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# **AC 2011-1535: AN OPTIMIZATION ROUTINE FOR ASSIGNING STUDENTS TO CAPSTONE PROJECT GROUPS**

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## Introduction

At the beginning of the first semester of the two-semester sequence a list of potential projects are offered to students in a multidisciplinary capstone course at The University of North Carolina at Charlotte via the course website. Each project is accompanied by a description submitted by the sponsoring organization or individual, and has been vetted by the course's faculty committee before display. These project descriptions include a suggested staffing level for the project, broken-down by major area of study (i.e., Mechanical, Electrical, Computer, Civil, etc.). Unless specified, there is no distinction between Engineering Sciences and Engineering Technology disciplines. The faculty committee associated with this course has decided that student choice in project assignments is a critical component to project success, and, therefore, enrolled students are granted the opportunity to rank their top three project choices. These student rankings are used, in association with the expertise requirements of the project, to staff projects each semester. In addition, the faculty has implemented a system where a student's cumulative GPA is used as a weighting factor. If two students from the same technical discipline rank projects in the same order, the student with the higher GPA would be given preference in obtaining their highest ranked project choice that is still open for staffing. The capstone course features projects that are sponsored internally as well as externally. Externally sponsored projects serve a dual purpose to the program and to the university at large. These projects provide students with the experience of working with established engineers. They also provide a marketing opportunity for the College of Engineering (COE), as well as the capstone design program. In the last four years, course population has increased from 60 to 265. The solution described herein for the student assignment problem allows projects to be staffed with students using a weighted coefficient for each student/project combination. This course begins with an event where project representatives are present to answer student queries regarding project specifics and expectations. The course timetable is such that project assignments need to be made quickly, so that an initial planning meeting with student teams, faculty supervisors and project sponsors can take place in week three of the semester.

When the entire class size was 30 students, the project staffing process was accomplished by hand. Now that the student population has exceeded 200, this is no longer an option, either from an accuracy or execution time standpoint. The vast majority of departments and programs have all students participate in the COE senior design, with an emphasis on drastic reduction of self-defined and self-funded projects. This is still a possibility, but all students are required to work on teams and a detailed project proposal must be submitted and before the semester begins. An automated method was desired, and its development and testing is the subject of this work.

## Implementation of the solution

Since the staffing process represents a multivariate optimization with a large search space (more than 200 students and 70 projects in Fall 2010), a Genetic Algorithm (GA) was chosen as the tool of choice to execute the problem.

A GA is a problem solving technique that uses the concepts of evolution and heredity to produce quality solutions to complex problems that typically have enormous search spaces and are therefore difficult to solve. GAs have proved to be very helpful in solving complex, combinatorial problems. Reference [1] is a survey of various implementations of GAs in solving complex, combinatorial production and operations management problems. A well designed GA allows for the efficient and effective exploration and exploitation of the problem's search space of feasible solutions in an effort to identify the global optimal, or near optimal, solution to difficult problems [2].

A GA creates and manipulates a group of possible solutions referred to as a population. Each possible solution within the population is called an individual. The population undergoes change throughout the run of the GA thereby evolving the individuals toward a best solution. Within the GA, the population loops through a series of processes a number of times; each executed loop is known as a generation. These processes include an evaluation process, an alteration process, and a selection process. These processes may occur in various orders; however, each is required at each generation. [2]

The evaluation process uses an evaluation function that assesses the relative fitness of each individual of the population at each generation. In addition, at each generation a number of individuals are subjected to some form of change. These alterations are manifested through the use of genetic operators. Genetic operators can be either mutation operators, which introduce small changes within a single individual, or crossover operators, which cut and paste different parts from two or more individuals together in order to create new individuals called offspring. The probability of an individual experiencing some form of transformation within any given generation is subject to the predefined parameters of the probability of mutation, and/or the probability of crossover. Through this process, some, or all, of the individuals are altered and used to create a new population for the next generation. Finally, the GA uses the evaluated fitness of each individual to promote the survival of the best individuals to the next generation. This use of selective pressure encourages the population to converge to a quality solution. The GA will run for a predetermined maximum number of generations or until some specified terminating condition is met. [3]

Each GA is unique in its design with regard to several important elements. Some of these elements include data structure, genetic operators, method for creating the initial population, constraint handling techniques, evaluation function, selection method, generational policy, parameters, and terminating conditions. Parameters include population size, maximum number of generations, probability of mutation, and/or the probability of crossover. However, regardless of the differences, all GAs attempts to evolve the individuals within the population through the

use of genetic operators and selective pressures to converge at a suitable solution to complex problems. [3]

The inputs for the GA used in this solution are given as:

**Population Size:** The number of individuals in each generation, during the execution of the algorithm.

**Crossover 1 Probability:** The probability that crossover operator #1 will be applied. If a randomly generated number is less than or equal to the crossover probability value, then crossover #1 will be performed.

**Crossover 2 Probability:** The probability that crossover operator #2 will be applied with the same rules as crossover operator #1.

**Mutation 1 Probability:** The probability that mutation operator #1 will be applied. If a randomly generated number is less than or equal to the mutation 1 probability value, then mutation #1 will be performed.

**Mutation 2 Probability:** The probability that mutation operator #2 will be applied with the same rules as mutation operator #1.

**Chance:** Applies to crossover #1, crossover #2, mutation #1, and mutation #2 operators. This value sets the number of attempts to perform each operator.

