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USE OF TETRA-SODIUM ETHYLENE DIAMINE TETRA-ACETATE IN PAD-STEAM DYEING OF COTTON WITH REACTIVE DYES

Awais Khatri*, Rajiv Padhye**, Max White***

ABSTRACT

Reactive dyeing of cotton textiles generates high levels of dissolved solids and oxygen demands in the disposed effluent due to the use of inorganic salt (sodium chloride or sodium sulphate) and alkali (sodium bicarbonate, sodium carbonate or sodium hydroxide). Considerable efforts are being undertaken within the textile industry to reduce effluent loads and to comply with environmental regulations. This paper presents results where the inorganic salt (sodium chloride) and alkali (sodium bicarbonate or sodium carbonate) are replaced by a biodegradable organic chemical, tetrasodium ethylene diamine tetra-acetate also known as sodium edate. The dyeing method selected for the study was pad-steam in which the solution containing the dye, the salt and the alkali is applied on cotton fabric by impregnating the fabric in the solution following squeezing the fabric to a designated pick-up of solution and steaming to achieve penetration and fixation of the dye to the fibres within the fabric. The study showed that the colour yield, dye fixation and ultimate colourfastness achieved by using sodium edate were closely comparable to those obtained using inorganic salt and alkali. An industrial trial produced the same findings where the dyeings made with sodium edate produced significant reductions in total dissolved solids, chemical oxygen demand and biochemical oxygen demand of the effluent.

1. INTRODUCTION

Dyeing cotton with reactive dyes is widely practised because the covalent bond that is formed between the fibre and the dye molecules produces excellent colourfastness to washing. However, all reactive dye systems require considerable quantities of inorganic salt (sodium chloride or sodium sulphate) and alkali (sodium bicarbonate, sodium carbonate or sodium hydroxide) to ensure efficient utilisation and fixation of reactive dyes [1-2]. Irrespective of the application method of the reactive dye, almost all of the salt and alkali is discharged to effluent. This creates high levels of dissolved solids and oxygen demands in the effluent, which is environmentally undesirable [3-4].There have been a number of developments for improving the quality of effluent for reactive dyeing of cotton. Development of better dye structures and modified dyeing processes offered considerable reductions in the amount of inorganic salt [5-8]. Cationization of cotton fabric before reactive dyeing has been revealed to be capable of eliminating the use of inorganic salt, and alkali in some instances [9-11]. However, cationization is an additional process step and the practice has yet to be adopted by industry.

Organic salts have been explored and found to be effective alternatives to inorganic salts [12-14]. Ahmed [15] has reported a method for exhaust reactive dyeing of cotton using the organic amine salt, tetrasodium ethylene-diamine-tetraacetate, also known as sodium edate, as an alternative to traditional inorganic salt and alkali. This paper presents findings of a study of the potential for sodium edate as more sustainable substitute to the inorganic salt and alkali in pad-steam dyeing of cotton with reactive dyes. In this study, unlike Ahmed's work, the scoured and bleached fabric was not further boiled with sodium carbonate and non-ionic detergent before dyeing.

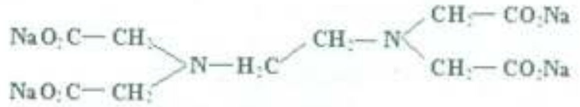

Figure 1: tetrasodium salt of ethylene diamine tetra-acetic acid

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2. EXPERIMENTAL

2.1 MATERIAL

(a) Cotton fabric

A commercially prepared (bleached) 100% cotton woven fabric (280 g/m^2, twill) was used for all dyeings.

The ready-to-dye fabric had an absorbency of 4 sec (AATCC 79 – 1995), pH of 7.7 and a CIE whiteness index of 84.0.

(b) Dyestuff & chemicals

A difluorochloropyrimidine dye, CI Reactive Red 147, and a sulphatoethylsulphone dye, CI Reactive Blue 250, were used. A non-ionic emulsifying detergent (Felosan RGN-S, CHT) was used for washing-off. The sodium chloride, sodium bicarbonate, sodium carbonate and Sodium edate were analytical grade.

2.2 METHODS

(a) Pad-steam dyeing

Fabric samples were dyed (20 g/l dye and the relevant salt and alkali or organic amine salt) by padding (two dip-two nip, BENZ laboratory padder, 70% liquor pick-up). The padded fabrics were then steamed (wet-temperature of 101 – 102°C, 100% moisture, Mathis laboratory steamer) for 60, 90 and 120 sec. For the conventional dyeings, the alkali used was sodium bicarbonate for the difluorochloropyrimidine (Red 147) and sodium carbonate for the sulphatoethylsulphone (Blue 250).

(b) Washing-off

The dyed fabrics were rinsed with cold then hot water, soaped with 2 g/l non-ionic detergent at the boil for 15 min, and then rinsed with hot water until bleeding stopped. The fabrics were finally rinsed with cold water and dried.

(c) Industrial scale dyeing

In order to validate and compare the effectiveness of sodium edate under production conditions two 50 m lengths of bleached cotton woven fabrics (156 g/m^2, plain weave) were dyed (20 g/l of Reactive Red 147) on a Benninger pad-steam range in an industrial dye-house. The new dyeing was carried out using sodium edate (100g/l). The conventional dyeing was carried out with the mill's standard recipe of 30 g/l sodium chloride and 15 g/l sodium bicarbonate. Commercial grade chemicals were used for the trial. The fabric was padded (70% liquor pick-up, ambient temperature), steamed (wet-temperature of 100-102°C, 100% moisture, 60 and 120 sec), washed-off (see Table 1) and then dried.

Table 1: Washing-off conditions on Benninger Dyeing Range

Parameters	Washing tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6
Temp (oC)	35	80	90	90	90	35
Soaping	-	-	2 g/l detergent	-	-	-
Flow rate (litre/min)	40	30		30		

*slightly anionic (Perlavin RIS, Dr Petry)

2.3 MEASUREMENTS AND ANALYSIS

(a) Colour yield and dye fixation

Colour yield (*K/S* value) was determined using a Datacolor 600 spectrophotometer at the maximum absorption. The specific measurement settings were: 30 mm sample aperture, illuminant D65, UV included, specular component included, reflectance mode and 1964 (10°) CIE Supplementary Standard Observer. Colour yield (*K/S*) was measured as final *K/S* value after washing-off. The approach for determining the extent of dye fixation using *K/S* values, used by other researchers [16-19], was followed. The percentage of reactive dye fixed on the fabric was measured using the equation;

$$\%F = [\,(K/S) / (K/S_{before\ washing\text{-}off})\,] \times 100. \qquad (1)$$

(b) Colourfastness testing

Fabric samples, dyed and washed-off, were tested for colourfastness to rubbing (AS 2001.4.3 – 1995), to washing (AS 2001.4.15C – 2006) and to light (AS 2001.4.21 – 2006). For comparing colourfastness properties, the shade depth of samples dyed using optimum sodium edate were matched with the samples dyed using optimum conventional chemicals.

(c) Effluent testing

Sodium edate and conventional dyeing effluent samples were collected from washing tanks during the industrial production run and tested for *pH*, *TDS* (Eutech Instruments), *COD* (HACH 8000) and *BOD* (HACH 10099).

3. RESULTS & DISCUSSIONS

As in Ahmed's work [15], sodium edate acts as an electrolyte when dissolved in water and can substitute the inorganic salt for promoting dye exhaustion. Because the amino groups in sodium edate provide a pH of 10 – 12 when dissolved in water, it can also replace the inorganic alkali used to activate dye-fibre reaction. The dye-fibre reaction between dye molecules and cellulose using sodium edate is believed to be same as using an inorganic alkali, i.e. a nucleophilic substitution mechanism in case of difluorochloropyrimidine dye and nucleophilic addition mechanism in case of sulphatoethylsulphone dye [1-2].

Following discussion identifies the optimum chemical concentrations for conventional pad-steam dyeing. Then it presents the effect of sodium edate concentration and steaming time on results of pad-steam dyeing of cotton with reactive dyes. The optimum results are compared with the optimum conventional pad-steam dyeing. The discussion concludes with results of an industrial trial with its effluent analysis.

3.1 OPTIMUM CONCENTRATIONS FOR CONVENTIONAL PAD-STEAM DYEING

Optimum colour yield and dye fixation were obtained with 50 g/l sodium chloride and 15 g/l sodium bicarbonate for CI Reactive Red 147 and 15 g/l sodium carbonate for CI Reactive Blue 250 at 60 sec steaming (Fig. 1).

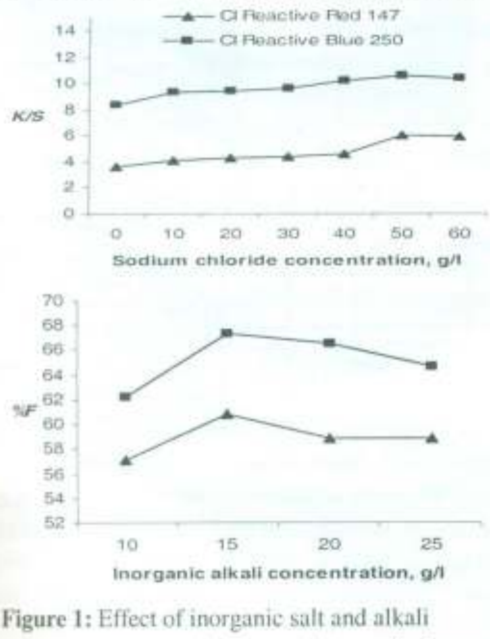


Figure 1: Effect of inorganic salt and alkali concentrations on pad-steam dyeing results

3.2 EFFECT OF SODIUM EDATE CONCENTRATION

Figure. 2 shows that both colour yield and dye fixation increased then decreased with increasing concentration of sodium edate. The optimum result is obtained at about 100 g/l of sodium edate. The optimum concentration of sodium edate was higher than that of inorganic chemicals in conventional dyeing. This is because the aqueous ionic strength of each of the organic salts is lower than that of sodium chloride and sodium bicarbonate / sodium carbonate together; thus, more organic amine salt is needed to achieve the required electrolytic effect for dye sorption [20-21].

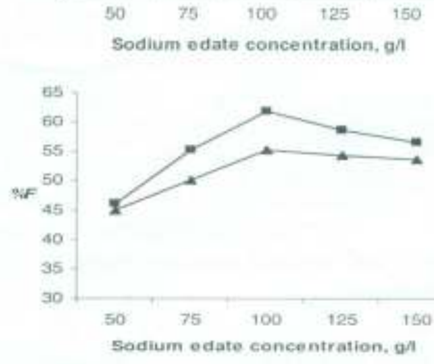


Figure 2: Effect of sodium edate concentration on colour yield and dye fixation at 60 sec steaming

3.3 EFFECT OF STEAMING TIME

Steaming of the fabric padded with reactive dye expedites dye-fibre reaction and promotes dye penetration into the fibre in presence of an electrolyte [22]. The steaming conditions in conventional pad-steam dyeing are always fixed, i.e. temperature of 102 – 104°C and 100% moisture. Therefore, the key process parameter is steaming time. To study the effect of steaming time, the range of up to 120 sec was selected, which is the maximum time for the industrial pad-steam dyeing machines. The effect of steaming time on colour yield and dye fixation with the optimum concentration of sodium edate is given in Fig. 3. The figure shows that colour yield and dye fixation continued to increase with steaming time.

Steaming time to maximum yield and fixation was not determined because the time exceeds standard industry practice.

