



Genetic Algorithms: Basic Concepts and Real World Applications

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Abstract—This paper introduces Genetic algorithms which is a part of evolutionary computing techniques. It is specially invented for development of natural selection and genetic evaluation. Genetic algorithms are an emerging technology for basic algorithms used to generate solution and one of the most efficient tools for solving optimization problem. The purpose of this paper is to provide solution for the real life problems which are always an immense challenge for researchers. The genetic algorithms are search and optimization algorithms based on the principles of natural selection and genetic evolution.

Keywords—Genetic algorithms, fitness function, genetic operators, flow diagram, real world applications.

I. INTRODUCTION

This paper introduces the elements of Genetic algorithms (GAs) and their application on general problem, genetic algorithms belong to the larger class of evolutionary algorithms (EA), which generate solutions to optimization problems using techniques inspired by natural evolution, such as inheritance, mutation, selection, and crossover [1]. The GAs were first proposed by John Holland in 1970 [2]. As a means to find good solutions to problems that were otherwise computationally intractable. Holland's schema theorem, this theorem is also called the fundamental theorem of genetic algorithms, is widely taken to be the foundation for explanations of the power of genetic algorithms. It says that short, low order schemata with above-average fitness increase exponentially in successive generations [3]. The GAs are emerging technology for basic algorithms used to generate solutions and one of most efficient tools for solving of optimization problems. The Genetic encoding instigates as a general model for adaptive process but has become effective in optimization [4]. In the early 1960s Rechenburge (1965) conducted studies at the technical university of Berlin on evolutionary strategy to minimize drag on a steel plate [7]. Goldberg (1983) used genetic algorithms to optimize the design of gas pipeline system.

This paper describes the basic GAs, selection, crossover and mutation. It also implements the optimization strategies by simulating evolution of species through natural selections. The GAs is generally composed of two processes. First process is selection of individual for the production of next generation and second process is

exploitation of the selected individual to form the next generation by crossover and mutation techniques [5]. In this first of all we will understand some terminologies to get insight of the process. Main terms are genes, chromosome, individual, population. The Gene is smallest unit of information carrying capacity. Individual is a set of genes carrying information [6]. The GAs differ from evolutionary computing in finer details. In evolutionary computing, the next generation of solutions is created primarily through mutation (random changes to the solution), while in genetic algorithms, the next generation of solutions is created primarily through crossover (combining pieces of solutions in the previous generation) [8].

II. BASIC CONCEPTS OF GENETIC ALGORITHMS

Genetic algorithms are good at taking larger, potentially huge, search space and navigating them looking for optimal combinations of things and solutions which we might not find in a life time [10]. The GAs is very different from most of the traditional optimization methods it need design space to be converted into genetic space. The algorithm can be easily implemented on a parallel computational architecture [9]. So genetic algorithms work is based on a coding of variables.

Three most important aspects of using GAs are:

- Definition of objective function.
- Definition and implementation of genetic representation.
- Definition and implementation of genetic operators.

The GAs are heuristic search algorithms [11]. The GA is a programming technique which forms its basis from the biological evolution [12]. It is basically used as a problem solving strategy in order to provide with a optimal solution. The Genetic Algorithm (GA) is computerized search and optimization algorithms based on the mechanics of natural genetics and natural selection, Fig1: shows the working of basic genetic algorithms. It is used for minimizing a function called the objective function or the fitness function [13]. Once these three have been defined, the GAs should work fairly well beyond doubt. We can, by different

variations, improve the performance, find multiple optima or parallelize the algorithms.

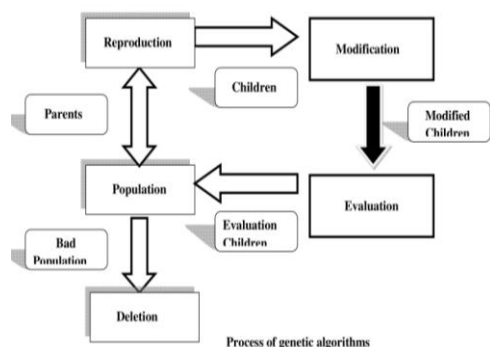


Fig.1: Working of Genetic Algorithms.

III. GENETIC ALGORITHMS

The genetic algorithm is a method for solving both constrained and unconstrained optimization problems that is based on natural selection.

