Operational Research Tools in Irrigation - A Review

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Abstract:

Operational research optimization is an old method for allocating scarce resources with maximum benefits and efficiency. With increasing global water scarcity, earliness and tiredness in demand base water supply, economical issues, maximizing crop per drop of water, OR is getting popular in irrigation and agriculture sector as well. This paper is intended to review different optimization techniques used so far in the field of irrigation.

Key Words: Operation research, optimization, irrigation, water delivery, genetic algorithm, simulated annealing, fuzzy sets, swarm optimization.

Introduction:

Heger, 2006, define operation research (OR) as the discipline that helps us in decision making and which is based upon the information technology. In other words it is the study of allocation of scarce resources.

Galati, unknown, OR is study of mathematical models for complex organizational systems. He further elaborate that OR started in Britain just before World War II, when team of scientists was assigned a task to research on the tactical and strategic military operation problems. Main objective was to utilize limited resource for more benefits. After that in peace time, same techniques was applied in different other fields as well.

Optimization Research:

As per Galati, unknown, optimization research is the branch of OR which uses mathematical techniques such as linear, nonlinear programming to drive value for the system variables that will optimize the performance.

Role of OR:

Both in private and public sector OR play an increasingly imported role. It can be very helpful in vast range of problem solving fields, like, revenue management, finance, IT operations, communications, production, transportation, inventory management, and much more. OR works on very simple approaches, i.e. decomposition of problem in basic components and then solving with the help of mathematical tools. Heger, 2006, mentioned that OR has many advantages like

1. Decrease investment/cost
2. Increase return/revenue
3. Reduce risk
4. Increase good management
5. Quality improvement
6. Decreasing delays
7. Effective utilization of scarce resources
8. Demonstrate feasibility and workability.

Heger, 2006, mentioned that in OR mainly either or combination of any of following three methods can be used:

1. Data Analysis Method: this method is good for situation where decision makers want to establish actual patterns and interconnection in the dataset.
2. Simulation Method: where decision makers want to develop simulators to look for improvement and to test and to establish bottom line for the improvement idea that are being made.
3. Optimization Method: where decision makers want to search among possible choices in efficient and effective way and practical acceptable time, as thousands or millions of choices can be possible.

Within each of the three basic groups, many probabilistic methods provide the ability to access risk uncertain factors.

Different Optimization Tools Available:

Chakraborty, 2010, mentioned following fig in his publication for taxonomy of research

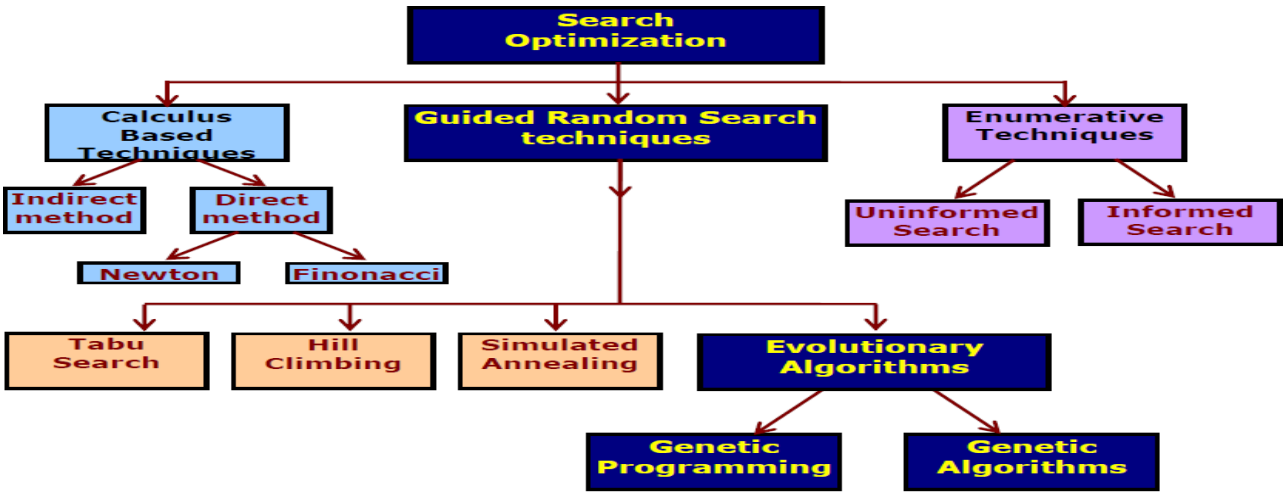

Fig. Taxonomy of Search Optimization techniques

Optimization techniques.

