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Modifications of Optinet work Software for the Implementation of Advance Genetic Algorithm on Existing Water Distribution Network

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Abstract

EPANET, a widely used water distribution package was linked to OptiGa, a Visual Basic ActiveX control for implementation of genetic algorithm, through Visual Basic programming technique, to modify the computer software called OptiNetwork. OptiNetwork in its modifications, Overcome all the shortcomings of the Demonstration Program, which includes: the introduction of selecting options for advanced genetic algorithm parameters (Top mate; Roulette cost; Random; Tournament methods; and one point crossover; two points crossover; uniform crossover methods and random seed number), handling of a water distribution network up to 150 pipes, and the Provision of additional design parameters (pressure constrain, velocity constrain and diameter constrain). An existing water distribution network (Badaawa /Malali) was applied to the modified software, and found that the performance of the OptiNetwork software was compared with OptiDesigner (a commercial software package). The results obtained shows that the introduction of the advanced genetic parameters of OptiNetwork is justified. This is because, it has been able to improve the search method in terms of achieving "least cost" of the distribution networks.

Keywords: Water distribution systems, cost, optimization, genetic algorithms

Introduction

Over recent years, there has been a significant increase in the number of software applications that have been released both in the commercial and in public domains. As this process continues, it becomes difficult for systems managers and designers to select a software package most adapted to local needs and circumstances (Skat Consulting 2002) [1].

The investigation has been extended towards non-commercial software. The facts have been compiled from information given by the respective software developers and / or distributors as well as by its users, Additional information are available at (Skat Consulting 2002) [1].

Literature Review

What is OptiNetwork Model

OptiNetwork model is a Windows software for the optimal design of water distribution network using "Genetic Algorithms". The program uses EPANET (a hydraulic simulator distributed by US EPA) for the drawing and analyzing the system. OptiNetwork software will design network pipes and find their minimal cost under a set of constraints, which includes:

- Minimal and maximal pressures at network nodes
- Minimal and maximal velocities at network pipes
- Minimal and maximal diameters of network pipes

With OptiNetwork software you can find the most cost effective design, rehabilitation and expansion of your water distribution system

Visual Basic Source Program Code

The Visual basic source program code for OptiNetwork model is presented under result. It takes care of all the listed modification highlighted in section 3.3.2. The program calls the EPANET input file from EPANET software through EPANET TOOLKIT (dynamic link library of functions that allows developers to customize EPANET's computational engine for their own specific needs), and uses the commercial diameter pipe sizes with equivalent cost file from text editor. The successful result is linked up to OptiGA (visual basic ActiveX control for implementation of genetic algorithm), for searching the optimum (least-cost) of the distribution network.

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EPANET SIMULATO

Epanet is a third generation software package for modeling water distribution networks. This programme performs extended period simulation of hydraulic and water quality conditions within pressurized pipe networks.

Previous works performed using "EPANET" includes the work by (TospornSampon et al 2007) [2], to solve a problem of split-pipe design of water distribution network. As mentioned earlier, the network simulation model used is EPANET.

(Rossman 2000) [3].It calculates nodal heads and flow in pipelines, storage in each tank, and concentration of substance throughout the system, and water age and source tracing both as strategic and dynamic loading conditions. Hazen Williams equation is used due to its wide applicability in water supply. EPANET was successfully used in this study in obtaining feasible solutions.

(Lion and Atiquizzaman 2006) [4], linked EPANET with a powerful optimization algorithm, shuffled complex evolution (SCE). In this study, an evolutionary optimization algorithm SCE (Duan et.al 1992) [5], has been coupled with the widely used water distribution network design. Two area networks were considered. Comparing the performance of SCE and other methods by other researcher's shows that SCE linked with EPANET SIMULATOR categorically yields better performance in terms of optimal design cost, and satisfying required minimum pressure head at certain demand nodes.

(Zheng .Y, et.al 2001)[6]LinkedEPANET with an optimization technique known as Genetic Algorithm (GA). A steady – state hydraulic analysis was used to evaluate the consequences of rehabilitation plans of a water distribution network multi-optimization, in terms of the objectives F1, F2 and F3 using the EPANET 2 Code(Rossman2000)[3] that were linked to a C^H code. It should be noted that EPANET 2 presents an efficient code for hydraulic calculation related to water distribution network.