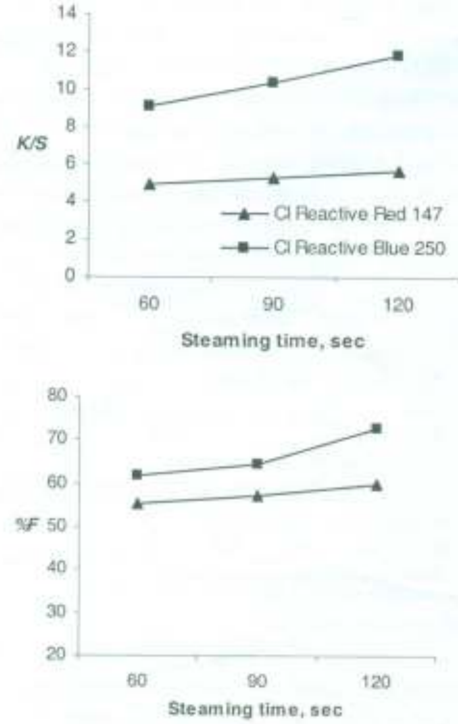


Figure 3: Effect of steaming time on colour yield and dye fixation with optimum concentration of sodium edate

4. COMPARISON BETWEEN SODIUM EDATE AND CONVENTIONAL DYEINGS

(a) Colour yield and dye fixation

The colour yield and the dye fixation of dyed fabric using optimum sodium edate and inorganic chemicals were compared and analysed at 60 and 120 sec steaming. Figure. 4 shows that the yield and fixation results for the sodium edate and conventional dyeings were significantly comparable. Use of sodium edate resulted better at 120 sec steaming where colour yield and dye fixation were effectively identical to those obtained in conventional dyeings.

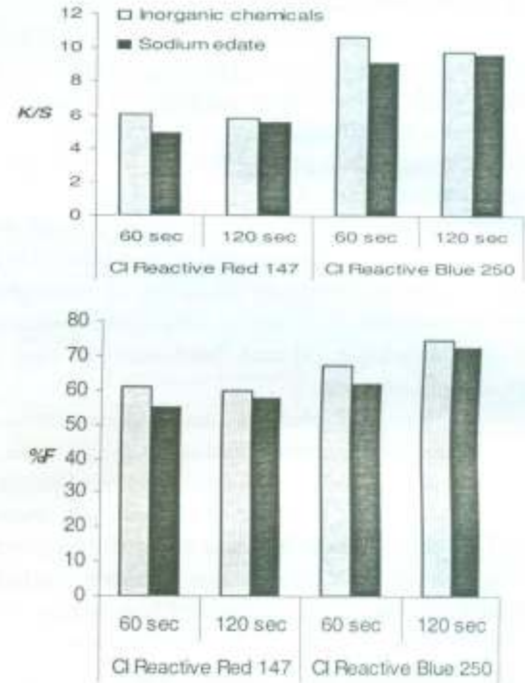


Figure 4: Colour yield and dye fixation of optimum sodium edate and conventional dyeings

(b) Colourfastness

As shown in Table 2, the colourfastness to rubbing, washing and light of the sodium edate dyeings are generally good to excellent and similar to that of the conventional dyeings. This encourages the use of sodium edate for successful pad-steam dyeing of cotton with reactive dyes.

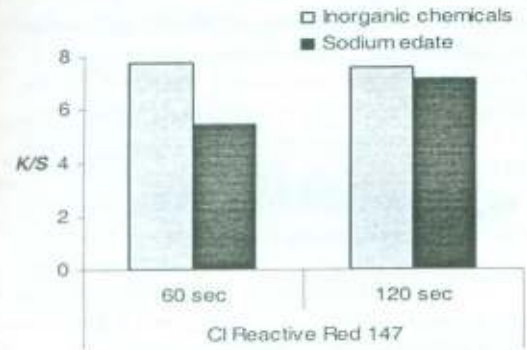
Table 2: Colourfastness of dyed cotton fabrics using optimum chemical concentrations

Dye	Dyeing	Rubbing fastness (Grey scale rating)		Washing fastness (Grey scale rating)		Light fastness
		Dry	Wet	Change in colour	Staining on white*	Blue wool reference
CI Reactive Red 147	Conventional	4-5	4	4-5	4-5	5
	Sodium edate	4-5	4	4-5	4-5	5
CI Reactive Blue 250	Conventional	4-5	4	4-5	4-5	3-4
	Sodium edate	4-5	4	4-5	4-5	3-4

All adjacent white fibres, secondary cellulose acetate, cotton, polyacrylonitrile, polyester, polyamide and wool, had same value (4-5).

5. INDUSTRIAL DYEING RESULTS

Figure. 5 shows the colour yield and fixation obtained with sodium edate were closely equivalent to those obtained with sodium chloride and sodium bicarbonate at 120 sec steaming. The colour yield and fixation achieved under production conditions were higher than those obtained on laboratory scale because the fabric used for production had a lower mass per unit area.



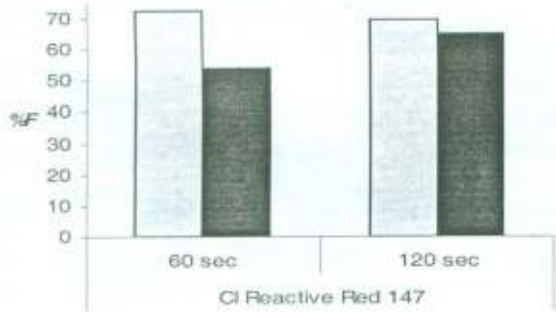


Figure 5: Colour yield and dye fixation of optimum sodium edate and conventional dyeings at production scale

(a) Effluent analysis

The results are shown in Table 3. It can be seen that sodium edate provided a 30% reduction in *TDS* and significantly lower levels of *COD* and *BOD* in the effluent. These results are highly encouraging because the higher cost of sodium edate relative to inorganic chemicals may be offset, in whole or part, by the costs of effluent purification or by load-based penalties on more polluted effluent.

Table 3: Effluent test results

Effluent sample	*pH*	*TDS* (ppm)	*COD* (ppm)	*BOD* (ppm)
Conventional dyeing	8	1000	82	28
Sodium edate dyeing	8	700	15	6

6. CONCLUSIONS

This investigation has shown that tetrasodium ethylene diamine tetra-acetate can be used for pad-steam dyeing of cotton with reactive dyes to improve the quality of dyeing effluent. Colour yield, dye fixation and colourfastness results of sodium edate dyeing are equivalent to those of conventional dyeings. On one hand the proposed dyeing using sodium edate is comparatively more expensive but on other hand the effluent characteristics, when using sodium edate, are markedly improved. Thus, it is suggested that refinements to the use of organic amine salts may lead to opportunities for further reductions in effluent loads from cotton dye-houses.

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COMPUTER SIMULATION OF A 3-ф SQUIRREL-CAGE INDUCTION MOTOR BY USING VISUAL BASIC 6.0

DR. NIAZ AHMED MEMON*

ABSTRACT

Computer Simulation is a well-known technique of understanding, testing as well as developing real systems in Engineering and Science. The author has been working on this since 1990-91. Initially, senior members of the research group at the University of Sussex UK did Computer Simulation of a single-phase squirrel-cage induction motor by using FORTRAN 77 as a programming tool [09]. The author accepted the challenge for an interactive simulation of a 3-ф squirrel-cage induction motor to cope with the so demanding investigations of systems using 3-ф squirrel-cage induction motors. Thorough investigation of the programming languages available was carried out at that time and ultimately Microsoft QBASIC 4.5 was chosen to perform the task. That was later on presented [1] for understanding trends and various operational modes of a thyristor fed, phase controlled induction motor (three-wire) model [2].

In this paper, Computer Simulation of the same model [2] is presented in Microsoft Visual Basic 6.0 by taking advantage of the tremendous growth of the Computer Programming Languages. This simulation extends the author's research work by utilizing the effectiveness of Microsoft Visual Basic 6.0 for its visual as well as graphical representation. This drifts up the researchers for a wider range of investigations and analysis options for research and development in the field.

1. INTRODUCTION

Microsoft Visual Basic 6.0 offers great visual as well as graphical representation which has been effectively utilized for the computer simulation of an induction motor model [2], previously performed by the author in the Microsoft QuickBasic 4.5 [1]. This is presented for a thyristor fed, phase controlled induction motor (three-wire) system. The simulation performed offers a highly effective solution for investigations and analysis of a variable voltage phase-controlled induction motor system by using inherent features of Visual Basic 6.0.

Complete study and graphical representation snap shots are presented. Simulation results presented deliberate their correctness while compared with the previous simulation results.

1.1 BACKGROUND

Modeling and simulation is becoming an important tool in solving and understanding numerous and diverse problems [10, and 11]. Computer programming and its versatility has given it a new trend especially when the computer simulation of real systems is concerned. This is proved as a comprehensive result of the computer simulations carried out by the author. It is a continuous process. This is clearly shown that the simulation in Microsoft Visual Basic 6.0 is more effective as compared to the one in FORTRAN 77 and even the one in Microsoft QBasic 4.5 [1]. This simulation is based on d-q axes model of 3-ф squirrel-cage induction motor which is widespread [1, 2, 6, and 07] for the machine analysis.

2. INDUCTION MOTOR MODEL ILLUSTRATION

Keeping in view the fact that; the squirrel cage induction motor inherently being less expensive and robust is extensively used in a variety of systems for various applications [3, 4, 08 and 12]. Thyristor, phase controlled induction motor system shown in figure -1 is simulated. In which voltage is applied to the motor stator windings by using back-to-back connected thyristors as controlled switches in series with the stator.

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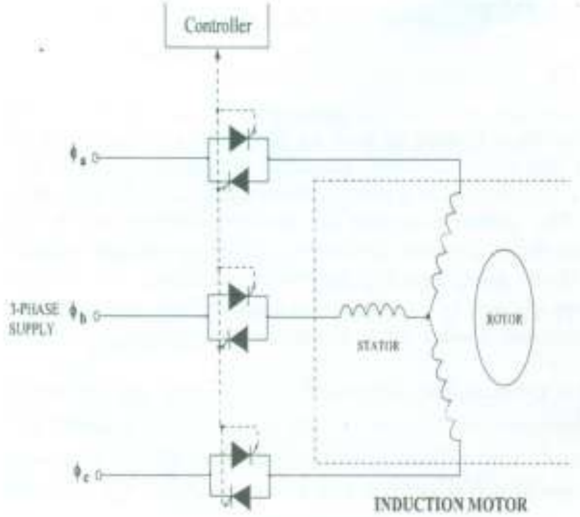

Figure 1: Induction Motor System

An equivalent scheme Figure-2 replaces thyristor pairs with switches S_1, S_2, S_3 in series with the 3-ϕ supply voltages at ϕ_a, ϕ_b, ϕ_c and a three-phase star-connected motor stator with phases as, bs, cs respectively.