Reibenschuh, Cus and Zuperl, 2010, mentioned following different types of optimization tools: Neural Network, Perception

1. Fuzzy System
2. Evolutionary computation includes
    a. GA
    b. Hybrid (neuro-fuzzy, pseudo outer –product – based fuzzy neural network)
    c. Harmony search
3. Swarm Intelligence
    a. Particle swarm optimization, PSO
    b. Ant swarm optimization, ASO
4. Ideas about probability
    a. Bayesian network
    b. Chao theory
    c. Support victor machine,SVM

Fuzzy System:

First proposed by Zadeh, 1965, he presented the idea of fuzzy sets such that partial membership of any of element of set in asetis possible. The lps to arrive to certain decisions, Reibenschuh, Cus and Zuperl, 2010.

Neural Network:

It is based on biological systems, like brain system. It system can learn, store and use knowledge learn from experience, Reibenschuh, Cus and Zuperl, 2010.

Genetic Algorithm:

Chakraborty, 2010, mentioned in his publication that it is adoptive heuristics search algorithm. Evaluation idea of natural selection and genetics are the basic of GA. Basically GA is inspired by Darwin's theory of evolution, which believes in Survival of Fittest. It uses random search for solving of optimization problems. In process of optimization in engineering, problem is first translated into a mathematical form, and then arriving at parameters that give best suitable results. It offers best results over the other methods, like, artificial intelligence, breath first, depth first, heuristics, linear programming. GA is good at searching in huge search space and arriving at good combination of parameters in reasonable time, which otherwise may not be possible in real life

time. A process that finds best/optimal solution for a given problem is called optimization. Mainly consist three factors:

1. Maximization or minimization objective function
2. Decision variable that effect objective function
3. Constraints, that allow decision variable to arrive at a certain value.

Optimization problem is the one which give best /optimal value of decision variable to maximize or minimize an objective function while satisfying all the constraints.

Evolutionary computation is a subset of artificial intelligence, which is powerful and search and optimization tool, mainly influenced by theory of evolution (natural selection and genetics). Evolutionary algorithms are the subset of evolutionary computation, which is a model developed by using randomness and genetic inspired operations. Genetic algorithm is the main paradigm of EC.

Simulating annealing:

Based on the cooling process of metal during annealing, SA is generic probability met heuristic. Reibenschuh, Cus and Zuperl, 2010.

Ant colony optimization (ACO):

It is a probabilistic technique for solving computational problems which can be reduced to finding good paths through graphs and data. It constitutes some of the Meta heuristics optimization. It was proposed by Dorigo, 1996. This technique is inspired by the cooperative attitude of ants, and now it is used to optimize real life problems. Reibenschuh, Cus and Zuperl, 2010.

Particle swarm optimization:

Kennedy and Eberhart, 1995, developed this technique and it is inspired by birds flocking or fish schooling. Reibenschuh, Cus and Zuperl, 2010.

Support vector machine:

Yao and Yang, 2009, proposed this method. It is a margin classifier. It used to maximize the margin for a credible separation of data point. Reibenschuh, Cus and Zuperl, 2010.

Harmony Search Optimization:

Geem, et al, 2001, proposed harmony search optimization technique. It is a solution finding technique that considers an optimal solution in engineering corresponding to an optimal sound in music. Unlike other heuristic optimization technique, HS doesn't involve natural phenomenal

rather it is based on an artificial phenomenon of harmony, i.e. music.