(Milan and Zayne 2009) [7], used EPANET because it is a reliable model that has been applied worldwide for various types of water distribution networks. In step 4 the of optimization procedure, the EPANET model is running with data taken from a new harmony which are coded. By comparing results of computation with observed values, many calibration purposes of hydraulic model of irrigation network were tackled successfully using EPANET software.

(Zongwoo c 2006) [8], this observed that the model was interfered with by a popular hydraulic simulator, EPANET, to check the hydraulic constraints, the model was successfully applied to five networks, and obtain design that were either the same or 0.28 – 10.26% cost less than those of competitive meter-heuristic algorithms such as GA, SA, TS under similar or less favorable conditions. The results show that Harmony search linked with EPANET software is suitable for water network design.

Methodology

Modification Introduced to the Demonstration Program

The demonstration program is purposely designed to optimize a fixed network called Waternet. The water distribution network consists of 8 pipes 6 nodes and overhead reservoir. No any other water distribution network can be optimized with the Demonstration program. Figure 3.1 below is the Window form of Demonstration program.

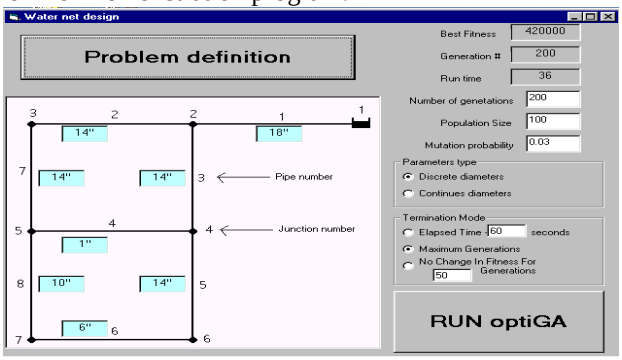

Figure 3.1: Window form of Demo Program

Short Comings of the Demonstration Program

Listed below are the short comings of the Demonstration program:

1. It can only optimize the Waternet, consisting of 8 pipes, 6 nodes and one reservoir.
2. It is designed for pressure constraint (build-in), of minimum pressure equal to 30 m and maximum pressure equal to 100 m.
3. No provision for selecting advanced genetic algorithm parameters (selection methods, crossover methods, random seed number) neither could it be varied.

Modified Program (OptiNetwork Software)

The modified program (Figure 3.2) is called OptiNetwork software and modified to:

1. Overcome all the listed shortcomings of the Demonstration Program.
2. It can handle a water distribution network up to 150 pipes.
3. Provide additional design parameters (pressure constrain, velocity constrain and diameter constrain).

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4. Open and locate a water distribution network file that needs to be optimized.

Provide options for the selection of advanced genetic algorithm parameters (selection methods, crossover methods and random seed number).

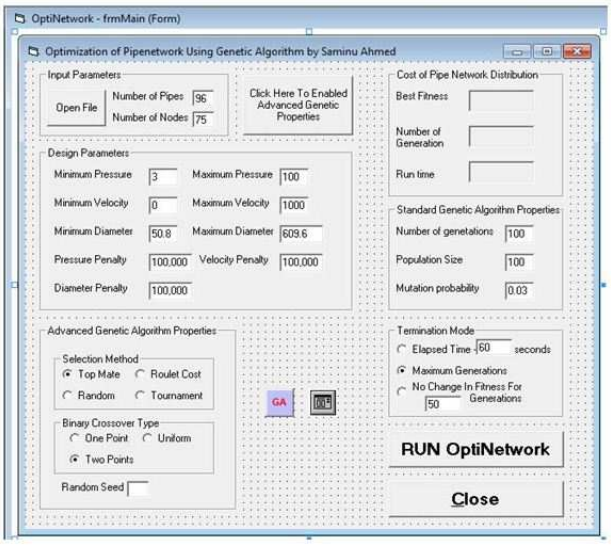

Figure 3.2 Modified program (OptiNetwork Software)

Description of the Modified Software (OptiNetwork)

The flow chat for the software modified (OptiNetwork model) is shown in Figure 3.6. It is divided into two main stages, the first stage is hydraulic simulation, which involves the simulation of the water distribution network using the data collected / available. EPANET (Rossman, 2000)[3] a computer program that performs extended period simulation of hydraulic and water quality behavior within pressurized pipe networks is used, when a successful run is obtained, the network is then exported as an input file for optimization process.