A genetic algorithm (GA) is a search and optimization method which works by mimicking the evolutionary principles and chromosomal processing in natural genetics. A GA begins its search with a random set of solutions usually coded in binary strings. Every solution is assigned a fitness which is directly related to the objective function of the search and optimization problem. The Genetic algorithm is generally composed of two processes. First process is selection of individual for the production of next generation and second process is manipulation of the selected individual to form the next generation by crossover and mutation techniques [5]. The GA is applied to any search or optimization algorithm that is based on Darwinian principles "survival of the fittest" as driving forces behind the biological evolution of natural selection. Genetic Algorithm is a population-based search and optimization method which mimics the process of natural evolution [14], Fig5 shows the Flow diagram of Genetic algorithms.

A. Fitness Function

Genetic algorithms are used for minimizing a function called fitness function, Fitness function is also known as objective function. It is used in genetic algorithms in each iteration of the algorithm to evaluate the solution in the current population, the objective function of a problem is main source providing the mechanism for evaluating the location of each chromosomes.

B. Genetic Operators

Genetic operators used in GAs maintain genetic diversity; it is a necessity for the process of evolution. Genetic operators are analogous to those which occur in the natural world [15]. The transition from one generation to the next consists of three basic components.

- Selection (or Reproduction).
- Crossover (or Recombination).

- Mutation.

C. Selection

Reproduction (or selection) is usually the first operator applied to a population. Reproduction selects good strings in a population and forms a mating pool. Parents used to create new individual are selected randomly. All individuals in the population have the same possibility to be selected for mating, except individual with the least fitness which will be removed from the population and replaced with the newly created individual [16]. The commonly used reproduction operator is the impartial selection operator, where a string in the current population is selected with probability proportional to the string's fitness, selection is a process of keeping the best fit individual and eliminating rest one [6]. It select the two parent chromosome from a population according to their fitness better the fitness greater the chance to be selected [2]. Widespread Methods of Selection are [17]:

- Roulette Wheel Method.
- Tournament Selection.
- Stochastic Remainder Selection.
- Elitism Selection.
- Boltzmann Selection.

D. Crossover

Once the individuals have been selected the next thing is to produce the offspring [18]. The most common solution for this is something called crossover, and there are many different kinds of crossover Techniques:

- One -point crossover.
- Two -point crossover.
- Uniform crossover.

a) One-Point Crossover

It is simplest among all method. A crossover point in the parent chromosomes is randomly chosen, and then the two different portions of each chromosome are swapped with other portion of chromosomes to form two new chromosomes.

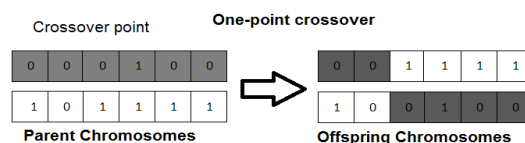


Fig.2: One -Point Crossover.

b) Two-Point Crossover

In this method we select two random point for crossover such that offspring adopt middle portion of parent 2 and rest from parent 1, Similar for offspring 2, Fig3 show of two-point crossover.

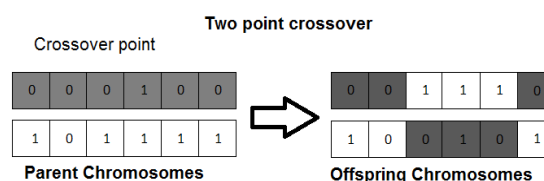


Fig.3: Two-Point Crossover.

c) Uniform Crossover

In this crossover is done at multiple site but these are uniformly spread across the chromosomes that is either even or odd ordering, Fig4 show in the below of uniform crossover.

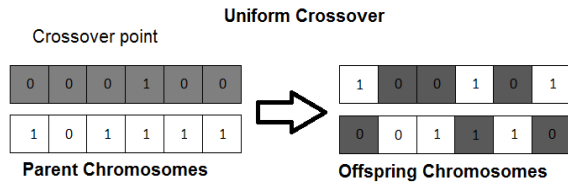


Fig.4: Uniform crossover.

E. Mutation

Mutation is performed after the crossover is done [19]. Mutation is a genetic operator used to maintain genetic diversity in chromosomes from one generation to the next generation of a population [20]. Mutation changes randomly in the new offspring, for binary encoding we can a few randomly chosen bit from 0 or 1 [20,21]. It is analogous to biological mutation; it is applied to each child independently after crossover. It arbitrarily alters each gene with a small probability. The next diagram shows the fifth gene of a chromosome being mutated, chance of variation in the solution is very low. So, the mutation probability should be kept as low as possible usually in range of 0.01 to 0.05[6]. This is to prevent falling of all solutions in a population for local optimum of the problem [21].