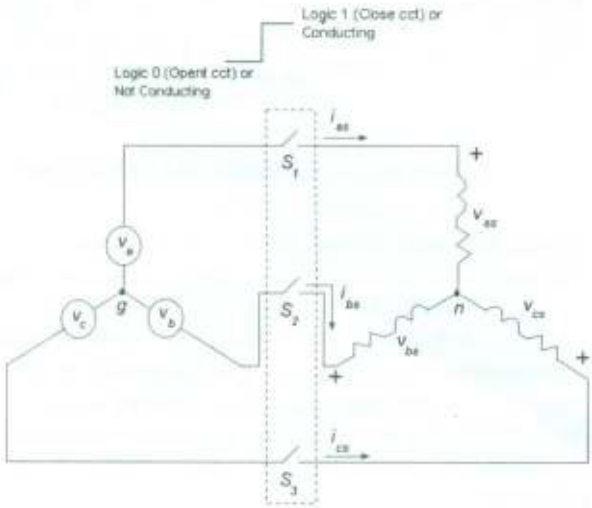

Figure 2: Stator Circuit with Switches

2.1 MATHEMATICAL REPRESENTATION

Chattopadhyay A [2] suggests d-q axes for phase control configuration for computer simulation of the squirrel-cage induction motor model. This along with generalized motor performance equations and their transformation to d-q axes representation and vice versa [5], for calculating instantaneous real values of the induction motor operational parameters is used as a base in the simulation. Five operational modes are worked out for a system figure-2, given as:

Mode	S_1	S_2	S_3	S	Φ-a	Φ-b	Φ-c	i_{as}	i_{bs}	i_{cs}
I	1	1	1	1	Conducting	Conducting	Conducting	Non-Zero	Non-Zero	Non-Zero
II	0	1	1	1	Open	Conducting	Conducting	Zero	Non-Zero	Non-Zero
III	1	0	1	1	Conducting	Open	Conducting	Non-Zero	Zero	Non-Zero
IV	1	1	0	1	Conducting	Conducting	Open	Non-Zero	Non-Zero	Zero
V	0	0	0	0	Open	Open	Open	Zero	Zero	Zero

During the analysis of this system, core losses, space harmonics and magnetic saturation are neglected.

Generalized set of equations [2, 5] are given below. Putting an appropriate state of the switches can drive equations for an individual mode of operation.

$$\frac{\rho}{\omega_b}\bar{i} = \bar{X}_g^{-1}(\bar{v}_g - \bar{R}\,\bar{i}) \qquad (1)$$

Where $\bar{v}_g$ is generalized voltage vector and $\bar{X}_g^{-1}$ is an inverse generalized reactance matrix, and are written in terms of the logic variables S_1, S_2, S_3, and S as below;

$$\bar{v}_g = \begin{bmatrix} S_1\left\{\dfrac{(S_2 - S_3)v_a - S_2 v_b - S_3 v_c}{(1 + S_2 + S_3)}\right\} \\ \dfrac{1}{2\sqrt{3}}\{S_1(S_2 - S_3)v_a - S_2(1 + S_3)v_b + S_3(1 + S_2)v_c\} \\ 0 \\ 0 \end{bmatrix}$$

and $\bar{X}_g^{-1} = \dfrac{1}{x_s x_r - S x_m^{\ 2}} \times$

$$\begin{bmatrix} x_s - S_2S_3(1-S_1)\frac{x_m^2}{x_r} & 0 & -S_1(S_2S_3+3)\frac{x_m}{4} & S_1(S_3-S_2)\frac{\sqrt{3}}{4}x_m \\ 0 & x_s & S_1(S_3-S_2)\frac{\sqrt{3}}{4}x_m & -(S_2+S_3+2S_2S_3)\frac{x_m}{4} \\ -x_m+S_2S_3(1-S_1)\frac{x_m^3}{x_sx_r} & 0 & x_r-(S_2+S_3+2S_2S_3-4S_1S_2S_3)\frac{x_m^2}{x_r} & S_1(S_2-S_3)\frac{\sqrt{3}x_m^2}{4x_r} \\ 0 & -x_m & S_1(S_2-S_3)\frac{\sqrt{3}x_m^2}{4x_r} & x_r-S_1(1-S_2S_3)\frac{3x_m^2}{4x_r} \end{bmatrix}$$

and S in terms of the logic variables S_1, S_2 and S_3, is given as $S = S_1 * S_2 + S_3(S_1 + S_2 - 2S_1S_2)$

Equations for any of the five operational modes can be obtained from the generalized form by substituting the appropriate values of S_1, S_2 and $S3$. Where as the electromagnetic torque in terms of d-q variables, and Per unit rate of change of synchronous speed are calculated as;

$$T_E = x_m\left(i_{qs}i_{dr} - i_{ds}i_{qr}\right) \quad (2)$$

$$\rho\omega = \frac{T_E - T_L}{2H} \quad (3)$$

ω is the per-unit rotational angular speed and is equal to $\frac{\omega_r}{\omega_b}$; where ω_b is the base angular speed $(2\pi f)$ and ω_r is the rotating angle speed i_{qs}, i_{ds}, i_{qr}, and i_{dr} are the respective d-q axes stator and rotor currents, ρ is the operator $\frac{d}{dt}$. Equations above are used to compute the performance of Induction Motor.

3. SIMULATION DETAILS

Input / motor parameters [1, 2, 09].;

Stator and rotor resistance and reactance (R_s, R_r, *and* X_s, X_r, X_m) are;

$R_{S=0.0386}$

$R_{r=0.0541}$

$X_{s=2.1440}$

$X_{r=2.1440}$

$X_{m=2.20400}$

Inertia ($H = 0.2200$),

Number of pole pairs (P),

Supply frequency (FS),

Load torque (TL),

Integration step time duration ($TINCRT$),

Data display time length ($JPRINC$),

Time to apply the load torque (TLS),

Type of operation i.e., direct-on-line operation ($DOL = 1$),

First firing time ($TFFP$),

Width of notch (γ) i.e., thyristor hold-off time,

Motor speed (WPU),

Time and total duration to store the data into appropriate files on a disk (*TDT and TDATA*),

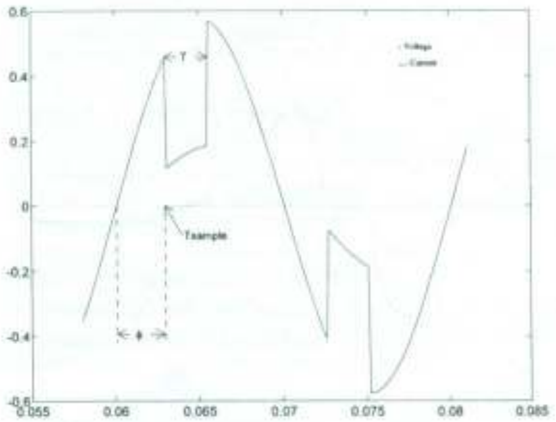

Figure 3: Definition of Various Terms on VI

Time range for graphical display (*TRANGE*), and maximum simulation run time (*TMAX*)

The simulation program run for a 3-ф, 415 V, 50 HZ, 4.1 A, 2.5 hp, squirrel cage induction motor with the basic per unit values as mentioned above.

The program flow chart is given below in Figure 4.

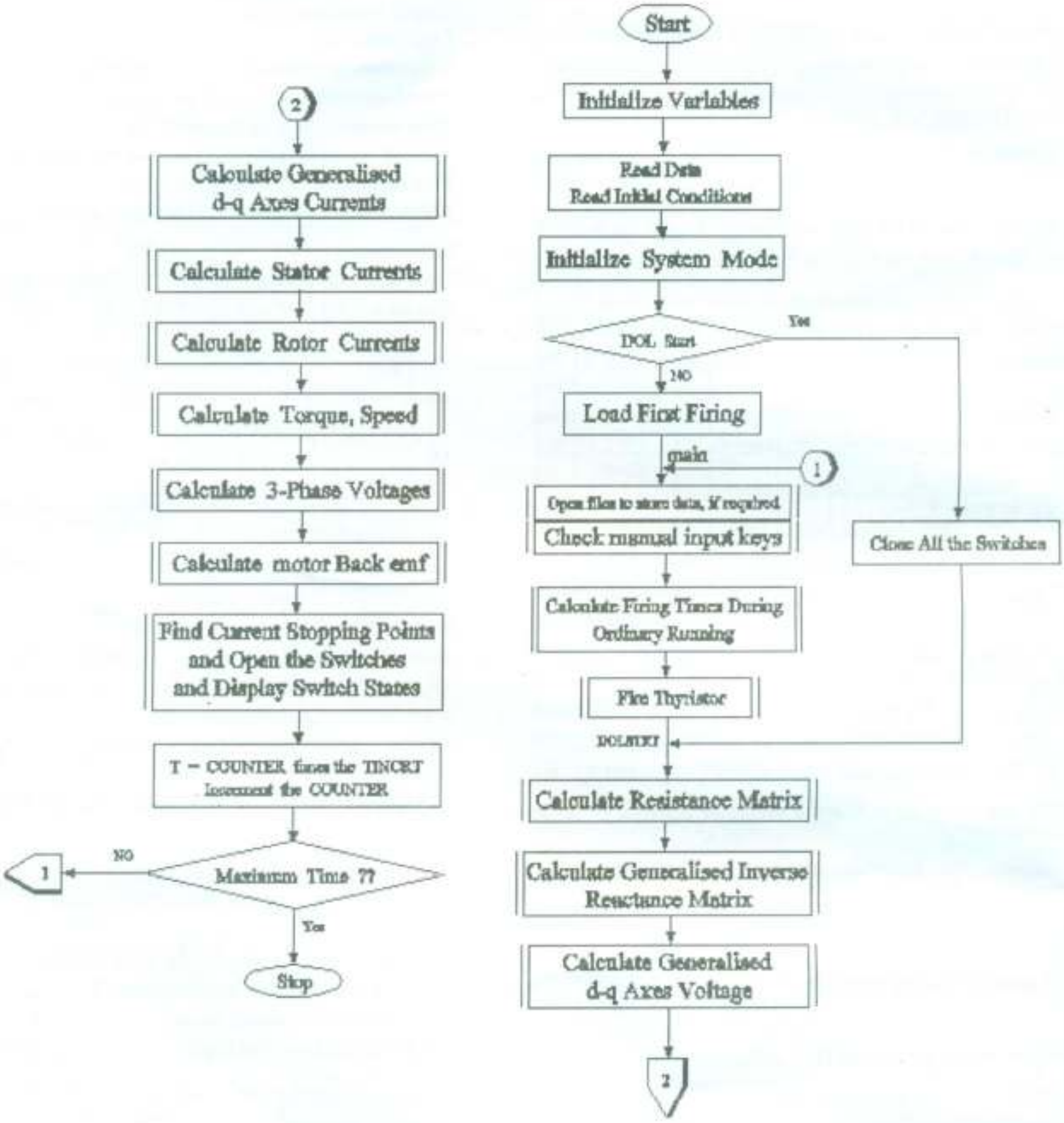

Figure 4: Main Program Flowchart

The program is fully interactive, specifically utilizing the visual as well as graphical features of VB 6.0.

3.1 SIMULATION RESULTS

Investigation of direct-on-line start (i.e., $S_1 = S_2 = S_3 = S = 1$ figure-5) as well as setting up the soft start figure-6 is an interesting feature of the author's computer simulation [1]. This can now be studied and researched more effectively with this new simulation in VB 6.0 Visualization feature and real time graphical representation of the transient behavior of the simulated system that eases in developing the required application oriented systems.

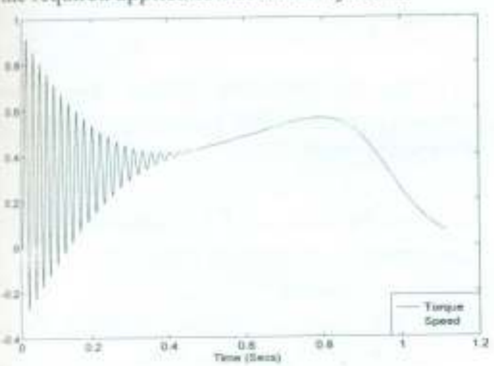

Figure 5: DoL Motor Torque, and Speed [1].

