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CREATING EDUCATIONAL PATHS FOR UNIVERSITY STUDENTS TO ADDRESS SOCIETAL PROBLEMS

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Abstract

It has been noted in literature that creating educational paths for University students to address societal problems are multifaceted undertakings. They are often driven by federal, state, and local government grant sponsors on one hand, and foundations as well as well non-profit entities, on the other hand. Faculty members write proposals to these sponsors to obtain funding for their research projects with students. Universities typically have offices dedicated to managing these sponsored projects, ensuring compliance with sponsor requirements and University policies. Faculty must meet educational and learning outcomes in their courses through those projects. Project learning has five key characteristics: Project outcomes are tied to curriculum and learning goals; Driving questions and problems lead students to the central concepts or principles of the topic or subject area; Students' investigations and research involve enquiry and knowledge building; Students are responsible for designing and managing much of their learning; and Projects are based on authentic real-world problems proposed by sponsors. Sponsored projects are ideal instructional approaches for addressing societal problems, because they employ the 4Cs: Critical thinking, Communication, Collaboration and Creativity with learning structured in real world contexts. In this paper we present one of those student research projects that focused on approaches from Genetic Algorithms (GA) research to establish an extensive structure-property correlation database library. The collection of recommendations was used to design a range of novel polymers and fibers with improved characteristics such as exceptional stretch, recovery, strength, increased bulk, easy to dye, as well as improved hand and comfort properties. These technically advanced fibers of commercial importance to the U.S. textile industry combined the best properties of nylon and polyester, all through students' research.

Keywords: *Higher education, industry sponsored student projects, social and community impact.*

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1. Project selection

Based on END 2025 Conference reviewers' input, a student project that helped to solve community and social challenges nationally and globally, was selected. However, it is essential to stress that human empathy, derived and coming from communities experiencing the issues, served as a guide for students in solving that very problem (Sztandera, 2023). Through the project, students at Jefferson were able to learn and see the applications of Genetic Algorithms (GA) in daily activities and things they interacted with, like the clothes they wear, for example (Sztandera, 2012). The goal of this project was ambitious. Initially, we addressed the issues of monomer design and polymerization in order to demonstrate proof of concept. Subsequently, the project expanded to fiber spinning, yarns and fabrics. With help of Genetic Algorithms (GA), we were able to create and examine extremely large virtual databases of polymer molecular structures. The project was theoretical in concept, but highly practical in both, its aims, implementation and eventual applications. We planned to design fibers that offered increased bulk, improved softness and were easy-dye. Such fabrics were ideally suited for the apparel, home furnishings and automotive markets, and offered cost-effective, high-performance alternatives to existing commercial textile products.

2. Background

Genetic Algorithms (GA) have been increasingly incorporated into industrial design and development projects, and we believed that the textiles of the future should include new materials produced using these advanced computational chemistry-based approaches. Production of fibers, yarns and fabrics represented a promising field for such computationally advanced processes; thus, this project laid the groundwork for applying Genetic Algorithm approaches to the production of new materials. This project was profoundly relevant to the mission of National Textile Center (NTC), a Consortium of Universities, supported by the U.S. Department of Commerce, to spur the development of new materials and innovative manufacturing processes.

Genetic algorithms (GAs) seek to solve optimization problems using the methods of evolution, specifically survival of the fittest. In a typical optimization problem, there are a number of variables which control the process, and a formula or algorithm which combines the variables to fully model the process. The problem is then to find the values of the variables which optimize the model in some way. If the model is a formula, then we will usually be seeking the maximum or minimum value of the formula. There are many mathematical methods which can optimize problems of this nature (and very quickly) for fairly "well-behaved" problems. These traditional methods tend to break down when the problem is not so "well-behaved."

Genetic Algorithms (GAs) are intelligent computer techniques based on the biological concepts of natural selection and genetics. In this approach, the variables that define the solution to a scientific problem are represented as genes on a chromosome. GAs features a group of candidate solutions (a “population” of solutions) on the response surface. Through a form of natural selection and the genetic operations of mutation and recombination, chromosomes with better fitness are found. Natural selection guarantees that chromosomes with the best fitness will propagate into future populations. Using the recombination operator, a GA combines genes from two parent chromosomes to form two new chromosomes with a high probability of superior fitness. Mutation allows new areas of the response surface to be explored. GAs offers a generational improvement in the fitness of the chromosomes and, after many generations, will create chromosomes containing optimized variable settings.

3. Approach

There are 6 basic steps in the manufacture of textile products (Chen et. al., 2008). They are design and synthesis of monomers, polymerization of monomers, fiber spinning (melt vs. solution spinning), yarn preparation from fibers, weaving or knitting of yarns into textiles, and finally dyeing/finishing. Our initial aim was to address the issues of monomer design and polymerization in order to demonstrate proof of concept. The project eventually expanded into fiber spinning, yarns and fabrics after a demonstration of concept.

