility location decision process combines the identification, analysis, evaluation of, and selection among alternatives. Facility location problem implies more than one dimension, many factors should be considered when comparing alternatives to choose among or rank them. In this article a Multi-Criteria Decision Making (MCDM) problem of facility location is presented and an international company’s facility location problem of a new manner is illustrated. The well-known VIKOR technique is employed to solve the MCDM problem.

Keywords: Facility Location; Multi-Criteria Decision Making; VIKOR.

1. Introduction

Facility location problems have attracted researchers with diverse backgrounds such as economics, industrial engineering, and geography (El-Santawy, 2011). The suitability of a specific location for proposed facility operations depends largely on what location factors are selected and evaluated as well as their potential impact on corporate objectives and operations. There are a large number of location factors that have an influence on location decisions. Facility location attribute is defined as a factor that influences the selection of facility location for a given activity. These attributes include: cost of land, cost of energy, availability of transportation, cost of transportation, proximity to raw material sources, cost of raw materials, government policies and incentives, and tax rates. Many researchers studied these attributes. For further details refer to Farahani and Hekmatfar (2009).

Facility location problem is a well known Multi Criteria Decision Making (MCDM) problem which involves many conflicting attributes. The merit of MCDM techniques is that they consider both qualitative parameters as well as the quantitative ones, MCDM includes many solution techniques such as Simple Additive Weighting (SAW), Weighting Product (WP) (Hwang and Yoon, 1981), and Analytic Hierarchy Process (AHP) (Saaty, 1980).

In this paper a new facility location problem existing in a multi-national company is presented. The technique used in this paper named VlseKriterijumska Optimizacija i Kompromisno Resenje in Serbian (VIKOR) is applied for ranking the alternatives. The rest of this paper is organized as follows: section 2 is made for the VIKOR approach, the case study of the facility location problem is presented in section 3, and finally section 4 is made for conclusion.

2. VIKOR

A MCDM problem can be concisely expressed in a matrix format, in which columns indicate criteria (attributes) considered in a given problem; and in which rows list the competing alternatives. Specifically, a MCDM problem with m alternatives (A₁, A₂, ..., Aₘ) that are evaluated by n criteria (C₁, C₂, ..., Cₙ) can be viewed as a geometric system with m points in n-dimensional space. An element xᵢⱼ of the matrix indicates the performance rating of the ith alternative Aᵢ, with respect to the jth criterion Cⱼ, as shown in Eq. (1):

\[
D = \begin{bmatrix}
C₁ & C₂ & C₃ & \cdots & Cₙ \\
A₁ & x₁₁ & x₁₂ & x₁₃ & \cdots & x₁ₙ \\
A₂ & x₂₁ & x₂₂ & x₂₃ & \cdots & x₂ₙ \\
\vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\
Aₘ & xₘ₁ & xₘ₂ & xₘ₃ & \cdots & xₘₙ
\end{bmatrix}
\]

(1)

The VIKOR method was introduced as an applicable technique to implement within MCDM (Opricovic, 1998). It focuses on ranking and selecting from a set of alternatives in the presence of conflicting criteria. The compromise solution, whose foundation was established by Yu (1973) and Zeleny (1982) is a feasible approach.
solution, which is the closest to the ideal, and here “compromise” means an agreement established by mutual concessions. The VIKOR method determines the compromise ranking list and the compromise solution by introducing the multi-criteria ranking index based on the particular measure of “closeness” to the “ideal” solution. The multi-criteria measure for compromise ranking is developed from the Lp-metric used as an aggregating function in a compromise programming method. The levels of regret in VIKOR can be defined as:

\[ L_{pj} = \left( \sum_{j=1}^{n} w_j (x_j^i - x_j^*) / (x_j^i - x_j^*) \right)^p, 1 \leq p \leq \infty, \]

where \( i = 1, 2, \ldots, m \). \( L_{1i} \) is defined as the maximum group utility, and \( L_{m i} \) is defined as the minimum individual regret of the opponent. The procedure of VIKOR for ranking alternatives can be described as the following steps (Huang et al., 2009):

**Step 1:** Determine that best \( x_j^* \) and the worst \( x_j^- \) values of all criterion functions, where \( j = 1, 2, \ldots, n \). If the \( j \)th criterion represents a benefit then \( x_j^* = \max_i f_j^i, f_j^- = \min_i f_j^i \).

**Step 2:** Compute the \( S_i \) (the maximum group utility) and \( R_i \) (the minimum individual regret of the opponent) values, \( i = 1, 2, \ldots, m \) by the relations

\[ S_i = L_{1i} = \sum_{j=1}^{n} w_j (x_j^i - x_j^-) / (x_j^i - x_j^-), \]
\[ R_i = L_{mi} = \max_j \left( \sum_{j=1}^{n} w_j (x_j^i - x_j^-) / (x_j^i - x_j^-) \right), \]

where \( w_i \) is the weight of the \( j \)th criterion which expresses the relative importance of criteria.

**Step 3:** Compute the value \( Q_i, i = 1, 2, \ldots, m \), by the relation

\[ Q_i = v (S_i - S^-) / (S^- - S^*) + (1 - v) (R_i - R^-) / (R^* - R^-), \]

where \( S^* = \min_i S_i, S^- = \max_i S_i, R^* = \min_i R_i, R^- = \max_i R_i \), and \( v \) is introduced weight of the strategy of \( S \) and \( R \).

**Step 4:** Rank the alternatives, sorting by the \( S \), \( R \), and \( Q \) values in decreasing order. The results are three ranking lists.