**Maximum number of generations:** This value sets the number of search iterations the algorithm will run. This is the number of generations a population of individual solutions will evolve. As the algorithm runs, the solutions evolve, thereby randomly sampling the problem's search space. For our implementation, the individual solution identified with the largest fitness value during the run of the GA is given as the "best" solution.

The development of a GA is complex. Generally, the larger the search space (in this case, the more student/project combinations), the larger the population size and maximum number of generations required in order to adequately examine the problem's search space. For the student assignment problem a population size of 20 to 40 was theorized as sufficient, along with a maximum number of generations below 200.

The data structure employed to solve the student assignment problem is a simple two-dimensional binary array as shown in Figure 1. Each student is assigned to exactly one project; however, each project may have many students. Each cell in the two-dimensional array represents a unique student/project combination. If a student is assigned to a given project there will be a one entered in that student/project index, otherwise the value will be zero.

Individual 1						
	Project 1	Project 2	Project 3	...	Project $m$	
Student 1	{0,1}	{0,1}	{0,1}	...	{0,1}	$\Sigma = 1$
Student 2	{0,1}	{0,1}	{0,1}	...	{0,1}	$\Sigma = 1$
Student 3	{0,1}	{0,1}	{0,1}	...	{0,1}	$\Sigma = 1$
:	{0,1}	{0,1}	{0,1}	...	{0,1}	$\Sigma = 1$
Student $n$	{0,1}	{0,1}	{0,1}	...	{0,1}	$\Sigma = 1$

Figure 1. Basic Data Structure for Individual Solutions.

As discussed, each project is assigned a weight based on its priority. The actual weight is not important, and, in fact, the spread of weights can be whatever is desired, the important thing is that the highest priority projects have the highest weights and the lowest priority projects have the lowest weights.

Furthermore, each student/project combination is given a weighted coefficient. The weighted coefficient is the product of the student's GPA, the choice weight based on the project choices made by the student, and the project weight. If a project is not one of a student's three top choices, the project's ranking is equal to one. Figure 2 illustrates how the student/project coefficient weights are calculated for each student/project combination. Figure 3 further illustrates that if a student/project combination is not selected then its cell value will be zero, and, therefore, its contribution to the overall individual's fitness value will be zero. If the student/project combination is selected, then the contribution to the overall individual's fitness value will be equal to the student/project cell's weight.

Individual 1					
	Project 1	Project 2	Project 3	...	Project $m$
Student 1	$w_{1,1} = \text{Student 1's GPA} * \text{Student 1's Project Choice Weight} * \text{Project 1's weight}$	$w_{1,2}$	$w_{1,3}$	...	$w_{1,m}$
Student 2	$w_{2,1} = \text{Student 2's GPA} * \text{Student 2's Project Choice Weight} * \text{Project 1's weight}$	$w_{2,2}$	$w_{2,3}$	...	$w_{2,m}$
Student 3	$w_{3,1} = \text{Student 3's GPA} * \text{Student 3's Project Choice Weight} * \text{Project 1's weight}$	$w_{3,2}$	$w_{3,3}$	...	$w_{3,m}$
:	...	...	...	...	...
Student $n$	$w_{n,1} = \text{Student } n \text{'s GPA} * \text{Student } n \text{'s Project Choice Weight} * \text{Project 1's weight}$	$w_{n,2}$	$w_{n,3}$	...	$w_{n,m}$

Figure 2. Calculation of Total Project Weight

Individual 1					
	Project 1	Project 2	Project 3	...	Project m
Student 1	{0,1} * $w_{1,1}$	{0,1} * $w_{1,2}$	{0,1} * $w_{1,3}$	...	{0,1} * $w_{1,m}$
Student 2	{0,1} * $w_{2,1}$	{0,1} * $w_{2,2}$	{0,1} * $w_{2,3}$	...	{0,1} * $w_{2,m}$
Student 3	{0,1} * $w_{3,1}$	{0,1} * $w_{3,2}$	{0,1} * $w_{3,3}$	...	{0,1} * $w_{3,m}$
:	...	...	...	...	...
Student n	{0,1} * $w_{n,1}$	{0,1} * $w_{n,2}$	{0,1} * $w_{n,3}$	...	{0,1} * $w_{n,m}$

\*w represents the Student/Project weight

Figure 3. Weighted Data Structure

Once the student/project weights are calculated, assignment of students to projects (initially done semi-randomly) creates the first generation of individuals, each representing a feasible solution, and a corresponding of fitness values, which is the cumulative weight of all selected student/project combinations. The aggregated fitness value is used, in part, to determine which individuals “survive” to the next generation (i.e., the set of solutions used in the next iteration).

Projects with larger staffing requirements can produce a larger fitness value to the total individual’s fitness value than that contributed by a project with smaller staff requirements. Therefore, the construction of this GA is such that large projects are given preference with respect to smaller ones for staffing, given an equal project priority. Small projects are often cancelled with extraneous personnel assigned to a larger project, rather than execution with a short staff. This solution facilitates rounding out group assignments in practice. Figure 4 illustrates the population of individuals, each student/project combination within each individual within the population will be assigned with a 0 or 1, where a 1 indicates that a student is assigned to a given project. A student is assigned to exactly one project. Each individual’s fitness value is the cumulative product of the weighted coefficient for each selected student/project combination.