Before Crossover: 1101101001101110

After Crossover: 1101100001101110

F. Process

Genetic algorithms are a part of evolutionary computing and they are inspired by nature of evolution. When they are applied to solve a problem, the first step is to define a representation that describes the problem states. An initial population is then defined, and genetic operators are used to generate the next generation. This procedure is repeated until the termination criteria are satisfied. This basic principle of genetic algorithm is outlined [20]. Fig5 shows the flow diagram of the Genetic algorithms process.

There are many parameters and settings that can be implemented differently in various problems:

- Identify good (above-average) solution in a population.
- Make multiple copies of the good solutions.
- Eliminate bad solutions from the population so that multiple copies of good solutions can be placed in the population.

1. [Start] Generate random population of n chromosomes (suitable solution).

2. [Fitness] Evaluate the fitness $f(x)$ of each chromosome x in the population.
4. [Selection] Select two parent chromosomes from a population according to their fitness (the better fitness, the better chance to be selected).
5. [Crossover] with a crossover probability cross over the parents to form a new offspring. If no crossover was performed, offspring (children) is the exact copy of parents.
6. [Mutation] with a mutation probability mutate new offspring's at each locus (position in chromosome).
7. [Accepting] Place new offspring's in the new population.
8. [Replace] Use new generated population for the further run of the algorithm.
9. [Test] If the end condition is satisfied, stop, and return the best solution in current population.
10. [Loop] Go to step 2.

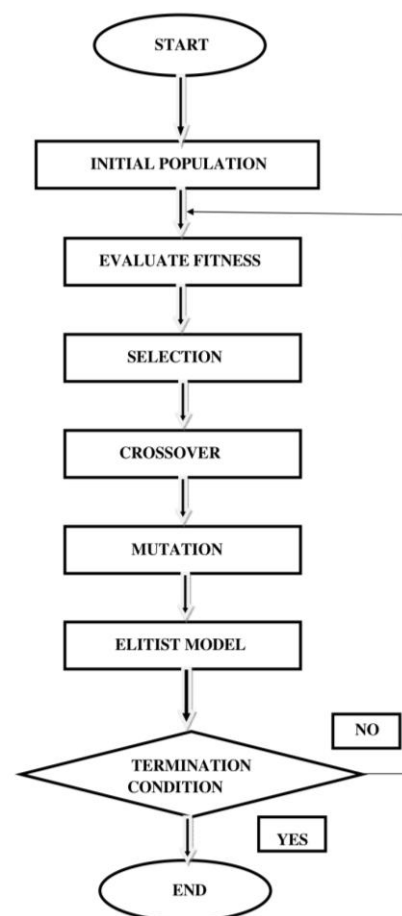


Fig.5:Flow Diagram of Genetic Algorithms.

IV. APPLICATION OF GENETIC ALGORITHMS TO SOME REAL WORLD PROBLEMS

- Control: missile simulation, destination, goal, pipes line.
- Scheduling: Manufacturing, facility scheduling[10], the process of arranging, controlling, optimizing works.
- Robotics: Trajectory planning, path planning[22].
- Department of chemical: Used in medicinal chemistry, conformational analysis.[22].
- Docking: it is in drug designing.
- Desing: Circuit board layout, communication network design, and Electronic circuit design.
- Computer science: Designing network, Machine learning, Computational learning: ,pattern recognition.
- Clustering[22]: it is used for genetic algorithms to optimize a wide range of different fit-function.
- Business: Economic Forecasting; Evaluating credit risks Detecting stolen credit cards before customer reports it is stolen.

A. Planning and Scheduling

Process planning and scheduling are two of the most important functions in manufacturing. Process planning function has many effects on the scheduling functions. Society of Manufacturing Engineers (SME) defines process planning as “the systematic determination of the methods by which a product is to be manufactured economically and competitively This is another area where the GAs can be comfortably applied. Optimization is often required for the planning of actions, motions, and tasks [11]. The GAs has been demonstrated as a power tool for such problems that can be even NP-completed. The applications of GAs is in the travelling salesman problem [23], pump scheduling in water industry [24], job-shop scheduling [25].