The second stage is the implementation of the Genetic Algorithm. This is achieved by the use of EPANET TOOLKIT, which is a dynamic link library of functions that allows developers to customize EPANET's computational engine for their own specific needs, and OptiGA (Visual Basic ActiveX control for implementation of genetic algorithm) Solomons (2001) [9]. The complete enumeration of these two stages is presented in sections 3.3.4 and 3 3.5 respectively.

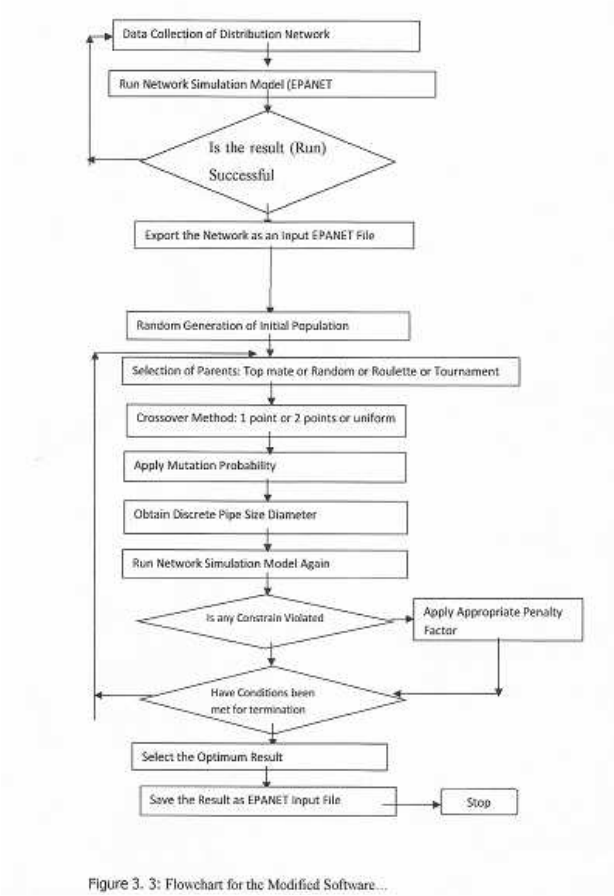

Figure 3. 3: Flowchart for the Modified Software...

Stage 1 Hydraulic Simulation

Hydraulic model EPANET Rossman (2000) [3], is to be used for this stage. Data required such as pipe lengths, diameters, roughness coefficient, nodal demands, elevation at nodes, reservoir(s) etc. are keyed into the EPANET model. The EPANET model is then run, if the run is unsuccessful the errors indicated are corrected until a successful run is obtained. The file is then exported as EPANET input file.

Stage 2 Implementation of Genetic Algorithm

The implementation of the genetic algorithm starts with a randomly generated initial population (set of coded strings (chromosomes)) representing potential solutions to the decision variables (discrete pipe size diameters) in binary number. This is done through OptiGA using random seed number. From the initial population generated, the fittest string, as measured by the objective functions value, is selected to pass their genetic information to the next generation. This operation called "selection" resembles the survival of the fittest in natural systems. There are four methods for implementing selection in OptiGA, these are:

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(a) Top Mate Method: In this method the first parent is selected by the fittest order, the second parent is selected randomly.
(b) Roulette Cost/ Rank Method: In this method, the chance of a chromosome to be selected is calculated according to their fitness (cost) or according to their rank.
(c) Tournament Method: In this selection method, a small subset of chromosome is selected and the one with the best fitness will become a parent.
(d) Random Method: This is the simplest method parents are simply selected randomly.