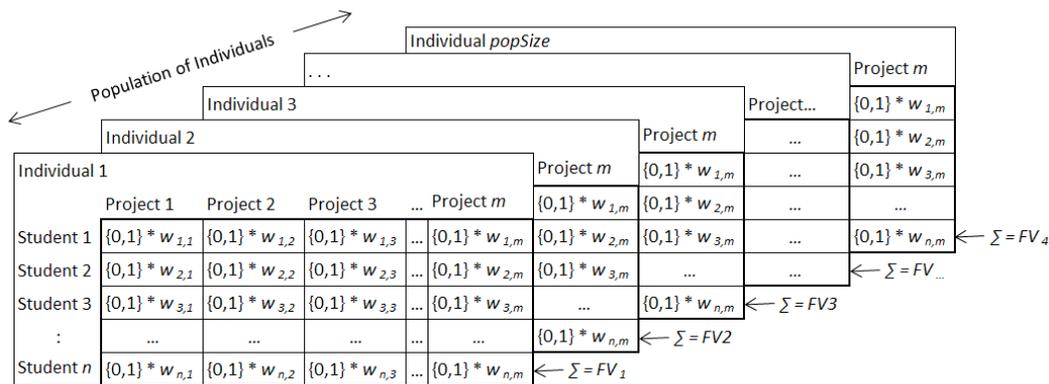


Figure 4. Calculation of Fitness Value

Once the initial generation of individual solutions has been created, the mechanism of the GA is engaged. Through two basic genetic operations, Crossover and Mutation, the solutions in a

generation’s population randomly undergo augmentation and change, thereby creating new individual solutions called offspring. These genetic operators produce feasible solutions, each with its own fitness value. Just as in nature, individuals with genetic changes with larger fitness values have a higher probability of being selected for the next generation. At the end of each generation, there is a pool of individuals that is comprised of the individuals in the population at the beginning of the generation and all offspring that have been created during the run of the generation.

The selection process for populating each successive generation is completed through the use of a tournament selection process. In the implementation of the tournament selection process used in this GA, three individuals are randomly selected from the pool of individuals at the end of a generation; the individual with the largest fitness value is deemed the “winner” and is copied into the next generation’s population. The selection process for the next generation’s population also employs an elites strategy, which entails copying the best solution found to that point from the run of the algorithm into each generation. The tournament selection process is then run  $popSize - 1$ , where  $popSize$  is the constant population size maintained from generation to generation.

Of the two basic genetic operations, Crossover and Mutation, this GA implements two crossover operators, designated as Crossover 1 and Crossover 2, and two mutation operators, designated Mutation 1 and Mutation 2. Both crossover operators create two “offspring”, or new individual solutions for possible inclusion in the next generation, by swapping a portion of each parent into each offspring. Both mutation operators create one “offspring”, by making a small change in one “parent” solution. Figure 5 illustrates how Crossover 1 operator works. Here a “cut-point” corresponding to a student number is randomly selected, i.e.,  $randStudentNum$ . The information from Student 1 to Student  $randStudentNum-1$  is copied from Parent 1 and Parent 2 into Offspring 1 and Offspring 2, respectively. Then the information from Student  $randStudentNum$  to Student  $n$ , where  $n$  is the total number of students, is copied from Parent 1 and Parent 2 into Offspring 2 and Offspring 1, respectively. This function perturbs the “student” information in the Parent individuals, thereby creating two new individuals, i.e., the row wise information encoded in contributing individuals.

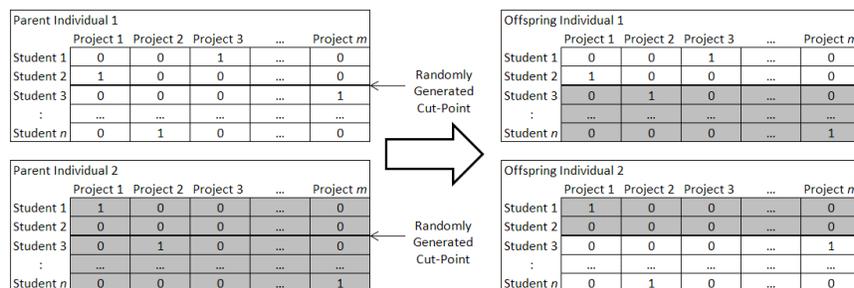


Figure 5. Offspring produced by the Crossover 1 Operator

For Crossover 2, again a “cut-point” is randomly selected. However, for this crossover operator the cut-point corresponds to a project number, i.e., *randProjectNum*. The information from Project 1 to Project *randProjectNum-1* is copied from Parent 1 and Parent 2 into Offspring 1 and Offspring 2, respectively. Then the information from Project *randProjectNum* to Project *m*, where *m* is the total number of projects, is copied from Parent 1 and Parent 2 into Offspring 2 and Offspring 1, respectively. This function perturbs the “project” information in the Parent individuals, thereby creating two new individuals, i.e., the column wise information encoded in contributing individuals, as shown in Figure 6.