Research Optimization Techniques inIrrigation:

Mtolera, et al, 2014 develop an algorithm using particle swarm optimization technique to optimize irrigation tree pipe networks layout and size. The model was linked to MATLAB software. A result obtained was compared to non-optimized method (step by step) and GA. They observed a quick response from their model with increase in search space as compared to step by step and GA.

Yo, et al, 2014, apply Harmony search optimization technique for identifying optimal pipe size in looped irrigation water supply system. Main aim of the research was to develop an algorithm and program to find out the optimal and cost effective pipe diameter for looped irrigation system. The result so obtained was tested in the field and was found the algorithm developed can be applied to real life problems. Researchers found the developed programed more promising than others available models, as this model also meet the hydraulic conditions through the combined use of HS and hydraulic analysis. They found that developed model shows 9% better results as compared to other available models.

Tranetal, 2011, developed a model based on dynamic optimization model for managing and optimizing multiple resources for irrigation and fisheries.Pais, et al, 2010, conducted a study to optimize cost of drip irrigation system using GA. The results show that there in improvement in the calculation runtime and in cost of drip system, as compared to other models available.

Bagher and Payman, 2009, use GA for optimizing water delivery program. They found that GA is useful for water distribution problem in irrigation channels.

Schutze et al, 2009, employed evolutionary optimization technique to find a near optimal solution of the global optimization problem within reasonable computational time. The results so obtained were compared with complex evolution algorithm, optimization algorithm, simulated annealing and differential evolution. The new tool developed shows striking superiority over the existing optimization techniques.

Ines, et al, 2006, conducted an interesting study by combining remote sensing simulation model and GA to discover water management option in irrigated agriculture. Results showed that adjusting sowing date and distribution with deficit irrigation, can improve regional yield.

Babel, Gupta and Nayak, 2005, developed a model for optimal allocation of water to competing demands using two optimization techniques, i.e. weighting technique (WT) and simultaneous compromise constraint (SICCON) technique. The developed model was found capable of

allocating water among six sectors with maximizing either satisfaction or net economic return or both.

Elmahi, et al, 2005, apply system dynamics optimization approach to management of irrigation demand. They coupled network simulation optimization model NSOM, to a linear programming mathematical algorithm including system constraints. After comparison with available commercial software, VENSIM^{TM}, they found that both models present same results. They conclude new model very useful tool for irrigation companies and catchment managers to evaluate alternative river system management.

Kuo, Liu, and Chen, 2003, conducted a study to compare three optimization techniques,i.e. GA, SA, and iterative improvement method. The research was concluded as that GA effectively and efficiently plans an irrigation project from economic benefit and can determine ideal crop area for a given water supply. SA almost perform similar to GA. whereas iteration method produce worse results than GA and SA.Kuo, nad Liu, 2002, develop irrigation simulation and optimization model and They report that the said model can tackle complicated irrigation planning and management problems efficiently. Which make it an effective tool to simulate the irrigation water demand and optimizing economic profit?

Nixon, Dandy, and Simpson, 2001, examine the use of GA optimization to identify water delivery schedules for an open channel irrigation system. They identified different constraints and objectives and incorporated it in GA. Main objective of the study was to minimize the variation in requested and schedule time. They found GA as a promising optimization technique for water deliveryscheduling.

Esfandiari and Maheshwari, 1997, estimate infiltration characteristics infurrow irrigation and its comparison with other methods using optimization method developed by Maheshwari et al, 1988 for estimating infiltration characteristics in border irrigation.

Maheshwari,etal,1988,apply pattern search optimization technique (value of objective function is found by sequential examination of a finite set of trial values of the function. Each trial is compared with the best previous trial and the new value is accepted if an improvement is observed) to estimate infiltration characteristics in border irrigation. Main aim of study was to minimize the difference in volume of actual water infiltrated and as estimated by using infiltration equations. They found the optimization technique very promising in estimating infiltration characteristics in irrigation borders.

Nandalal and Ratnayke, unknown, apply dynamic programming optimization technique due to its ability to incorporate nonlinear objective functions and constraints without simplification, to optimize water

allocation in diversion type irrigation systems.

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