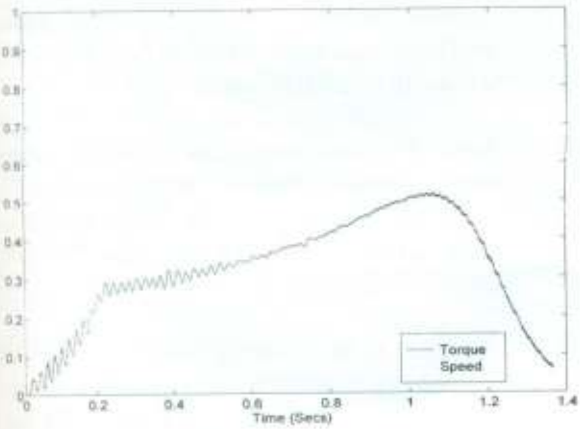

Figure 6: Motor Torque, and Speed, during soft start [1].

Figures below compare the Motor terminal voltages and currents at a certain rate of γ (gamma). Figure -7 is the simulation already presented In Microsoft QBASIC 4.5 [1] for comparison and measurement of the exactness of new simulation. Where as Figure -8 shows the new simulation results in Visual Basic 6.0.

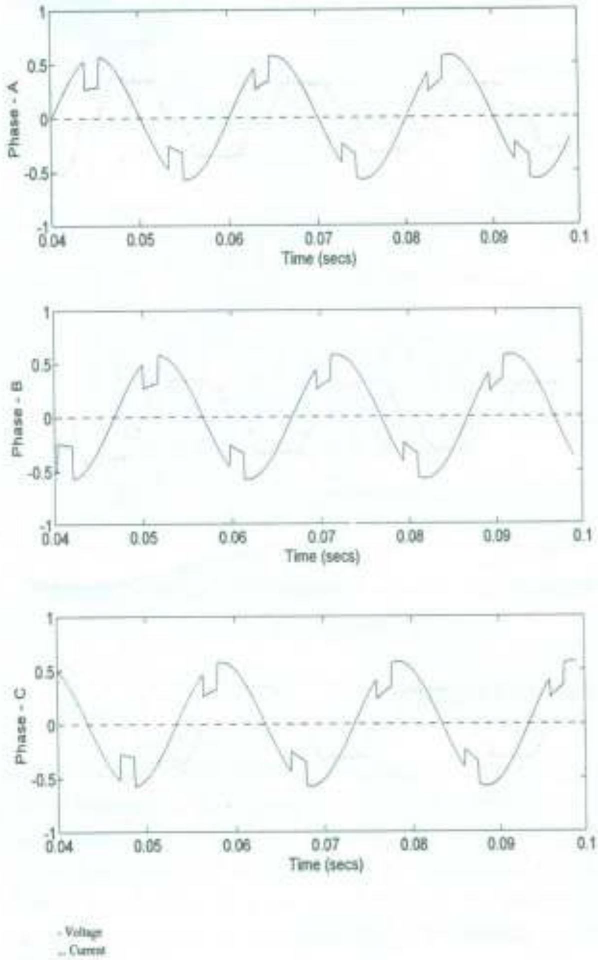

Figure 7: Three Phase Voltages and Currents ($\gamma = 30^0$, Per Unit Speed = .97) [1].

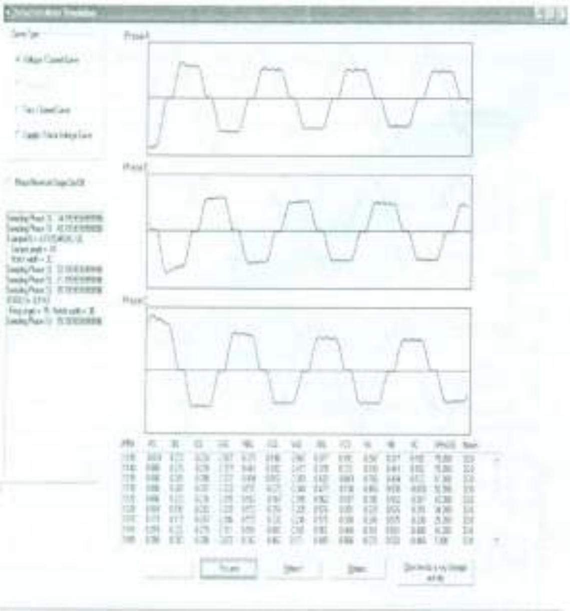

Figure 8: Three Phase Voltages and Currents ($\gamma = 30^0$, Per Unit Speed = .97)

4. CONCLUSIONS

Conclusively, computer simulation based research and development is a continuous process. Development of the programming paradigms gives it a new shape each time. That is accordingly incorporated for a thyristor fed, phase controlled 3-ϕ squirrel-cage induction motor based system for a variety of applications as a competitor for an expensive system based on DC motors. Simulation results of the Visual Basic 6.0 model have been accordingly tested for various operational modes of the simulated system and exactness of this new simulation has been verified. 3-ϕ Voltage and Current waveforms have been presented in this paper.

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I am indebted to the QUEST Nawabshah where I have been able to explore my work. Also I am thankful to my faculty members Mr. AR Nizamani and Mr. Fareed Ahmed Jukhio who helped me specifically at a very initial stage of this new simulation.

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NUMERICAL SOLUTION OF SINGULAR TWO-POINT BOUNDARY VALUE PROBLEMS USING GALERKIN'S FINITE ELEMENT METHOD

SHAUKAT IQBAL*, NISAR AHMED MEMON**

ABSTRACT

Galerkin's finite element method is presented for numerical solution of singular two-point boundary value problems (BVPs) for certain ordinary differential equation having singular coefficients. These problems arise while reducing partial differential equations to ordinary differential equations by physical symmetry. The numerical results show the capability of Galerkin's finite element method, to remove the difficulty of convergence due to singularity for singular BVPs. Some examples are given to demonstrate the effectiveness of the method and comparison of the numerical results made with the exact solutions.

Keywords: Galerkin Method, Finite Element Method, Ordinary Differential Equations, Singular Points, Boundary Value Problems.

1. INTRODUCTION

Galerkin's Finite Element Method (FEM) is one of the computational techniques for obtaining approximate solutions to many complicated problems that would be intractable by other techniques [1, 2]. The method involves dividing the domain of solution into a finite number of simple sub-domains, the finite elements. It is a well established numerical technique. In this paper, the method of weighted residual in Galerkin's finite element formulation is used for obtaining smooth approximations to the solution of a system of second-order singular two-point boundary value problems (BVPs) of the type:

$$y''(x)+\frac{1}{x}y'(x)+q(x)y(x)=f(x), \qquad (1)$$

subject to the boundary conditions

$$y(a)=\alpha_1 \quad \text{and} \quad y(b)=\alpha_2 \qquad (2)$$

where $q(x)$ and $f(x)$ are continuous functions on $(0,1]$ and α_1, α_2 are real constants. These problems (1)–(2) are generally encountered in many areas of science and engineering e.g., in the fields of fluid mechanics, elasticity, reaction–diffusion processes, chemical kinetics and other branches of applied mathematics [3]. Numerical solutions of these problems are of great importance due to its wide application in scientific research. Singular BVPs have been studied by several researchers. Convergence difficulties have been faced due to the singularity at $x=0$ on the left side of the differential equation (1). Attempts by many researchers for the removal of singularity are based on using the series expansion procedures in the neighborhood $(0,\delta)$ of singularity (δ is vicinity of the singularity) and then solve the regular boundary value problem in the interval $(\delta,1)$ using any numerical method. Kamel Al-Khaled [4] used the Sinc-Galerkin method and homotopy-perturbation method (HPM) to search for approximate solutions of a certain class of singular two-point BVPs. Junfeng Lu [5] used variational iteration method (VIM) to solve two-point BVPs.

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Abu-Zaid et al [6] provided a finite difference approximation to the solution of the above problems. A method based on cubic splines for solving a class of singular two-point BVPs was presented by Ravi Kanth and Reddy [7]. Recently, Bataineh [8] extended application of the modified homotopy analysis method for singular two-point boundary value problems and Ravi Kanth [9] demonstrates the differential transform method for the solution the same problems. The existence of a unique solution of (1)–(2) was discussed in [6, 10].

The aim of this paper is to introduce a numerical technique as an alternative to the existing numerical methods to remove the difficulty of convergence due to singularity at $x=0$ in solving singular two-point BVPs and solutions are computed in the entire domain. Once the solution has been computed, the information required for FEM interpolation between mesh points is available for the entire solution domain. This is particularly important when the solution of the boundary-value problem is required at different locations in the solution interval $[a,b]$.

The paper is organized as follows. In Section 2, the Galerkin's finite element formulation is formulated using linear Lagrange polynomial. Comparison with exact solutions and discussion regarding results of three examples is given in Section 3 and 4.

2. GALERKIN'S FINITE ELEMENT FORMULATION

The Galerkin's method [1, 2, and 12] in the finite element context requires that we choose a suitable trial or basis function that is applied locally over a typical finite element in the complete x domain. Let us denote this trial function by $\bar{y}$. In this case it is necessary to satisfy inter-element compatibility with respect to displacements. In other words the trial function is C^0-continuous. Each element has two nodes. We interpolate the function at each node of the element. This requires one unknown parameters at each node of the element. Let the unknown trial function $\bar{y}=a_1+a_2x$ for any arbitrary element of the discretized region. Rather than formulating the problem in terms of arbitrary constants a_1 and a_2, we prefer to express the linear trial function in terms of values of the dependent functions at nodes i and j (the convention used by Zienkiewicz, Stasa and Shaukat Iqbal et al. [1, 2 and 12]).

$$\bar{y}(x)=N_1y_i+N_2y_j \quad (3)$$

$$\bar{y}(x)=[\mathbf{N}]\{\mathbf{y}\} \quad (4)$$

Here $\{\mathbf{y}\}^T=\begin{bmatrix} y_i & y_j \end{bmatrix}$ and $[\mathbf{N}]=\begin{bmatrix} N_1 & N_2 \end{bmatrix}$ are the matrices of interpolation functions and $N_1=x_j-x/x_j-x_i$ & $N_2=x-x_i/x_j-x_i$, the trial function constants now are the nodal variables of the dependent variable $\bar{y}$.

Now, the governing differential equation (1) can be written as:

$$\frac{d}{dx}(x\frac{dy}{dx})+xq(x)y=xf(x) \quad (5)$$

Galerkin's finite element formulation as given in [1, 2, and 12], is used for our particular problem and after substituting the trial functions, the equation (5) can be written in discretized form as:

$$wx\bar{y}'\Big|_{X_1}^{X_2}-\sum_{e=1}^{n}\left[\int_{X_e}xw'\bar{y}'dx-\int_{X_e}xwq(x)\bar{y}dx+\int_{X_e}xwf(x)dx\right]=0 \quad (6)$$

where $'e'$ represents the element and $'n'$ represents the total number of elements in the discretized region. Writing equation (6), in matrix form, we obtain:

$$\sum_{e=1}^{n}\left(\int_{X_e}x\left[\mathbf{N}'\right]^T\left[\mathbf{N}'\right]\{y\}dx-\int_{X_e}xq(x)[\mathbf{N}]^T[\mathbf{N}]\{y\}dx\right) \quad (7)$$
$$=[\mathbf{N}]^T x\bar{y}'\Big|_{X_1}^{X_2}-\sum_{e=1}^{n}\int_{X_e}x[\mathbf{N}]^T f(x)dx$$

The equations for the elements must combine in such a manner that only the boundary terms for element nodes on the region boundary will contribute; all other terms for interior nodes will be zero. This implies that the boundary terms for elements at common interior nodes cancel each other. Therefore, equation (7) in matrix notation can be written as:

$$[\mathbf{K}]\{\mathbf{y}\}=\{\mathbf{F}\}+\{\mathbf{Q}\} \quad (8)$$

where $\mathbf{K}$ is a stiffness matrix, $\mathbf{F}$ is a force vector and $\mathbf{Q}$ is a vector regarding boundary conditions.