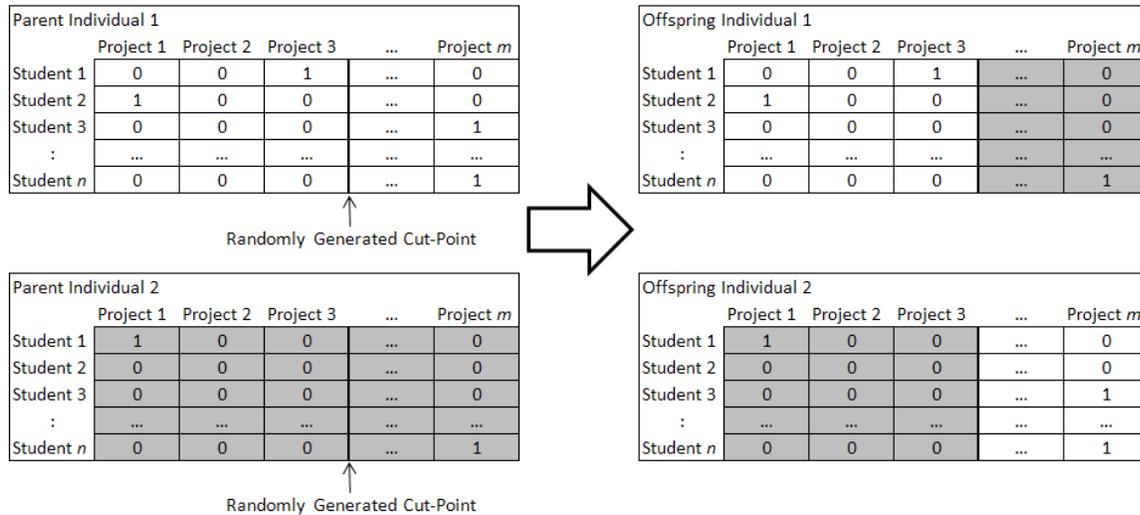


Figure 6. Offspring Produced by the Crossover 2 Operator

Rather than producing offspring through combination of genetic material, the mutation operator produces a changed individual by randomly changing only a small amount of information within one Parent individual. Mutation 1 generates two random numbers which correspond to two student numbers. The information for each of the two student numbers is then swapped, thereby producing a new individual for possible inclusion in the next generation of solutions. This process is illustrated in Figure 7.

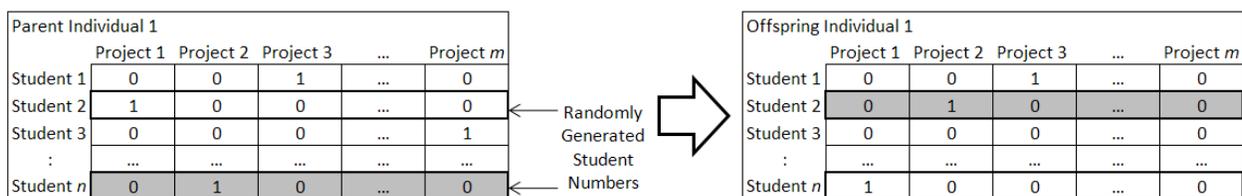


Figure 7. New individual produced by the Mutation 1 Operator

Mutation 2 is a more targeted change. A Parent individual is selected, and a single student/project allele is designated randomly for assignment. The student/project allele previously assigned is deleted, as shown in Figure 8.

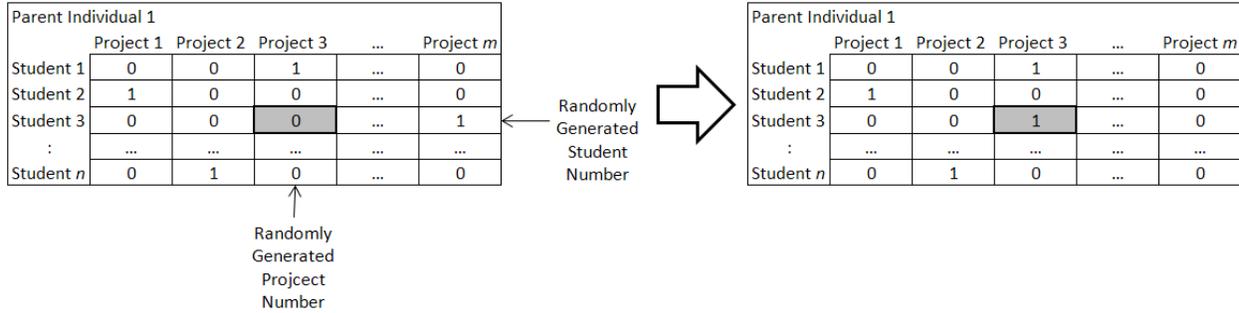


Figure 8. New individual produced by the Mutation 2 Operator

The GA application is designed so that any or all of the four genetic operators can be applied. For our initial tests, all four operators were used, where the probability of each (i.e., Crossover 1 Probability, Crossover 2 Probability, Mutation 1 Probability, and Mutation 2 Probability) were all set to 0.5. Here the associated probabilities indicate when the operator will be implemented. For this GA, for each genetic operator a random number is generated *Chance* times, where *Chance* is an additional input variable. If the random number generated is less than the genetic operator's probability, then the operator is implemented. For this GA, the *Chance* is the same for all genetic operators and can be changed. For the initial tests, *Chance* was set equal to the population size. The *Chance* parameter and the different genetic operator probabilities are a mechanism of how much perturbation is desired between generations. The program code for this GA is included as Appendix I.