Results

Sample of some least-cost results of **$195,200.00**, obtained from Existing network for BADARAWA/MALALI using the modified OptiNetwork software under **advance genetics algorithm option** was achieved at Topmate selection method, two point crossover method and at mutation probability of 0.03. Which is much lower than **$435,118.00** obtained from OptiDesigner (a commercial software).Shown in table below:

Table 4.1: Cost in $ of Badarawa and Malali Network With two Reservoir using 3 bits binary representative
Two points crossover method

No. of Runs	Top Mate	Roulette Cost	Random	Tournament
1	199,000	200,800	198,200	210,600
2	197,200	199,600	203,800	207,800
3	195,200	198,500	199,500	207,800
4	198,200	197,300	201,000	205,200
5	199,802	199,200	203,200	206,600

Below is some portion of the Visual basic source program code for OptiNetwork model:

OptiNetwork Model

```
Dim i As Integer
Dim NumberOfPipes As Integer
Dim NumberOfNodes As Integer
Dim Diam() As Variant
Dim DiamPrice() As Variant
Private SubcmdAdvancedGenetic Parameters Click ()
FrmAdvancedGeneticProperties.Enabled = True
FrmSelectionMethod.Enabled = True
FrmBinaryCrossoverType.Enabled = True
FrmAdvancedGeneticProperties.Visible = True
End Sub
Private Sub cmdClose_Click()
End
End Sub
Private Sub cmdRun_Click()
```

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```
Dim i As Integer
Dim vMin As Variant
Dim vMax As Variant
Dim nBits As Variant
Dim binSolution
Dim realSolution
 NumberOfPipes = txtNumberofPipes
 NumberOfNodes = txtNumberofNodes
On Error GoToData_Err
With optiGA1
'reset optiGA
    .ResetOptiGA
'make sure a report will be generated every generation
    .ReportEveryGeneration = 1
.
.
.
.
.
'Calculate the pipes cost
        Fitness = Fitness + DiamPrice(BinaryGenes(P - 1)) * 1000
    Next P
Else 'Continues diameters
'set the current chromosome diameters
    For P = 1 To NumberOfPipes
i = ENsetlink value (P, EN_DIAMETER, RealGenes(P - 1) * 25.4)
```

```
        If i<> 0 Then MsgBox "ENsetlink value = " &i

        D = RealGenes(P - 1)

'Calculate the pipes cost

        Fitness = Fitness + (0.0313 * D ^ 3 - 0.4161 * D ^ 2 + 4.499
* D - 2.3995) * 1000

    Next P

End If

'solve the network

i = ENsolveH

'look at the node pressure and apply penalty

For N = 1 To NumberOfNodes

i = ENgetnodevalue(N, EN_PRESSURE, Pressure(N))

    If i<> 0 Then MsgBox "ENgetnodevalue  = " &i

'if pressure is below 30 the apply penelty

    If Pressure(N) < 30 Then

PressureDif = Abs(30 - Pressure(N))

        If   MaxPressureDif<PressureDif   Then   MaxPressureDif   =
PressureDif

    End If

Next N

'add the penalty to the fitness

Fitness = Fitness + MaxPressureDif * 100000

End Sub

Private   Sub   optiGA1_GenerationReport(BestFitness   As   Single,
GenerationNumber  As  Long,  BinaryGenes  As  Variant,  RealGenes  As
Variant,   IntegerGenes   As   Variant,   ElapsedTime   As   Long,
GenerationMeanFitness As Single)

'-------------------------------------------------------------------
-------------------------------------------------------------------
```

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```
-------------------------------------------------------------------------
---------
Dim i As Integer
'update the current results
lblBestFitness = BestFitness
lblGenetarionNumber = GenerationNumber
lblRunTime = ElapsedTime
'update the diameters lables
If optDis.Value = True Then 'Discrete diameters
    For i = 0 To NumberOfPipes - 1
LBL(i) = Diam(BinaryGenes(i)) & "'"
    Next i
Else 'Continues diameters
    For i = 0 To NumberOfPipes - 1
LBL(i) = Format(RealGenes(i), "0.00") & "'"
    Next i
End If
End Sub
```

Conclusion

The modifications provide the options for selection of advanced genetic parameters (Top mate; Roulette cost; Random; Tournament methods; and one point crossover; two points crossover; uniform crossover methods and random seed number)Using Badarawa/Malali Water Distribution network. And also overcomes other aforementioned shortcomings before the upgrading. Also the performance of the OptiNetwork software was compared with OptiDesigner a commercial software package, the results obtained prove the introduction of the advanced genetics Parameters by the modified OptiNetwork has been able to improve the search in terms of achieving optimum cost of the distribution network.

Recommendations

Although the present software used only investment cost of pipes in the analysis, it is recommended that further research should be extended to include operational and maintenance cost.

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