B. Robotics

It is basically used for trajectory planning, path planning in robotic applications. Robotics involves human designers and engineers trying out all sorts of things in order to create useful machines that can do work for humans. Fig.6 shows the robotic design. Each robot's design is dependent on the job or jobs it is intended to do, so there are many different designs out there. The problem of robot navigation has been approached in various ways, and it is now an accepted ‘useful’ test problem and model problem for both control and optimization schemes[26]. GAs can be programmed to search for a range of optimal designs and components for each specific use, or to return results for entirely new types of robots that can perform multiple tasks and have more general applications.



Fig.6: Robotics design

C. Engineering Design

As modern computational and modelling technologies grow, engineering design heavily relies on computer modelling and simulation to accelerate design cycles and save cost. A complex design problem will involve many design parameters and tables. Exploring design space and finding optimal solutions are still major challenges for complex systems [27].

The GAs can also be used for engineering designs that includes optimizing the structural and operational design of buildings, factories, machines object shaping, circuit layout, etc. These are being created for such uses as optimizing the design of heat exchangers, robot gripping arms, satellite booms, building trusses, flywheels, turbines, and just about any other computer-assisted engineering design application. Fig.7 shows the engineering design of system. There is work to combine GAs optimizing particular aspects of engineering problems to work together, and some of these can not only solve design problems, but also project them forward to analyze weaknesses and possible point failures in the future hence these can be avoided.

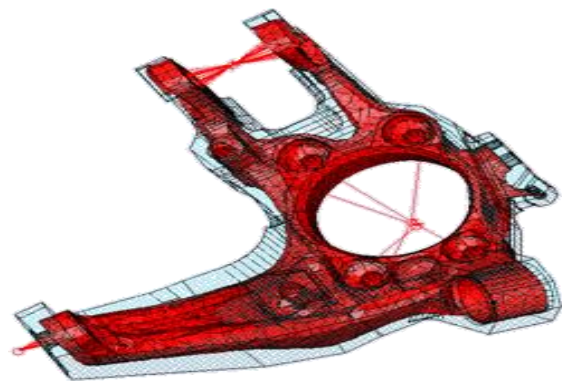


Fig.7: Engineering design

D. Evolvable Hardware

Evolvable hardware (EH) is a new field about the use of evolutionary algorithms (EA) to create specialized electronics without manual engineering. It brings together reconfigurable hardware, artificial intelligence, fault tolerance and autonomous systems. Evolvable hardware refers to hardware that can change its architecture and behaviour dynamically and autonomously by interacting with its environment. The

applications are electronic circuits created by The GAs computer models that use stochastic (statistically random) operators to evolve new configurations from old ones. As the algorithm does its thing in the running model, eventually a circuit configuration will come along that does what the designer wants. Think of reconfigurable circuits in something like a space robot[28].

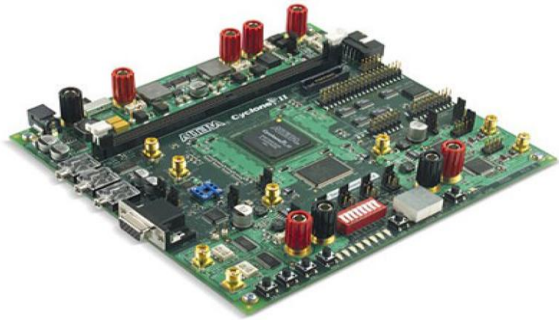


Fig.8: Evolvable Hardware.

E. Medical

Genetic Algorithms can be used throughout the medical field. The GAs can help develop treatment programs, optimize drug formulas, improve diagnostics, and much more. Plasma X-ray Spectra Analysis: X-ray spectroscopic analysis is a powerful tool for plasma diagnostics. Golovkin et al. use genetic algorithms to automatically analyze experimental X-ray line spectra and discuss a particular implementation of the genetic algorithm suitable for the problem. Since spectroscopic analysis may be computationally intensive, they also investigate the use of case injected genetic algorithms for quicker analysis of several similar (time resolved) spectra.