## Results

To test the algorithm, two data sets were used. The first data set consisted of 67 students and 24 projects. The number of individuals, the chance for genetic change and the maximum number of generations were varied to check for convergence of the method. The output of the solutions generated by the algorithm are shown in Table 1. These solutions were obtained with the following input parameters:

- Crossover 1 Probability = 0.5
- Crossover 2 Probability = 0.5
- Mutation 1 Probability = 0.5
- Mutation 2 Probability = 0.5

Table 1. Convergence Study

Population Size	Chance	Max # Generations	Over 5 Runs			Student Choice (Average over 5 runs)				% Student Choice (Average over 5 runs)			
			Maximum	Minimum	Average	1st	2nd	3rd	other	1st	2nd	3rd	other
10	10	20	84,345	81,420	81,420	37.2	12.4	4.6	12.8	55.5%	18.5%	6.9%	19.1%
20	20	20	83,627	80,955	82,374	36.6	11.4	6.4	12.6	54.6%	17.0%	9.6%	18.8%
30	30	20	84,275	81,836	82,654	38	12.6	5.8	10.6	56.7%	18.8%	8.7%	15.8%
40	40	20	84,753	82,099	83,382	35	13.4	5.4	13.2	52.2%	20.0%	8.1%	19.7%
50	50	20	83,478	81,002	82,506	38	13.2	5.4	10.4	56.7%	19.7%	8.1%	15.5%
10	10	40	84,415	82,560	83,615	34.6	12.2	6.2	14	51.6%	18.2%	9.3%	20.9%
20	20	40	84,729	81,519	83,675	37.4	13.6	5	11	55.8%	20.3%	7.5%	16.4%
30	30	40	84,109	79,795	82,645	38	12.8	6.2	10	56.7%	19.1%	9.3%	14.9%
40	40	40	84,941	79,790	82,250	38.6	11.8	5.4	11.2	57.6%	17.6%	8.1%	16.7%
50	50	40	84,441	81,908	83,343	38.6	13.2	5.6	9.6	57.6%	19.7%	8.4%	14.3%
10	10	60	91,274	80,293	84,568	33.2	12	5	16.8	49.6%	17.9%	7.5%	25.1%
20	20	60	85,366	82,274	83,825	38.4	13	5.8	9.8	57.3%	19.4%	8.7%	14.6%
30	30	60	89,536	82,599	84,680	35.4	13.4	5.6	12.6	52.8%	20.0%	8.4%	18.8%
40	40	60	85,906	81,079	82,873	37.2	12.6	4.6	12.6	55.5%	18.8%	6.9%	18.8%
50	50	60	84,774	80,061	82,514	37.4	12.4	5.2	12	55.8%	18.5%	7.8%	17.9%
10	10	80	86,391	82,192	83,915	38	12.2	5	11.8	56.7%	18.2%	7.5%	17.6%
20	20	80	84,131	81,311	83,387	37	13.2	5.6	11.2	55.2%	19.7%	8.4%	16.7%
30	30	80	87,774	80,760	83,278	37.2	11.8	6.2	11.8	55.5%	17.6%	9.3%	17.6%

40	40	80	84,848	81,001	83,207	37.6	12.8	5.8	10.8	56.1%	19.1%	8.7%	16.1%
50	50	80	84,707	81,306	82,720	39.2	12	6.4	9.4	58.5%	17.9%	9.6%	14.0%
10	10	10 0	85,454	82,622	83,864	33	12.8	4.2	17	49.3%	19.1%	6.3%	25.4%
20	20	10 0	87,243	81,541	84,472	38.6	12.6	6	9.8	57.6%	18.8%	9.0%	14.6%
30	30	10 0	84,831	79,614	83,216	39.4	12.2	6.4	9	58.8%	18.2%	9.6%	13.4%
40	40	10 0	85,684	83,450	84,415	37.4	13.2	5.8	10.6	55.8%	19.7%	8.7%	15.8%
50	50	10 0	85,747	82,049	83,738	37	12.2	5	12.8	55.2%	18.2%	7.5%	19.1%

For this problem a relatively small population size and small maximum number of generations (i.e., population size = 10 and max # generations = 20) provides approximately the same results with respect to student choice. Of course, these results may change depending on the underlying problem configuration, which includes the combined student choices, the weights of the choices, the project weights, and the maximum and minimum number of students required to staff each project. However, with respect to fitness value, it appears from the test data shown here that the best values are found when the population size is relatively small (i.e., 10, 20, or 30) and the maximum number of generations is moderately high (i.e., 60, 80, or 100). It is important to point out that the final fitness value includes a reward and penalty function. If a project within an individual solution has the maximum number of students assigned to it, it is rewarded and its fitness value is increased. If a project does not have the minimum number of students, it is penalized and its fitness value is decreased. Based on this convergence study, the parameters chosen for implementation of a larger problem (200 students and 80 projects), were chosen to be:

- Population (Number of Individuals) = 20 or 40
- Maximum Number of Generations = 20 - 120
- Chance = 20% or 40%

For the larger problem, the highest fitness values occur for the largest maximum number of generations tested (i.e., 120 generations) for both population sizes, 20 and 40 individuals. Interestingly, the highest fitness value of 1,484,288.8, occurred when the population size was 20 and the maximum number of generations was 120, also produced the worst results with respect to student choice. While the results were acceptable, they were lower than the other test data for the large problem. This goes to show the dual nature of the objective of trying to assign students to their choice projects while also trying to pressure the algorithm to assign students to higher weighted projects (i.e., projects with higher priority) and also give rewards when the minimum

number of students are assigned to a project and penalize when the maximum number of required students are not assigned to a project.