The number of potential polymeric materials is enormously large: numerous different types of monomers exist, they can be combined with one another in varying proportions, and in a wide range of molecular stereochemistry. Each factor – monomeric identities, stoichiometry, and stereochemistry – may profoundly influence the physical properties of the resulting polymer. Because of the enormous number of different polymers possible to synthesize, it is not viable to attempt to identify those polymers with desirable properties by synthesizing every conceivable polymer in order to test its properties. Some means of intelligent search through the range of potential products is therefore required. In view of the magnitude of the problem, Genetic Algorithms, which are ideally suited to this kind of large-scale multidimensional search, were used. The Genetic Algorithms made use of industrial and scientific data on the properties and performance of commercial textiles, and combined those data as appropriate with molecular quantum mechanical calculations on new species of potential interest. Thus, an extensive structure-property correlation repository could be developed. That repository was used both to evaluate the feasibility of Genetic Algorithms in the developmental phase of the project, and to aid it in the search for novel materials in the exploitation phase. The GA databases included:

- relationship between monomer parameters (chemical structure) and physical, thermal, mechanical properties of their resulting polymers;
- relationship between fundamental characteristics of polymers (molecular weight, level of crystallinity, orientation) and their physical, thermal, mechanical properties of polymers;
- relationship between reaction parameters (temperature, concentration, time, catalyst etc.) of monomers during polymerization of monomers into polymers and the fundamental characteristics of the resulting polymers;
- relationship between fiber spinning parameters (molecular weight of polymers, temperature, pressure, flow rate, draw ratio, annealing condition etc.) and fiber properties (level of crystallinity, degree of orientation, mechanical strength, etc.);
- relationship between fiber parameters (size, mono vs. multifilament etc.) and yarn processing (twist);

- relationship among fiber and yarn parameters, weaving/knitting of fabrics and fabric properties (air permeability, abrasion, tear, tensile, bursting, stiffness, comfort, dyeability).

Our approach to designing novel fibers made from polymers was to allow a GA search over monomer space to find polymers that possess a specified set of physical and chemical properties. GAs outperformed other optimization methods in a search of monomer space because the space was large and discontinuous. The representation used in the project was in the form of GA programming language strings that represented backbones and side chain groups. The graphical user-interface made that transparent to a user, which was critical for applications. The new GA which we proposed in this project, encompassed four important steps:

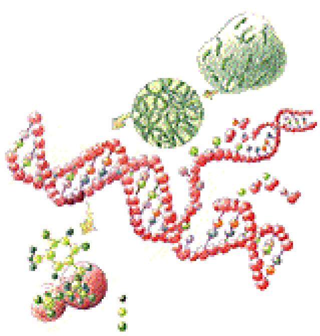
- The initial population of chromosomes was created either randomly or by perturbing an input chromosome (a sequence of physicochemical properties)
- In the evaluation step, fitness was computed using either a function derived from a summation of the properties of individual genes, or the more sophisticated Bohachevsky function
- The third step was the exploitation or natural selection step. Chromosomes with the largest fitness scores were placed semi-stochastically into a mating subset. Chromosomes with low fitness scores were removed from the population. Thus, we proposed a binary tournament mating subset selection method
- The fourth step, exploration, involved use of recombination and mutation operators. Two chromosomes from the mating subset were randomly selected and, using the uniform crossover method, recombination was applied to the individual genes in the chromosome. After the exploration step, the population was full of newly created chromosomes, and steps two through four were repeated for a predetermined number of generations.

The unique proposed operators used with polymers were:

1) *Asymmetric Crossover*: monomers could be of a variable length, so there is no advantage in choosing the same crossover point for the two parents. However, the crossover operator must leave realizable offspring, so a crossover point in the backbone was always chosen;
2) *Blending*: this operator concatenates two parents to produce one offspring whose length was the sum of those of the two parents;
3) *Mutation*: the mutation operator can act on either the backbone or the side chains;
4) *Insertion and Deletion*: backbone and side chain units can be deleted or inserted;
5) *Hopping*: the hop operator switches positions of the two backbone units.

The fitness function used was also novel in that it required the properties of the designed polymer to lie within a specified tolerance of the desired value.

Figure 1. A sample DNA sequence used in Genetic Algorithm approach.



After the establishment of the GA derived structure-property correlation database repository, a few model polymers were synthesized and their properties were evaluated for determining the feasibility of the proposed concept in designing novel polymers and fibers.

4. Conclusions

Commercially available monomers, polymers, and chemical reagents were used in the highlighted project to facilitate industry sponsored student project that led eventually to the technology transfer. Close relationships between academia and industry were established through exchange of ideas and the feedback of information on the production and performance of new products. Consultation with personnel from related chemical and fiber industries were sought to explore product and market possibilities and to provide feedback on industrial needs in this area of research. In the three years of this project, we demonstrated that utilizing Genetic Algorithms technology could overcome the design limitations of existing polymers and fibers, thus paving the way to production of yarns and textiles with novel functionality (Chen et. al. 2014).

Educational and learning outcomes in the course project were achieved through students pursuing their research challenge. The highlighted project learning had all required five key characteristics: Outcomes were tied to curriculum and learning goals; Driving questions and problems led students to the central concepts or principles of the topic or subject area; Students' investigations and research involved enquiry and knowledge building; Students were responsible for designing and managing much of their learning; and Project was based on authentic real-world problem proposed by the sponsor.

Industry sponsored student projects are ideal instructional approaches for addressing societal problems, because they employ the 4Cs: Critical thinking, Communication, Collaboration and Creativity with learning structured in real world contexts.

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