3. NUMERICAL RESULTS AND DISCUSSIONS

In this section, we illustrate the numerical scheme by three singular two-point boundary value problems, which have been discussed in literature [4, 5, 8, 9 and 11].

Example 1.

First we consider the following singular two-point boundary value problem [8, 9 and 11]:

$$y''(x)+\frac{1}{x}y'(x)+y(x)=f(x) \tag{9}$$

where

$$f(x)=4-9x+x^2-x^3 \quad 0<x\le 1, \tag{10}$$

subject to the boundary conditions

$$y(0)=0 \quad \text{and} \quad y(1)=0. \tag{11}$$

Equation (15) can be formed as:

$$\frac{d}{dx}\left(x\frac{dy}{dx}\right)+xy-xf(x)=0. \tag{12}$$

The exact solution of (9) subject to (11) in this case is $y(x)=x^2-x^3$. Now, applying the procedure given in section 2, we will get:

$$wx\bar{y}'\Big|_{x_1}^{x_2}-\int_X xw'\bar{y}'dx+\int_X xw\bar{y}dx-\int_X wx(4-9x+x^2-x^3)dx=0 \tag{13}$$

Example 2.

Consider the following singular two-point boundary value problem [5, 8 and 9]:

$$y''(x)+\frac{1}{x}y'(x)+y(x)=f(x) \tag{14}$$

where

$$f(x)=\frac{5}{4}+\frac{x^2}{16} \quad 0<x\le 1, \tag{15}$$

subject to the boundary conditions

$$y(0)=1 \quad \text{and} \quad y(1)=17/16. \tag{16}$$

Equation (14) can be formed as:

$$\frac{d}{dx}\left(x\frac{dy}{dx}\right)+xy-xf(x)=0. \tag{17}$$

The exact solution of (14) subject to (16) in this case is $y(x)=1+\frac{x^2}{16}$. Now, applying the procedure given in section 2, we will get:

$$wx\bar{y}'\Big|_{x_1}^{x_2}-\int_X xw'\bar{y}'dx+\int_X xw\bar{y}dx-\int_X wx\left(\frac{5}{4}+\frac{x^2}{16}\right)dx=0 \tag{18}$$

Example 3.

Finally we consider the following singular two-point boundary value problem [4, 8 and 9]:

$$\left(1-\frac{x}{2}\right)y''(x)+\frac{3}{2}\left(\frac{1}{x}-1\right)y'(x)+\left(\frac{x}{2}-1\right)y(x)=f(x) \tag{19}$$

where

$$f(x)=5-\frac{29x}{2}+\frac{13x^2}{2}+\frac{3x^3}{2}-\frac{x^4}{2} \quad 0<x\le 1, \tag{20}$$

subject to the boundary conditions

$$y(0)=0 \quad \text{and} \quad y(1)=0. \tag{21}$$

Equation (19) can be formed as:

$$\frac{d}{dx}\left[(2x-x^2)\frac{dy}{dx}\right]+(1-x)\frac{dy}{dx}+(x^2-2x)y-2xf(x)=0. \tag{22}$$

The exact solution of (19) subject to (21) in this case is $y(x)=x^2-x^3$. Now, applying the procedure given in section 2, we get:

$$w(2x-x^2)y'\Big|_{x_1}^{x_2}-\int_X (2x-x^2)w'y'dx+\int_X (1-x)wy'dx+\int_X (x^2-2x)wydx$$
$$-\int_X wx(10-29x+13x^2+3x^3-x^4)dx=0 \tag{23}$$

The numerical results for examples 1, 2 & 3 are shown in Tables 1, 2 & 3 for 40 elements ($h=1/40$). The computed solutions compare very well with the exact solutions at various values of x. The numerical results presented in tables 1, 2 & 3 clearly show the existence of the solution at singular points, which reflects the potential of the Galerkin's finite element method. Due to the singularity at $x=0$ in the given examples, people neglect the effect of singularity on the solution and makes calculations in the immediate neighborhood of the singular point. Convergence difficulties faced by other numerical methods have been removed by formulating the singular BVPs by Galerkin's finite element method. These examples have been considered by Cui Geng [11], Junfeng [5] and Al-Khaled [4]. Figure. 1 shows the convergence of the maximum error for three examples with the decrease in the step size (decrease in element size) or increase in the number of elements. Results indicate the formulation is accurately approximating the solution.

4. CONCLUSIONS

Solutions of singular two-point boundary value problems have been investigated for certain ordinary differential equation having singular coefficients using Galerkin's finite element formulation. This method enables us to approximate the solution at every point of the domain of the problem. Convergence difficulties faced by other numerical methods due to singularity have been removed by formulating the singular BVPs by Galerkin's finite element method. The results obtained are very encouraging and FEM performs better than other existing numerical methods. Examples demonstrate that the numerical results of the finite element method are generally very accurate and in excellent agreement with the exact solution. The numerical results which are presented in Tables reinforce the conclusions made by many researches that the efficiency of the finite element method gives it much wider applicability.

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Table 1: Numerical Results for 40 elements of Example 1

$(h = 1/40)$

x	FEM	Exact	Error
0.0	0	0	0
0.1	9.1672E-3	9.0000E-3	1.6719E-4
0.2	3.2175E-2	3.2000E-2	1.7522E-4
0.3	6.3165E-2	6.3000E-2	1.6526E-4
0.4	9.6148E-2	9.6000E-2	1.4762E-4
0.5	1.2513E-1	1.2500E-1	1.2581E-4
0.6	1.4410E-1	1.4400E-1	1.0162E-4
0.7	1.4708E-1	1.4700E-1	7.6175E-5
0.8	1.2805E-1	1.2800E-1	5.0320E-5
0.9	8.1025E-2	8.1000E-2	2.4734E-5
1.0	0	0	0

Table 2: Numerical Results for 40 elements of Example 2

$(h = 1/40)$

x	FEM	Exact	Error
0.0	1.0	1.0	0
0.1	1.000626	1.000625	1.1074E-6
0.2	1.002501	1.002500	1.2826E-6
0.3	1.005626	1.005625	1.3221E-6
0.4	1.01000128	1.01	1.2827E-6
0.5	1.01562618	1.015625	1.1826E-6
0.6	1.022501	1.022500	1.0308E-6
0.7	1.0306258	1.0306250	8.3276E-7
0.8	1.04000059	1.0400000	5.9263E-7
0.9	1.05062531	1.05062500	3.1395E-7
1.0	1.0625	1.0625	0

Table 3: Numerical Results for 40 elements of Example 3

$(h = 1/40)$

x	FEM	Exact	Error
0.0	0	0	0
0.1	9.0723E-3	9.0000E-3	7.2331E-5
0.2	3.2063E-2	3.2000E-2	6.3038E-5
0.3	6.3052E-2	6.3000E-2	5.2129E-5
0.4	9.6042E-2	9.6000E-2	4.1548E-5
0.5	1.2503E-1	1.2500E-1	3.1753E-5
0.6	1.4402E-1	1.4400E-1	2.2924E-5
0.7	1.4702E-1	1.4700E-1	1.5174E-5
0.8	1.2801E-1	1.2800E-1	8.6319E-6
0.9	8.1003E-2	8.1000E-2	3.4807E-6
1.0	0	0	0

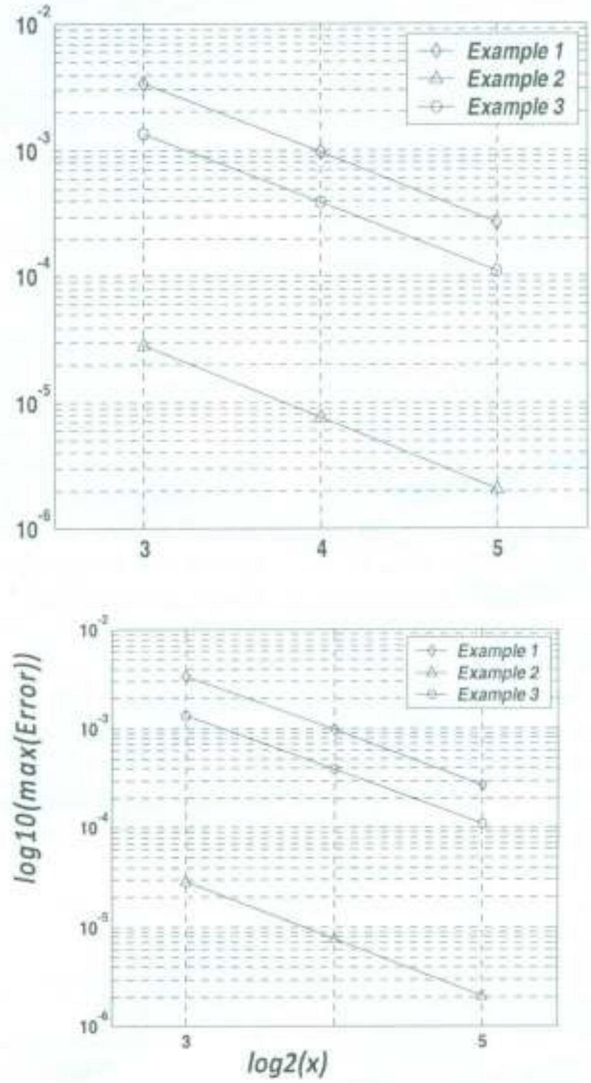

Figure 1: Error convergence with decreasing step size or increasing

USE OF SPATIO-TEMPORAL ASSOCIATION RULE MINING FOR HAZARD MITIGATION

ABDUL FATTAH CHANDIO*, AKRAM SHAIKH**, ATTAULLAH KHAWAJA***

ABSTRACT

This paper presents spatio-temporal based association rule mining approach for hazard mitigation. The main aim of this research is to formulate mechanism that can predict the occurrence of hazards. In this paper authors used association rule mining technique for prediction of hazards. In this research history of hazards that collected with reference of time and space is used. The Apriori algorithm based association rule mining is used for prediction of rules that may be used for hazard mitigation. These AI based rules potentially can be helpful to mitigate the catastrophic effects caused by natural hazards.

Key Words: Hazard Mitigation, Association Rule Mining, Spatio- Temporal Data Mining,

1. INTRODUCTION

Hazard mitigation is the most important and most attention required subject of these days, especially in the case of thickly populous countries like Pakistan, China or India. In these countries thousands of people are affected by various types of natural hazards annually. The most of fatalities in Pakistan regarding natural hazards are done because of lack technology and shortage education towards the awareness these hazards. The main theme of this research is the use of spatiotemporal data mining techniques to hazard mitigations and providing the future guidelines of developing hazard mitigation system.

Spatio-temporal applications have been increased in the last decade [1]. In spatio-temporal applications objects are related with each other in complex manner. The spatio-temporal databases provides platform for generation of new set of rules that may encompasses changes [2]. Data mining techniques are typically used for identification of unknown patterns that are embedded inside that data and useful for future strategy.