Table 2. Application of Converged Algorithm

Population Size	Chance	Max # Generations	Fitness Value	Student Choice (Average over 5 runs)				Total # Students	% Student Choice (Average over 5 runs)			
				1st	2nd	3rd	other		1st	2nd	3rd	other
20	20	20	1,395,539.9	141	40	10	9	200	70.5%	20.0%	5.0%	4.5%
20	20	40	1,391,030.9	143	38	10	9	200	71.5%	19.0%	5.0%	4.5%
20	20	60	1,395,624.1	143	39	10	8	200	71.5%	19.5%	5.0%	4.0%
20	20	80	1,393,201.9	143	39	10	8	200	71.5%	19.5%	5.0%	4.0%
20	20	100	1,394,532.7	143	39	9	9	200	71.5%	19.5%	4.5%	4.5%
20	20	120	1,484,288.8	129	36	11	24	200	64.5%	18.0%	5.5%	12.0%
40	40	20	1,390,652.1	143	38	10	9	200	71.5%	19.0%	5.0%	4.5%
40	40	40	1,389,698.6	143	37	9	11	200	71.5%	18.5%	4.5%	5.5%
40	40	60	1,394,664.7	143	38	11	8	200	71.5%	19.0%	5.5%	4.0%
40	40	80	1,394,043.9	143	38	11	8	200	71.5%	19.0%	5.5%	4.0%
40	40	100	1,394,043.9	141	41	10	8	200	70.5%	20.5%	5.0%	4.0%
40	40	120	1,402,551.1	144	38	11	7	200	72.0%	19.0%	5.5%	3.5%

## Conclusions

A Genetic Algorithm (GA) for assigning student groups for a capstone course has been presented. The algorithm uses input of student rankings, project importance, staffing level and competencies required. This GA runs in a small fraction of the time formerly devoted to student staffing by course instructors. The particular nature of the competing parameters in this solution

(student choice versus sponsoring organization priority) are highlighted in the algorithm performance.

## Appendix I

### Computer Code

Option Explicit

Option Base 1

Public numStudents As Integer

Public numCol As Integer

Private majorCountArray() As Integer

Private majorArray() As String

Private studentMajorArray() As Integer

Public numProjects As Integer

Public students() As Variant

Public projects() As Variant

Public choiceWeights(3) As Integer

Public weightsArray() As Double

Public activeGenArray() As Integer

Public activeGenArrayFV() As Double

Public offSpringArray() As Integer

Public offSpringArrayFV() As Double

Public numOffspring As Integer

Public tempOffspring() As Integer

Public maxMajor() As Integer

Public minMajor() As Integer

Public historyArray() As Integer

Public historyArrayFV() As Double

Public crossoverProb1 As Double

Public crossoverProb2 As Double

Public mutationProb1 As Double

Public mutationProb2 As Double

Public chance As Integer

Public i As Integer

Public j As Integer

Public k As Integer

Public m As Integer

Public n As Integer

Public p As Integer

Private major As String

Private majorCount As Integer

Private diffMajorCount As Integer

Private studentMajorCount As Integer

Public maxMajors As Integer

Public minMajors As Integer

Public Count As Integer

Public Count1 As Integer

Public Count2 As Integer

Public popSize As Integer

Public rndNum As Double

Public rndNum1 As Integer

Public rndNum2 As Integer

Dim fV As Double

Public flag As Boolean

Public flag1 As Boolean

Public flag2 As Boolean

Public stop1 As Boolean

Public stop2 As Boolean

Public gen As Integer

Public maxGen As Integer  
Public bestFV As Double  
Public bestFVIndex As Integer  
Public historyBestFV As Double  
Public historyBestFVIndex As Integer  
Public feasibilityArray() As Double  
Public x As Double  
Public y As Integer  
Public z As Integer  
Public t As Integer  
Public start As Integer  
Public finish As Integer  
Public feasibilityBestIndex As Integer  
Public feasibilityBestProjNum As Integer  
Public feasibilityBestWeight As Integer  
Public infeasibleIndex() As Integer  
Public infeasibleTemp() As Integer  
Public Sum As Integer  
Public infeasible As Integer  
Public q As Integer  
Public r As Integer  
Public Form As Boolean  
Public sheetName As String

Sub Main()

'Student Assignment Problem

'January 4, 2011

```
sheetName = "Projects"
```

```
'Delete information and formatting from following worksheets
```

```
ActiveWorkbook.Worksheets("matrix").Range("A1:XD1000").Clear
```

```
ActiveWorkbook.Worksheets("Output").Range("A1:XD1000").Clear
```

```
ActiveWorkbook.Worksheets("Solution Summary").Range("A1:XD1000").Clear
```

```
'Reads input values from the "Inputs" worksheet
```

```
With ActiveWorkbook.Worksheets("Inputs").Range("A1")
```

```
    popSize = .Offset(1, 2)
```

```
    crossoverProb1 = .Offset(2, 2)
```

```
    crossoverProb2 = .Offset(3, 2)
```

```
    mutationProb1 = .Offset(4, 2)
```

```
    mutationProb2 = .Offset(5, 2)
```

```
    chance = .Offset(6, 2)
```

```
    maxGen = .Offset(7, 2)
```

```
End With
```

```
'Determine the total number of students and assign each student a number in order
```

```
Call DetermineNumStudents
```

```
diffMajorCount = 1
```

```
ReDim majorArray(diffMajorCount)
```

```
'Determine the number of students for each major
```

```
Call DetermineNumStudentsInEachMajor
```

```
'Determine the number of projects
```