F. Automotive Design

Using Genetic Algorithms [GAs] to both design composite materials and aerodynamic shapes for race cars and regular means of transportation (including aviation) can return combinations of best materials and best engineering to provide faster, lighter, more fuel efficient and safer vehicles for all the things we use vehicles for. Rather than spending years in laboratories working with polymers, wind tunnels and balsa wood shapes, the processes can be done much quicker and more efficiently by computer modeling using the GAs searches to return a range of options human designers can then put together however they please. Fig10. Shows the automatic design of cars. Multi-body dynamics has been used extensively by automotive industry to model and design vehicle suspensions. Before modern optimization methods was introduced, when conducting an “optimization” on a design, engineers must first change the values of parameters and then re-perform the whole analysis again until a set of performance measures became acceptable. Design optimization, parametric studies and sensitivity analyses were difficult, if not impossible to perform. This

‘manual’ process usually accompanied by prototype testing, could be difficult and time-consuming for complete systems with nonlinear performance measure [29].

Automotive Design
2003 Class Project

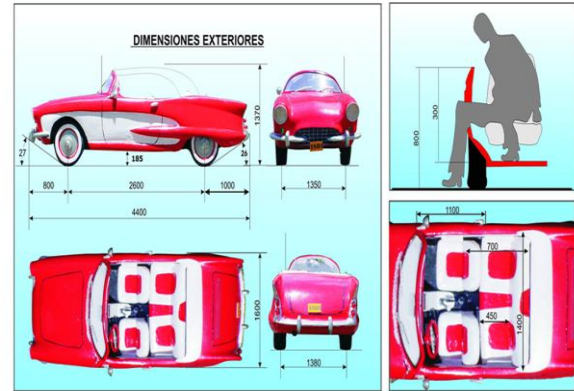


Fig.10: Automotive Design.

G. Computer Gaming

Those who spend some of their time playing computer Sims games (creating their own civilizations and evolving them) will often find themselves playing against sophisticated artificial intelligence the GAs instead of against other human players online. These GAs have been programmed to incorporate the most successful strategies from previous games - the programs 'learn' - and usually incorporate data derived from game theory in their design. Game theory is useful in most all GA applications for seeking solutions to whatever problems they are applied to over the last few years the videogame industry has become a huge and important entertainment industry [30]. Fig.11: shows the computing gaming model.

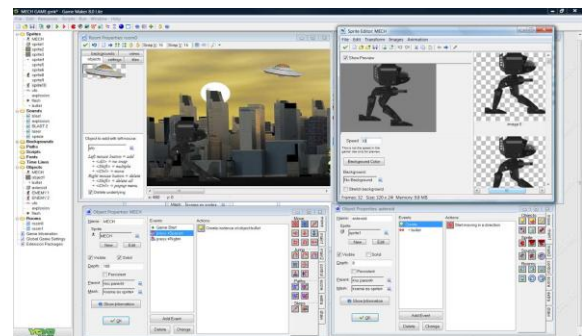


fig.11: Computing Gaming programming.

H. Trip, Traffic signal timing and Shipment Routing

New applications of a GA known as the "Travelling Salesman Problem" or TSP can be used to plan the most efficient routes and scheduling for travel planners, traffic routers and even shipping companies. The shortest routes for travelling. The timing to avoid traffic tie-ups and rush hours. Most efficient use of transport for shipping, even to including pickup loads and deliveries along the way. The program can be modelling

all this in the background while the human agents do other things, improving productivity as well. Fig.12: shown in the bellow. Chances are increasing steadily that when you get that trip plan packet from the travel agency. The genetic algorithm approach to solve traffic signal control and traffic assignment problem is used to tackle the optimisation of signal timings with stochastic user equilibrium link flows. Signal timing is defined by the common network cycle time, the green time for each signal stage, and the offsets between the junctions [31].

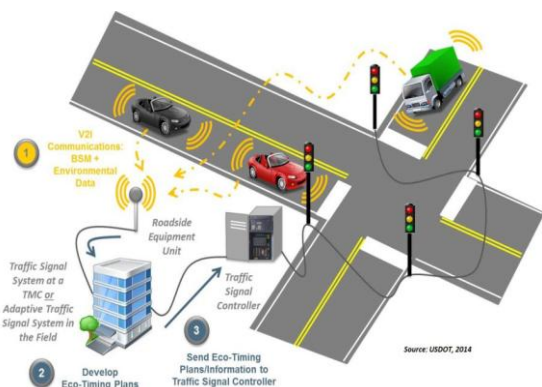


Fig.12: Trip, Traffic signal timing

I. Encryption and Code Breaking

Encryption for sensitive data as well as to break those codes.