2. SPATIAL ASSOCIATION RULES

For this research, association rule mining can be used because to detect unknown relationships between different entities. Spatial association rules are those rules showing certain relationships among different geographical and non-geographical attributes which are spatially and temporally associated with each other. These objects/attribute are indicated as predicates [3, 4, 5]. Spatial association rule mining is a main derivative of the spatial data mining [7].

Spatial Association rule mining is of 'IF X THEN Y' format of rules. Here in this research rules are generated in the format of if X then Y followed by (Cover% Conf% Cover Count Sup Count Sup%,) defined in section 6.

3. SPATIO- TEMPORAL HAZARD ASSOCIATION RULE MINING

Here in this research database used for data mining is applied is arranged in a concept of hierarchical classification. Association rule mining of data that arranged in such concept is known as multiple level association rule mining [6,1]. The spatio-temporal process is used to show the response of particular event occurred on a geographical location during certain time interval. Objects can be described by spatial attributes, non-spatial attributes and their relationships with other objects and others indices [8]. It is evident from literature it is found that most of researchers faced problems while applying

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association rule mining over spatio-temporal data, which contains geographical maps, raster and vector shapes [9]. The use of association rule mining over spatio-temporal data means to dig out certain valuable unknown patterns from spatio-temporal data which are embedded inside. In this research this problem has been addressed by converting geographical data into table format and then processed for association rule mining. In this research the data selected for spatio temporal hazard rule mining is flood hazard data related to Pakistan.

4. FLOOD IN PAKISTAN

Pakistan is one of most severely affected country of flood hazards,139 floods has been recorded in different cities as shown in Figure-1. These floods resulted thousands of life losses and millions of displacements plus billions of revenue losses. The flood hazard study area is comprised of all portions of Pakistan that were actively affected from flood hazards.

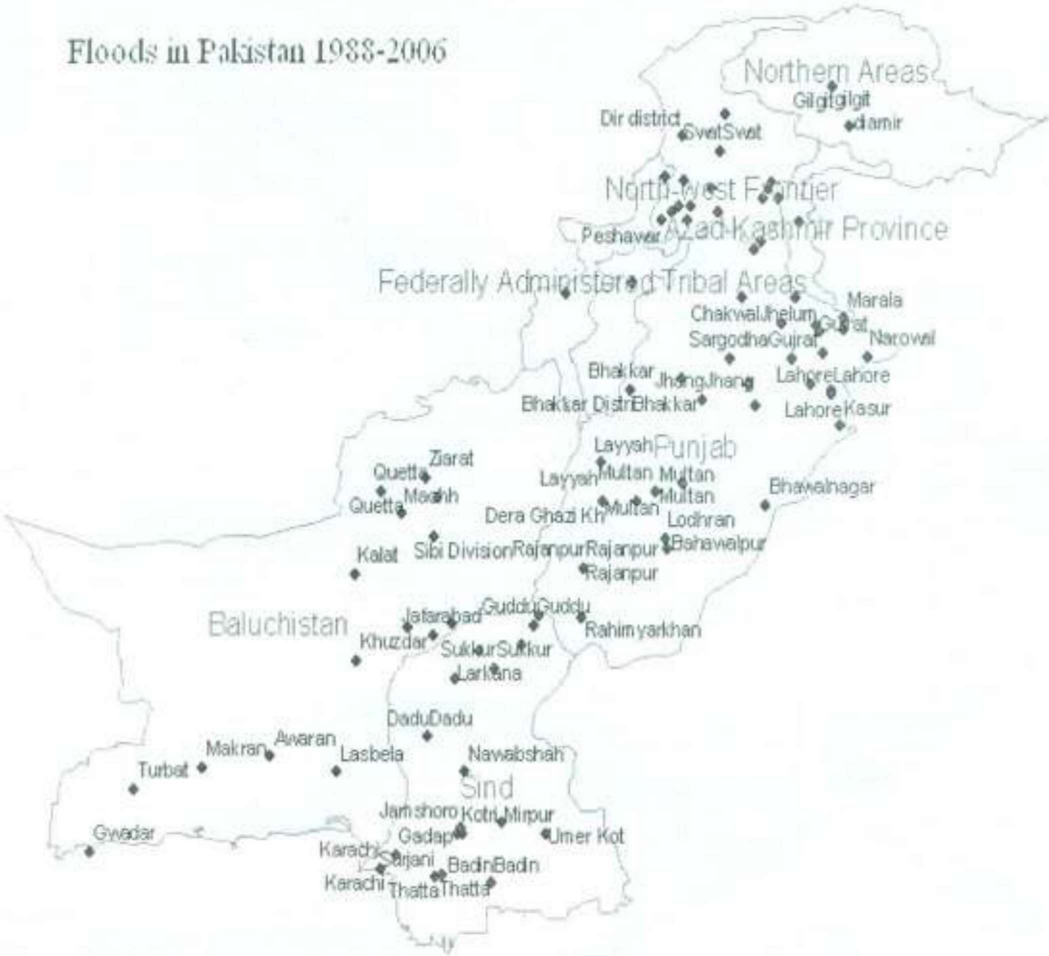

Figure 1: Floods in Pakistan 1988-2006 (name of cities)

The objectives of Association rule mining applied in this research is to dig out the patterns inside hazards database which contains data related to death toll of social population, effected area, names of places and the date of events. Note that the data about casualties were not available specifically so casualty indexes are added fictitiously. Figure-2 Floods in Pakistan 1988-2006 date wise events

Figure 2: Floods in Pakistan 1988-2006 date wise events

As it is mentioned above that it is very much complicated to process association rule mining over spatio-temporal data. Here GIS is used to preprocess spatio-temporal data and convert it into tabular format which can be accessed by association rule mining techniques. For association rule mining the Apriori based data mining software [9] is used in which the spatial data is used in tabular format.

Table 1: History of floods in Pakistan 1988-2006

Name of cities	year	month	Began	Ended	Dead	Displaced	Affected Region (sq km)	latitude	longitude
Bahawalpur	1988	sept	09/21/88	10/08/88	low	152	6,980	29.3900	71.6700
Gujrat	1988	sept	09/21/88	10/08/88	low	122	460	32.5600	74.0600
Lahore	1988	sept	09/21/88	10/08/88	high	2	1,220	31.5710	74.3130
Narowal	1988	sept	09/21/88	10/08/88	medium	3	125	32.1000	74.8830
Sialkot	1988	sept	09/21/88	10/08/88	high	2	1,235	32.5000	74.5170
Wazirabad	1988	sept	09/21/88	10/08/88	low	54	433,500	32.4500	74.1170
Gujranwala	1988	sept	09/21/88	10/08/88	high	123	460	32.1500	74.1800
Multan	1988	sept	09/21/88	10/08/88	high	21	1,430	30.1830	71.4830
Shahdara	1988	sept	09/21/88	10/08/88	none	32	1,232	31.6300	74.3100
Bhakkar District	1990	july	07/10/90	07/12/90	low	21	123	31.6330	71.0670
Charsadda	1991	jun	06/11/91	06/12/91	none	21	212	34.1400	71.7300
Nowshera	1991	jun	06/11/91	06/12/91	high	12	121	34.0170	71.9800
Peshawar	1991	jun	06/11/91	06/12/91	medium	21	1,255	34.0170	71.5500
Karachi	1992	aug	08/10/92	08/15/92	none	21	100	24.8670	67.0500
Bhawalnagar	1993	july	7/8/93	8/13/1993	medium	21	1,021	30.0000	73.2500
Faisalabad	1993	july	7/8/93	8/13/1993	medium	21	1,220	31.4170	73.0800
Gujranwala	1993	july	7/8/93	8/13/1993	high	1	433,500	32.1500	74.1800
Jhang	1993	july	7/8/93	8/13/1993	high	12	22,332	31.5000	72.2200
Kasur	1993	july	7/8/93	8/13/1993	high	4	6,980	31.1170	74.4500
Khanewal	1993	july	7/8/93	8/13/1993	none	12	3,213	30.3000	71.9330
Lahore	1993	july	7/8/93	8/13/1993	high	2323	460	31.5710	74.3130
Lodhran	1993	july	7/8/93	8/13/1993	high	212	122	29.5330	71.6330
Multan	1993	July	7/8/93	8/13/1993	high	122	1,232	30.1830	71.4830
------	------	------	------	------	------	------	----	------	------
------	------	------	------	------	------	------	------	------	------
------	------	------	------	------	------	------	------	------	------
Gilgit	2006	July	28-Jun-05	12-Jul-06	high	10	460	35.9170	74.3000
North Waziristan district	2006	July	1-Jul-06	13-Jul-06	Medium	50	6,980	33.0000	70.0000

5. RULES AND DISCUSSIONS

Form Table-1 showing the history of floods occurred in Pakistan 1988-2006, association rules has been generated for four main parameters; name of places, year of floods, month of floods and casualties rate which are mentioned periodically in Table-1.

Name of places that was affected by flood:
These attributes contains the names of different places where floods are occurred. Theses attributes has 85 different names of cities.

Year of flood: This shows years of floods that occurred ranging 1988 to 2006

Month of floods: Represents months of floods.

Casualties rate / death rate: This shows the rate of casualties, high, low, medium and none.

Table -2 to Table-5 are showing the statistics of different attributes, after applying association rule mining.

Table 2: Years of floods in Pakistan

Attribute Value	Frequency	Probability
1988	9	6.50%
1990	1	0.70%
1991	3	2.20%
1992	1	0.70%
1993	16	11.50%
1994	6	4.30%
1997	9	6.50%
1998	1	0.70%
1999	5	3.60%
2001	9	6.50%
2002	6	4.30%
2003	36	25.90%
2005	33	23.70%
2006	4	2.90%

Table 3: Months of floods in Pakistan

Attribute Value	Frequency	Probability
Aug	16	11.50%
Feb	8	5.80%
July	89	64.00%
Jun	10	7.20%
March	1	0.70%
May	5	3.60%
Sept	10	7.20%

Table 4: Casualties during floods in Pakistan

Attribute Value	Frequency	Probability
casualities_greater_then_100	51	36.70%
casualities_greater_then_10_less_then100	15	10.80%
casualities_less_then10	34	24.50%
none	32	23.00%

Table 5: Names of places and frequency of floods in Pakistan

Attribute Value	Frequency	Probability
Gwadar	1	0.70%
Awaran	1	0.70%
Badin	2	1.40%
Bagh district	1	0.70%
Bahawalpur	1	0.70%
Bhawalnagar	1	0.70%
Charsadda	2	1.40%
Chiniot	1	0.70%
Chitral	1	0.70%
Dadu	2	1.40%
Dera Ghazi Khan	3	2.20%
------	------------	----------
------	------------	----------
Umer Kot	1	0.70%

In this research 154 rules were generated from association rule mining related to flood disasters in Pakistan. However these rules are interesting and potentially helpful for hazard mitigations. Formation of rules is elaborated in section-6 Rule Format.

6. RULE FORMAT

Each rule has 'If X then Y' sentence followed by five range values parenthesized by square brackets; *(Cover% Conf% CoverCount SupCount Sup%,)*. The first one "*Cover%*"indicates the covering percentage, the percentage of occurrence of that attributed event (**X**) in total number of events. The second one *Conf%* is the confidence percentage, this shows percentage of occurrence of second attributed event (**Y**) while first event (**X**) is occurred. The third one "*CoverCount*" is derived by mean of count of X events out of all (flood) events. The fourth one "*SupCount*" is the counting of occurrence of both events (X & Y). and fifth one is the "*Sup%*" percentage of supporting count out of total number of events Here are few temporal rules that were generated.