Call DetermineNumProjects

'Project/Major requirements from the "Project" worksheet

Call ProjectMajorMinMax

'Populate student array with each student's last name, first name, GPA, Major,

'1st, 2nd, and 3rd project choices

'NOTE: Array index corresponds to student number

Call PopStudentArray

'Populate project array with each project's name, sponsor, and weight

'NOTE: Array index corresponds to project number

Call PopProjectsArray

'Populate the choiceweights array with the weights for each of the student's

'three choices. The weights for the three choices can be changed by changing

'the values in K4, K5, and K6 on the "Students" worksheet

Call PopChoiceWeights

'Populate the weights array. This array contains the coefficient value

'associated with each student/project combination. The weight for each

'combination is equal to the product for the student's GPA, the student's

'weighted choice for that project, and the project's weight

'Note: If a given project is not one of the student's three choices, it is

'given a weight of 1

Call PopWeightsArray

'Print array of weights on the "matrix" worksheet. This worksheet shows the

'weights associated with each student/project combination. These weights are  
'the product of the project's weight, the student's GPA, and the student's  
'choice weight for a given project. If a project is not one of the student's  
'three choices, it is given a choice weight of 1

Call PrintWeightsArray

'Start with generation 1

gen = 1

'Redimensionalize the activeGenArray and the activeGenArrayFV. These arrays  
'work together. The activeGenArray contains the beginning population of  
'chromosomes for each generation, and the activeGenArrayFV contains the  
'corresponding fitness value for each chromosome in the activeGenArray

ReDim activeGenArray(numStudents, numProjects, popSize)

ReDim activeGenArrayFV(popSize)

'Redimensionalize the historyArray and the historyArrayFV. These arrays  
'work together. The historyArray contains the best chromosomes found  
'in each generation, and the historyArrayFV contains the corresponding fitness  
'value for each chromosome in the historyArray

ReDim historyArray(numStudents, numProjects, maxGen)

ReDim historyArrayFV(maxGen)

'Creates the initial population. The initial population is populated using the  
'student's choices. It is important that the data in the "Students" worksheet  
'be sorted by Major first, and then by GPA. Those student's with the highest  
'GPA will be assigned to their choice projects, if they are not filled, first

Call InitializePop

'Determine the fitness value for each chromosome in the offspring array

Call FitnessValueInitialPop

'Run program for maximum generations. The maximum number of generations (maxGen)

'can be changed by changing the value in cell C7 on the "Inputs" worksheet

'Generally, the larger the search space, i.e., the larger the number of possible

'Student/Project combination, the larger the maxGen should be. This allows the

'algorithm more time to find a good solution. However, the larger the maxGen

'the longer it will take for the algorithm to run. It should be noted that no

'matter how long the algorithm runs, do to the randomness employed in the algorithm,

'there is no guarantee that a good solution will be reached. If a solution does

'not appear good, the algorithm can be run again, at which point the input data

'might be changed as desired. This algorithm will run for maxGen.

Do While gen <= maxGen

'Copy the present generation's population of chromosomes into the offspring array

Call CopyActivePopToOffspring

'Crossover operation#1

Call Crossover1

'Crossover operation#2

Call Crossover2

'Mutation operation#1

Call Mutation1

'Mutation operation#2

Call Mutation2

'Determine the fitness value for each chromosome in the offspring array

Call FitnessValue

'Checks for feasibility, assigns awards and penalties

Call Feasibility

'Select best chromosome from offspring array and store in History Array

Call SelectBestFromOffspring

'Select next generations chromosomes

Call NextGen

gen = gen + 1

Loop 'generational loop

'Print the absolute best from the history array

Call PrintAbsoluteBest

End Sub

Sub DetermineNumStudents()

'Determine the total number of students and assign each student a number in order

With ActiveWorkbook.Worksheets("Students").Range("A4")

numStudents = .CurrentRegion.rows.Count - 3

```
numCol = .CurrentRegion.Columns.Count
```

```
For i = 0 To numStudents - 1
```

```
    .Offset(i, 0).Value = i + 1
```

```
Next
```

```
End With
```

```
End Sub
```

```
Sub DetermineNumStudentsInEachMajor()
```

```
    'Determine the number of students for each major
```

```
    With ActiveWorkbook.Worksheets("Students").Range("A3")
```

```
        For j = 0 To numCol - 1
```

```
            If .Offset(0, j).Value = "Major" Then
```

```
                major = .Offset(1, j).Value
```

```
                studentMajorCount = 0
```

```
                majorCount = 0
```

```
                diffMajorCount = 1
```

```
            For i = 1 To numStudents
```

```
                If major = .Offset(i, j).Value Then
```

```
                    majorCount = majorCount + 1
```

```
                    studentMajorCount = studentMajorCount + 1
```

```
                Else
```

```
                    ReDim Preserve majorArray(diffMajorCount)
```

```
                    majorArray(diffMajorCount) = major 'records name of major
```

```
                    ReDim Preserve majorCountArray(diffMajorCount)
```

```

    majorCountArray(diffMajorCount) = majorCount 'records the number students in each array
    ReDim Preserve studentMajorArray(diffMajorCount)

    studentMajorArray(diffMajorCount) = studentMajorCount 'records the number of students in each
array; Redundant

    majorCount = 1

    studentMajorCount = 1

    diffMajorCount = diffMajorCount + 1

    major = .Offset(i, j).Value

End If

Next

    ReDim Preserve majorArray(diffMajorCount)

    majorArray(diffMajorCount) = major

    ReDim Preserve majorCountArray(diffMajorCount)

    majorCountArray(diffMajorCount) = majorCount

    ReDim Preserve studentMajorArray(diffMajorCount)

    studentMajorArray(diffMajorCount) = studentMajorCount

Exit For

End If

Next

End With

End Sub

```

```

Sub DetermineNumProjects()

```

```

'Determine the number of projects

```

```

With ActiveWorkbook.Worksheets(sheetName).Range("A4")