Encrypting data, protecting copyrights and breaking competitors' codes have been important in the computer world ever since there have been computers, so the competition is intense. Every time someone adds more complexity to their Encryption algorithms, someone else comes up with a GA that can break the code. It is hoped that one day soon we will have quantum computers that will be able to generate completely Indecipherable codes, the processes of encryption/decryption. A cryptosystem is a set of algorithm, indexed by some keys(s), for encoding messages into cipher text and decoding them back into plaintext [32].



Fig.13: Encryption and Code Breaking.

J. Computer-Aided Molecular Design

Designing new molecules possessing desired properties is an important activity in the chemical and pharmaceutical industries. Much of this design involves an elaborate and expensive trial-and-error process that is difficult to automate. The present study describes a new

computer-aided molecular design approach using genetic algorithms [33].

The de novo design of new chemical molecules is a burgeoning field of applied chemistry in both industry and medicine. The GAs are used to aid in the understanding of protein folding, analyzing the effects of substitutions on those protein functions, and to predict the binding affinities of various designed proteins developed by the pharmaceutical industry for treatment of particular diseases. The same sort of the GAs optimization and analysis is used for designing industrial chemicals for particular uses, and in both cases the GAs can also be useful for predicting possible adverse consequences. This application has and will continue to have great impact on the costs associated with development of new chemicals and drugs.

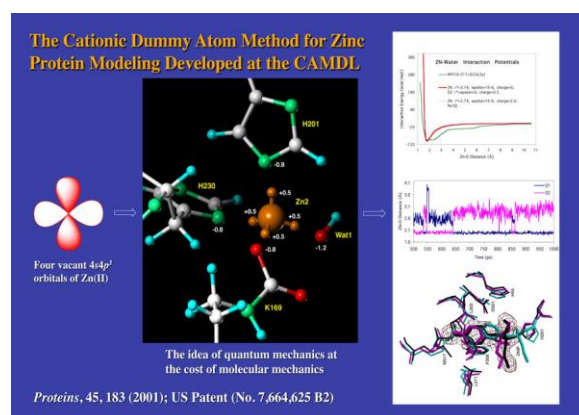


Fig.14: Computer-Aided Molecular Design.

K. Finance and Investment Strategies

In the current unprecedented world economic meltdown one might legitimately wonder if some of those Wall Street gamblers made use of GA-assisted computer modeling of finance and investment strategies to funnel the world's accumulated wealth into what can best be described as dot-dollar black holes. But then again, maybe they were simply all using the same prototype, which hadn't yet been de-bugged. It is possible that a newer generation of GA-assisted financial forecasting would have avoided the black holes and returned something other than bad debts the taxpayers get to repay. Who knows?



Fig.15: Finance and Investment Strategies

L. Optimizing Chemical Kinetic Analysis

In the not-so rarified realm of fuels and engines for combustion technologies, GAs are proving very useful toward optimizing designs in transportation, aerospace propulsion and electrical generation. By being able to predict ahead of time the chemical kinetics of fuels and the efficiency of engines, more optimal mixtures and designs can be made available quicker to industry and the public. Some computer modeling applications in this area also simulate the effectiveness of lubricants and can pinpoint optimized operational vectors, and may lead to greatly increased efficiency all around well before traditional fuels run out.

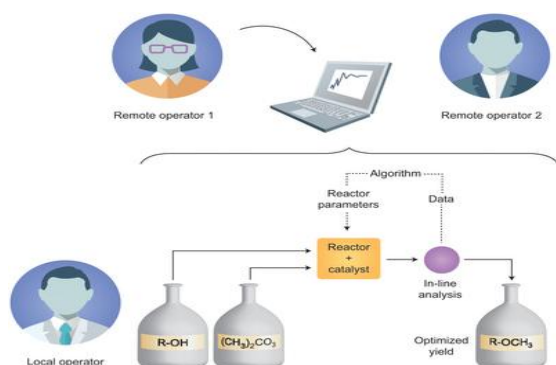


Fig.16: Optimizing Chemical Kinetic Analysis.

V. CONCLUSION

Some basic concepts and technology of genetic algorithms have been discussed in this paper. With the help of which we can understand the algorithm in a much better sense. It is basically used as problem solving technique in order to present with optimal solutions of given problems. The various concepts of fitness function, genetic operators, crossover, selection and mutation has also been explained in this reviewed paper. The various ways to implement genetic operators also working of each operator has been reviewed and explained, with various applications of genetic algorithms.

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