Rule 1:

class = casualities_greater_then_100
-> month = July
(36.691% 64.71% 51 33 23.741%)

Rule 2:

month = July
-> class = casualities_greater_then_100
(64.029% 37.08% 89 33 23.741%)

Explanation of Rule #1: It shows the casualties more then 100 if flooding month is July, where:

1) **Cover%** =

$$\frac{\text{Total count of casualties greater then 100}}{\text{Total count of floods 1988 - 2006}} * 100 = \frac{51}{139} * 100$$

= 36.691%

2) **Conf%**=

$$\frac{\text{Count of floods with casualties greater then 100 in the month of july}}{\text{Count of floods with casualties greater then 100 out of total flood event}} * 100$$

$$= \frac{33}{51} * 100 = 64.71$$

3) **Total count of floods with casualties greater then 100** = 51

4) **Count of floods with casualties greater then 100 in the month of july** = 33

5) **Sup%** =

$$\frac{\text{Count of floods with casualties greater then 100 in the month of july}}{\text{Total count of floods 1988 - 2006}} * 100 = \frac{33}{139} * 100 = 23.741\%;$$

Similarly we can understand rule #2.

7. CONCLUSIONS

This research shows the importance spatio temporal data mining for mitigation of hazards. The main focus of this research is development of modular strategy based on spatio temporal hazard data mining for mitigation of hazards in Pakistan. This research shows how to identify proper time, that has more probability of floods in Pakistan. After implementation and analyzing association rule mining it is evident from the results that is month of July has more probability of floods in Pakistan. However, identification of useful patterns is complicated task and need sufficient amount of knowledge over spatio-temporal database. In this research, process of spatio-temporal association rule mining for hazard mitigation guidelines is provided. That composed of development of hazard database to implementation of association rule mining for mining out the useful patterns which are potentially helpful for future mitigation.

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USE OF GREAT - CIRCLE DISTANCE FOR AERIAL ROUTE GUIDING IN HILLY AREAS

ABDUL FATTAH CHANDIO*, ATTAULLAH KHAWAJA**

ABSTRACT

Path planning always remains hot issue in every era of civilization. It plays vital roles in all aspects of daily life. However, this issue becomes crucial during emergency like situations for example hazards. It is evident from history that most portion of losses, either in the form of human lives, or in the form of economic occur because of late arrival of relief work, and selection of optimal path plays key role. Here, in this research, authors focuses on the addition of elevation difference function for more accuracy while path planning particularly mountainous areas. This research is the part of research carried out by author while working on the use of advanced computer technology for hazard mitigation.

Key Words: Hazard Mitigation, Path Planning, Great Circle.

1. INTRODUCTION

On 8th October 2005 at 8:50 AM, an earthquake of 7.6 on the Richter scale struck through the mountainous region of northern Pakistan [1]. The most devastating destruction was struck in northern parts of Pakistan. The northern region of Pakistan is comprised of mountains and hilly areas, where after this destructing disaster the ordinary means of transportations and routes were destroyed severely (80% wiped off) most of casualties were resulted because of late arrival of relief work and relief goods. There were 10800 plus villages in that mountainous region which were suffered by that earthquake [1], as shown in figures 1,2 and 3.

The earthquake struck zone consists of 10835 villages that were badly affected by earthquake. The plots in figures are sketched from latitudinal and longitudinal values of places from Excel file Shown in figure 4.

The problem in these earthquake affected regions was that these villages were located at different heights shown in figure 5, and most of the roads were destroyed. This kind of resource constrained shortest path problem asks for the computation of a least cost path that obeys set of resource constraints [4]. Here computing of shortest paths is a fundamental issue and can be resolved by different techniques [5]. However, for immediate relief in those areas aerial route was most suitable by mean of using choppers. For this problem a great circle distance formula can be used.

2. THE GREAT- CIRCLE DISTANCE

The great-circle distance is considered as the shortest distance between any two points on the earth when measured along the surface of earth. It can be concluded from literature that this is commonly used for distances between two points on sea [6]. The distance between two points in Euclidean space is the length of a straight line from one point to another. Where as it is evident from literature that there is no straight line on spherical surface

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of earth. Therefore for measurement of distance between two points on earth, straight lines are replaced with geodesics. Geodesics on the sphere are the great circles.

Let X1,Y1; X2,Y2 be the longitude and latitude in degrees of two points, respectively. ΔX the longitude difference and Δσ the angular distance between two points measured in radians.

Then:

$$\Delta\sigma = \arccos\{\sin y_1 \sin y_2 + \cos y_1 \cos y_2 \cos \Delta x\}$$

Where: x_1=X_1*π/180.

Similarly x_2, y_1 and y_2 can be computed in the same way in radians.

Δσ is the angle made by those two points X1,Y1 and X2,Y2 on the surface of earth. Thus the angular distance between two points is say D, then

D= Δσ *radius of earth (kilometers, miles or nautical miles)

3. ELEVATION DIFFERENCE FUNCTION

Earth surface is not pure round (or flat) and different points have different respective heights or elevations. If we incorporate the elevation of those locations, this can supplement more accuracy in distance computation [2]. It is evident from literature that consideration of two dimensional path is insufficient in case of hilly areas[3]. In straight line distance matrix if the elevation difference between two points is 20% of their horizontal distances it will contribute approximately 2% addition in minimum distance so we can add a supplementary function in our path calculating function, that if elevation difference between two points is 20 % or higher of measured distance then it must be incorporated.

4. CONCLUSIONS

In this paper importance of elevation while computing the distance between two points is presented. The main focus of this research aimed for contribution of supplemented function that may be helpful for computation of shortest paths between those two points whose elevation has much differences as compared to their two dimensional distance in the perspectives of Great Circles. It is clearly evident from the computations done by Elevation Difference function that if elevation difference between two points is equal to 20% of total computed distance, then it will add supplementary distance of 2%. So in the opinion of author if elevation difference between two points is higher then 20 percent then this may supplement the accuracy by 2 percent or more accordingly.

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Figure 1: Global map of Pakistan depicting the affected region