**Step 5:** Propose as a compromise solution the alternative \( A' \) which is ranked the best by the minimum \( Q \) if the following two conditions are satisfied:

- **C1. “Acceptable advantage”:**
  \[ Q(A'') - Q(A') \geq DQ, \]
  where \( A'' \) is the alternative with second position in the ranking list by \( Q, DQ = 1/(m - 1) \) and \( m \) is the number of alternatives.

- **C2. “Acceptable stability in decision making”:**
  Alternative \( A' \) must also be the best ranked by \( S \) or/and \( R \). This compromise solution is stable within a decision making process, which could be: “voting by majority rule” (when \( v > 0.5 \) is needed), or “by consensus” (\( v \approx 0.5 \)), or “with vote” (\( v < 0.5 \)). Here, \( v \) is the weight of the decision making strategy “the majority of criteria” (or “the maximum group utility”). \( v = 0.5 \) is used in this paper. If one of the conditions is not satisfied, then a set of compromise solutions is proposed (Huang et al., 2009). Recently, VIKOR has been widely applied for dealing with MCDM problems of various fields, such as environmental policy (Tzeng et al., 2002) data envelopment analysis (Tzeng and Opricovic, 2002), and personnel training selection problem (El-Santawy, 2012).

3. **Case Study**

A German multi-national company that works in hyper supermarkets has many branches in several countries like Turkey, Germany, France, Italy and more than 30 other countries. Three years ago, the strategic planning department in the German company had prepared a long-term plan to enter the Egyptian market; consequently the feasibility and economic aspects had been studied for constructing more than 40 branches all over Egypt of total investment exceeding 2 milliards. During the last two years the company had acquired 6 locations (lands of the branches); the company after prepared the feasibility study, budgets for each branch to be opened. The company employed many Egyptian consultants; expert houses as well as technical companies specialized in marketing analysis, surveys and decision support systems during the planning phase and preparing the feasibility study. As a part of this consulting the company wants to know what location (branch) is preferable to start with. Selecting accurately the branch to construct first will be reflected on the company’s whole long-term plan to be achieved.
The process of ranking the 6 branches in order to select optimally the branch to begin with is a typical facility location problem which is a MCDM problem. Table 1 shows the location of each branch acquired by the company and its given index for simplicity.

<table>
<thead>
<tr>
<th>Index</th>
<th>Branch Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOC1</td>
<td>Alexandria</td>
</tr>
<tr>
<td>LOC2</td>
<td>Cairo-Alexandria agriculture road (kilo 30)</td>
</tr>
<tr>
<td>LOC3</td>
<td>6-October city</td>
</tr>
<tr>
<td>LOC4</td>
<td>El-Sherouk city</td>
</tr>
<tr>
<td>LOC5</td>
<td>El-Salam city</td>
</tr>
<tr>
<td>LOC6</td>
<td>Port-said</td>
</tr>
</tbody>
</table>

The criteria to be compared is limited by the company to be 5 criteria. The values of $C_1$ are extracted directly from the feasibility study prepared for each branch, and presented in millions of L.E. $C_2$ describes the number of expected customers to visit the branch in thousands per week. $C_3$ is computed as a rank from 1 to 9 by specialized consulting companies. $C_4$ is the distance in kilometers from the nearest industrial zone to the branch location; finally $C_5$ is the completion time of constructing each branch computed in days. Table 2 shows the criteria, their computation units, and their relevant weights as given by the company. The company presented the data included in the decision matrix found in Table 3 showing the 6 alternatives and their performance ratings with respect to all criteria.

<table>
<thead>
<tr>
<th>Index</th>
<th>Branch Location</th>
<th>Units</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_1$</td>
<td>Initial Costs</td>
<td>Millions of L.E.</td>
<td>0.225</td>
</tr>
<tr>
<td>$C_2$</td>
<td>Expected Customers</td>
<td>1000 customers</td>
<td>0.103</td>
</tr>
<tr>
<td>$C_3$</td>
<td>Infra-Structure</td>
<td>Grade from 1-9</td>
<td>0.082</td>
</tr>
<tr>
<td>$C_4$</td>
<td>Industrial zone Neighbourhood</td>
<td>Kilo meters</td>
<td>0.165</td>
</tr>
<tr>
<td>$C_5$</td>
<td>Completion Time</td>
<td>Days</td>
<td>0.425</td>
</tr>
</tbody>
</table>

By using the procedure of VIKOR, we can calculate the $S$, $R$ and $Q$ values as shown in Table 4 to derive the preference ranking of the alternatives. The company should select the fourth location (LOC4) to start with. El-Sherouk city location has the minimum $S$, $R$, and $Q$ values; also, the two conditions mentioned earlier in section 2 are satisfied.

<table>
<thead>
<tr>
<th>Index</th>
<th>$S$</th>
<th>$R$</th>
<th>$Q$</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOC1</td>
<td>0.27327795</td>
<td>0.15</td>
<td>0.208322887</td>
<td>2</td>
</tr>
<tr>
<td>LOC2</td>
<td>0.78173913</td>
<td>0.3917</td>
<td>1</td>
<td>6</td>
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<td>LOC4</td>
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<td>1</td>
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<tr>
<td>LOC5</td>
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<td>0.421125462</td>
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<tr>
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<td>0.471704969</td>
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<td>0.352880613</td>
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</tr>
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</table>

4. Conclusion

A VIKOR method is presented to solve the facility location MCDM problem. A real-life problem of a new manner existing in multinational company is introduced. The VIKOR method is employed to rank the alternatives. It might be combined to other techniques in further research. The MCDM problem should be reformulated and solved if any parameter or alternative is added or deleted because of its sensitivity to any changes.

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