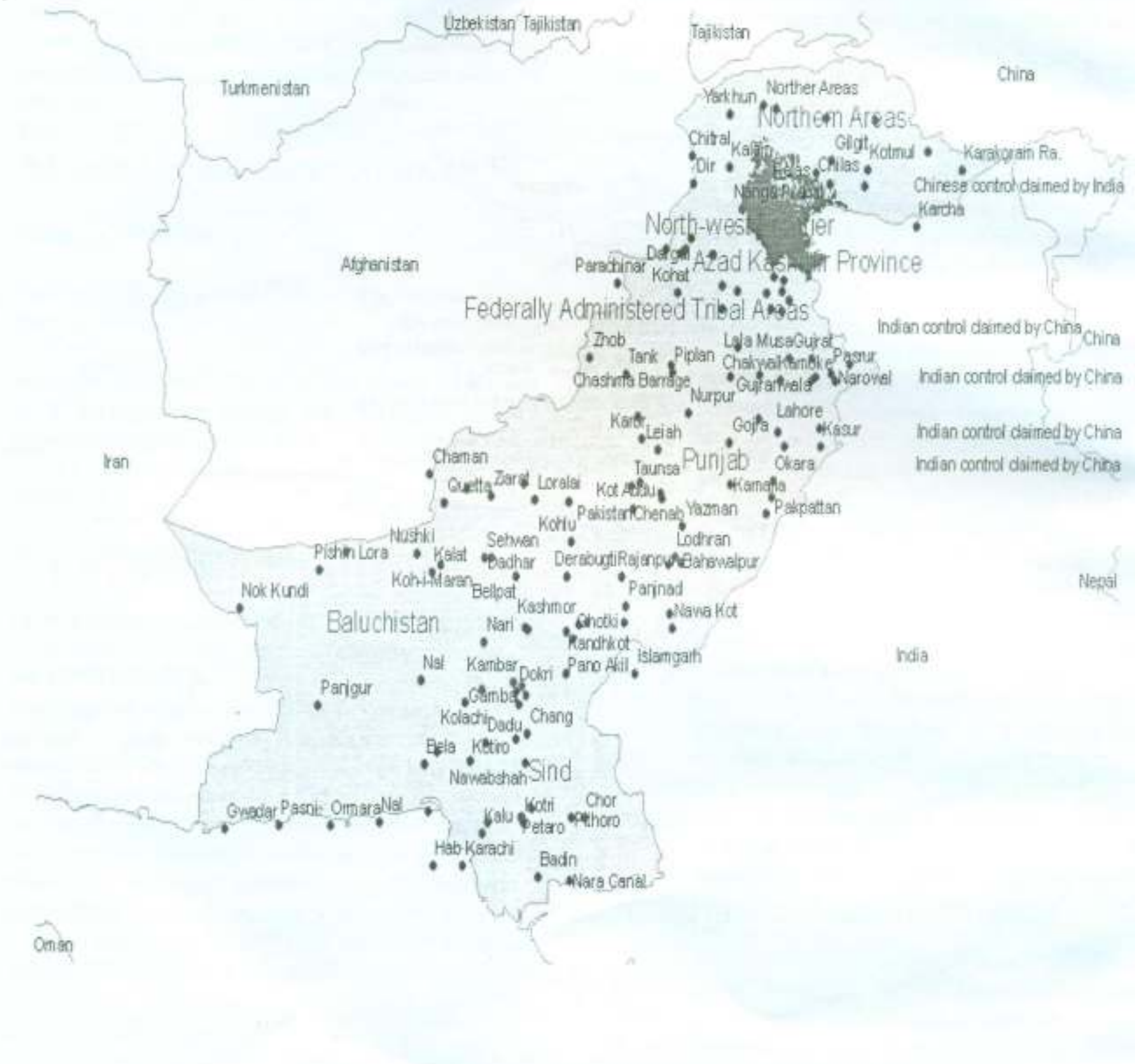

Figure 2: Map of Pakistan with major cities and earthquake affected region

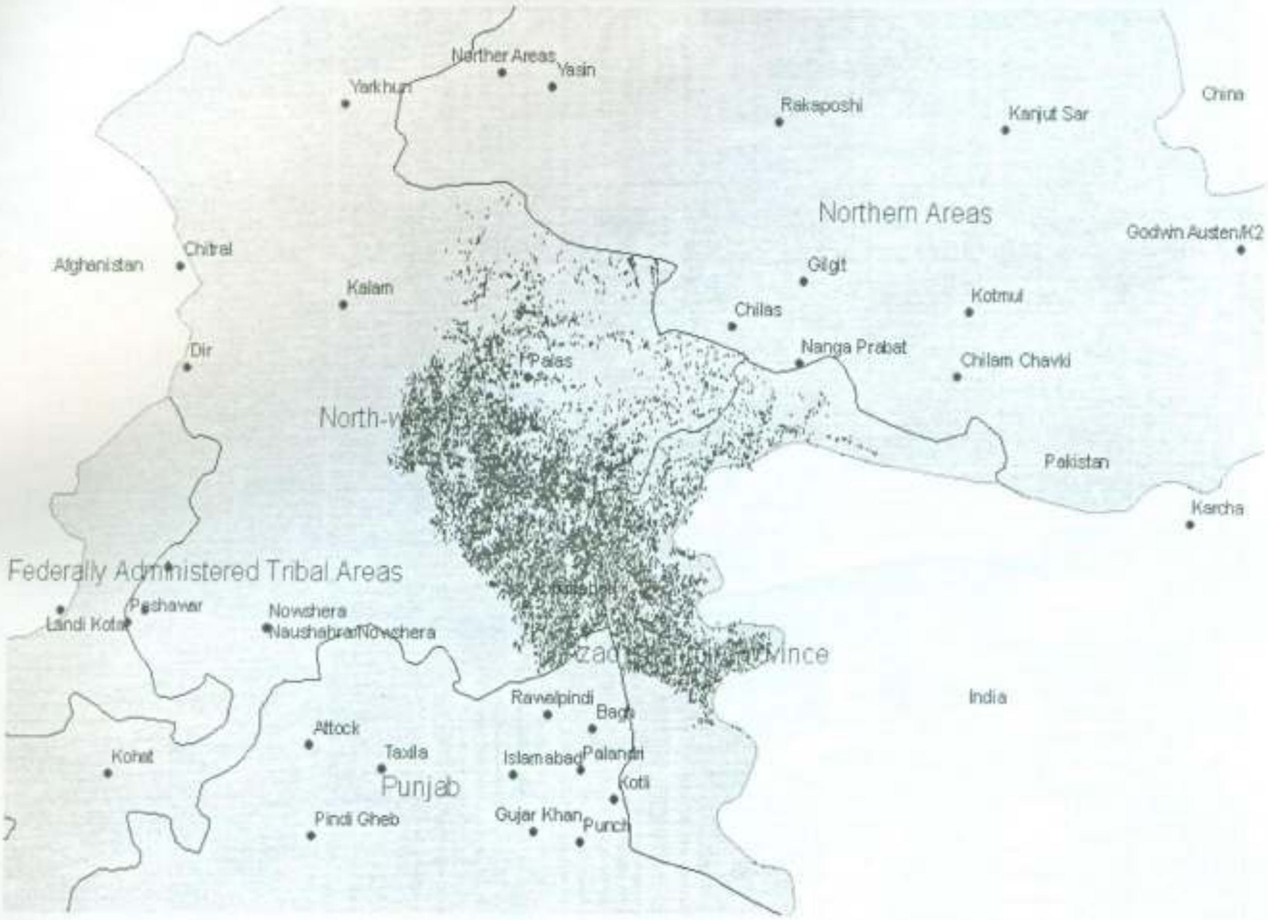

Figure 3: Earthquake affected zone.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	PROV_NAME	DIST_NAME	DIST_CODE	TEHS_NAME	TEHS_CODE	PLACE_NAME	UC_NAME	UC_CODE	PCODE	ELEVATION_M	ELEVATION_FT	X (long)	Y(lat)	SETTLEMENT_TYPE
2	N.W.F.P.	Abbottabad	2055	Abbottabad	3153	Abbott Abad	Abbotabad	4300	60004	1246	3997	73.2111	34.151	District Center
3	N.W.F.	Abbottabad	2055	Abbottabad	3153	Banda Sinjalian	Abbotabad	4300	65894	1282	4113	73.1944	34.149	Settlement
4	N.W.F.	Abbottabad	2055	Abbottabad	3153	Baniwali Gali	Abbotabad	4300	60485	1438	4613	73.1961	34.158	Settlement
5	N.W.F.	Abbottabad	2055	Abbottabad	3153	Cantonment	Abbotabad	4300	61044	1250	4010	73.2116	34.154	Settlement
6	N.W.F.	Abbottabad	2055	Abbottabad	3153	Dheri	Abbotabad	4300	70004	1400	4491	73.1867	34.151	Settlement
7	N.W.F.	Abbottabad	2055	Abbottabad	3153	Malak Pura	Abbotabad	4300	64077	1348	4324	73.1972	34.152	Settlement
8	N.W.F.	Abbottabad	2055	Abbottabad	3153	Bagh	Bagh	4301	67980	1683	5399	73.2994	34.099	UC Center
9	N.W.F.	Abbottabad	2055	Abbottabad	3153	Bagh Mira	Bagh	4301	60198	1651	5296	73.3161	34.104	Settlement
10	N.W.F.	Abbottabad	2055	Abbottabad	3153	Dewal	Bagh	4301	61738	1946	6243	73.31	34.098	Settlement
11	N.W.F.	Abbottabad	2055	Abbottabad	3153	Joghian	Bagh	4301	62657	1683	5399	73.2933	34.073	Settlement
12	N.W.F.	Abbottabad	2055	Abbottabad	3153	Juma Bagla	Bagh	4301	62833	1824	5851	73.3056	34.087	Settlement
13	N.W.F.	Abbottabad	2055	Abbottabad	3153	Jurian	Bagh	4301	70008	2165	6945	73.3303	34.076	Settlement
14	N.W.F.	Abbottabad	2055	Abbottabad	3153	Kachamacha	Bagh	4301	62843	1905	6111	73.3265	34.09	Settlement
15	N.W.F.	Abbottabad	2055	Abbottabad	3153	Kanthia Yala	Bagh	4301	70006	1819	5835	73.3233	34.093	Settlement
16	N.W.F.	Abbottabad	2055	Abbottabad	3153	Kohalian	Bagh	4301	63510	1485	4764	73.289	34.082	Settlement
17	N.W.F.	Abbottabad	2055	Abbottabad	3153	Kutli	Bagh	4301	70005	2196	7045	73.3417	34.094	Settlement
18	N.W.F.	Abbottabad	2055	Abbottabad	3153	Nari Gali	Bagh	4301	64622	2278	7308	73.3237	34.07	Settlement
19	N.W.F.	Abbottabad	2055	Abbottabad	3153	Rijwala	Bagh	4301	65179	2237	7176	73.3317	34.093	Settlement
20	N.W.F.	Abbottabad	2055	Abbottabad	3153	Sunan	Bagh	4301	66010	2187	7016	73.3128	34.076	Settlement
21	N.W.F.	Abbottabad	2055	Abbottabad	3153	Tami Gali	Bagh	4301	66072	2153	6907	73.3089	34.069	Settlement
10828	P.A.K.	Poonch	2007	Rawalakot	3017	Raruta	Thorar	4588	65229	733	2351	73.5938	33.865	Settlement
10829	P.A.K.	Poonch	2007	Rawalakot	3017	Saher Thorar	Thorar	4588	74909	1536	4927	73.6142	33.838	Settlement
10830	P.A.K.	Poonch	2007	Rawalakot	3017	Sardi Balgran	Thorar	4588	64999	970	3112	73.6056	33.859	Settlement
10831	P.A.K.	Poonch	2007	Rawalakot	3017	Sardi Khas	Thorar	4588	65529	1276	4093	73.6247	33.84	Settlement
10832	P.A.K.	Poonch	2007	Rawalakot	3017	Sauntala Therar	Thorar	4588	74911	924	2964	73.6128	33.864	Settlement
10833	P.A.K.	Poonch	2007	Rawalakot	3017	Serra Thorar	Thorar	4588	74912	1116	3580	73.5972	33.834	Settlement
10834	P.A.K.	Poonch	2007	Rawalakot	3017	Siroli	Thorar	4588	65911	1036	3323	73.5942	33.836	Settlement
10835	P.A.K.	Poonch	2007	Rawalakot	3017	Thoral	Thorar	4588	66235	1582	5075	73.6411	33.849	UC Center

Figure 4: Excel file showing 10835 villages with different heights.

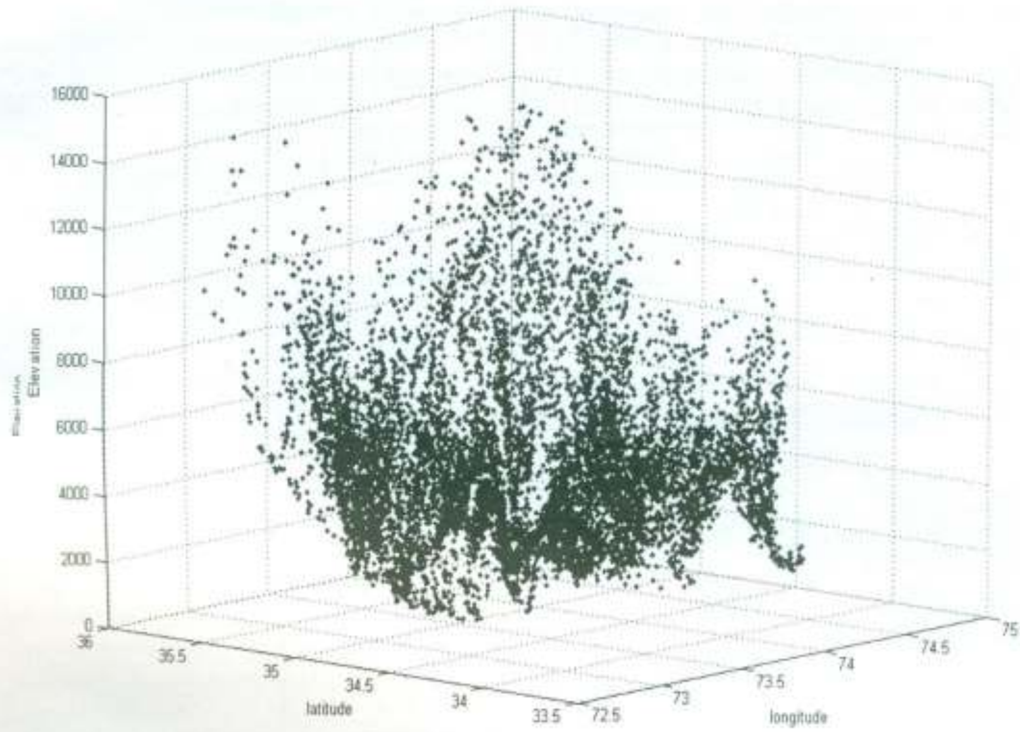

Figure 5: Village points in earthquake effected zone

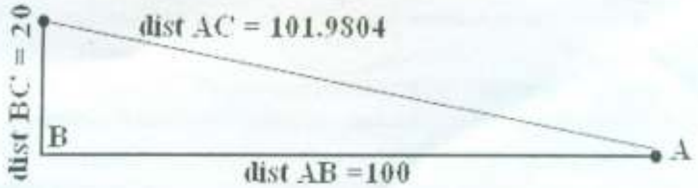

Figure 6: Elevation difference model

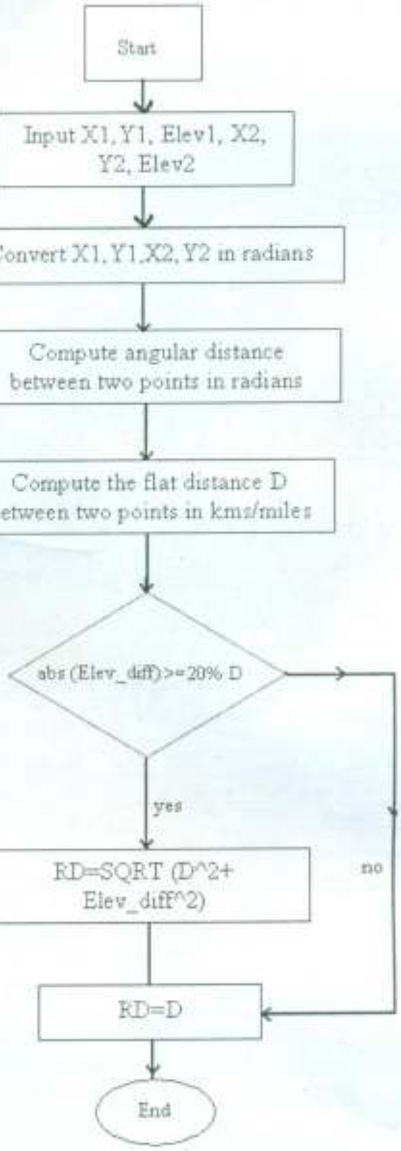

Figure 7: Program routine for the great-circle distance computation.

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