```

```

    numProjects = .CurrentRegion.rows.Count - 3

```

```

    numCol = .CurrentRegion.Columns.Count

```

```
For i = 0 To numProjects - 1
    .Offset(i, 0).Value = i + 1
Next
End With
End Sub
```

```
Sub ProjectMajorMinMax()
```

```
'Project/Major requirements from the "Project" worksheet
'Records the maximum number of students from each major for each
'project, and the minimum number of students from each major
'for each project. This information is used in the feasibility
'sub-routine to reward solutions with project that have at least
'the minimum number of each major and penalize those projects that
'have more than the maximum number of each major. These are soft
'constraints however and do not guarantee that the final, best,
'solution will not violate the min/max for each project
ReDim maxMajor(numProjects, diffMajorCount)
ReDim minMajor(numProjects, diffMajorCount)
Count = 0
```

```
With ActiveWorkbook.Worksheets(sheetName).Range("A3")
```

```
'Determine the maximum number of each major required for each project in the Project worksheet
```

```
Count = 4
```

```
Do While Count < diffMajorCount + 4
```

```
For j = 1 To diffMajorCount
```

```
For i = 1 To numProjects
```

```

        maxMajor(i, j) = .Offset(i, Count).Value
    Next
    Count = Count + 1
Next
Loop

'Determine the minimum number of each major required for each project in the Project worksheet
Count = 7
Do While Count < diffMajorCount + 7

    For j = 1 To diffMajorCount
        For i = 1 To numProjects
            minMajor(i, j) = .Offset(i, Count).Value
        Next
        Count = Count + 1
    Next
Loop
End With
End Sub

```

```

Sub PopStudentArray()

```

```

    'Populate student array with each student's last name, first name, GPA, Major,

```

```

    '1st, 2nd, and 3rd project choices

```

```

    'NOTE: Array index corresponds to student number

```

```

    ReDim students(numStudents, 7)

```

```

    With ActiveWorkbook.Worksheets("Students").Range("A3")

```

```

For i = 1 To numStudents
    students(i, 1) = .Offset(i, 1).Value 'last name
    students(i, 2) = .Offset(i, 2).Value 'first name
    students(i, 3) = .Offset(i, 3).Value 'GPA
    students(i, 4) = .Offset(i, 4).Value 'Major
    students(i, 5) = .Offset(i, 5).Value '1st choice
    students(i, 6) = .Offset(i, 6).Value '2nd choice
    students(i, 7) = .Offset(i, 7).Value '3rd choice
Next
End With
End Sub

Sub PopProjectsArray()
    'Populate project array with each project's name, sponsor, and weight
    'NOTE: Array index corresponds to project number
    ReDim projects(numProjects, 3)

    With ActiveWorkbook.Worksheets(sheetName).Range("A3")
        For i = 1 To numProjects
            projects(i, 1) = .Offset(i, 1).Value 'name
            projects(i, 2) = .Offset(i, 2).Value 'sponsor
            projects(i, 3) = .Offset(i, 3).Value 'weight
        Next
    End With
End Sub

Sub PopChoiceWeights()
    'Populate the choiceweights array with the weights for each of the student's

```

'three choices. The weights for the three choices can be changed by changing  
'the values in K4, K5, and K6 on the "Students" worksheet

```
With ActiveWorkbook.Worksheets("Students").Range("J3")
```

```
For i = 1 To 3
```

```
    choiceWeights(i) = .Offset(i, 1).Value '1st choice weight
```

```
    choiceWeights(i) = .Offset(i, 1).Value '2nd choice weight
```

```
    choiceWeights(i) = .Offset(i, 1).Value '3rd choice weight
```

```
Next
```

```
End With
```

```
End Sub
```

```
Sub PopWeightsArray()
```

'Populate the weights array. This array contains the coefficient value  
'associated with each student/project combination. The weight for each  
'combination is equal to the product for the student's GPA, the student's  
'weighted choice for that project, and the project's weight  
'Note: If a given project is not one of the student's three choices, it is  
'given a weight of 1

```
ReDim weightsArray(numStudents, numProjects)
```

```
For i = 1 To numStudents
```

```
    For j = 1 To numProjects
```

```
        If students(i, 5) = j Then '1st choice
```

```
            weightsArray(i, j) = choiceWeights(1) * projects(j, 3) * students(i, 3)
```

```
        ElseIf students(i, 6) = j Then '2nd choice
```

```
            weightsArray(i, j) = choiceWeights(2) * projects(j, 3) * students(i, 3)
```

```
        ElseIf students(i, 7) = j Then '3rd choice
```

```
            weightsArray(i, j) = choiceWeights(3) * projects(j, 3) * students(i, 3)
```

```

Else 'Project is not one of the students 3 choices, then weight = 1
    weightsArray(i, j) = projects(j, 3) * students(i, 3)
End If
Next
Next
End Sub

```

```

Sub PrintWeightsArray()

```

```

'Print array of weights on the "matrix" worksheet. This worksheet shows the
'weights associated with each student/project combination. These weights are
'the product of the project's weight, the student's GPA, and the student's
'choice weight for a given project. If a project is not one of the student's
'three choices, it is given a choice weight of 1
ActiveWorkbook.Worksheets("matrix").Range("A1:XD1000").Clear

```

```

With ActiveWorkbook.Worksheets("matrix").Range("A1")

```

```

    For i = 1 To numStudents
        For j = 1 To numProjects
            .Offset(i, j).Value = weightsArray(i, j)

            If students(i, 5) = j Then '1st choice
                .Offset(i, j).Interior.Color = vbBlue
            ElseIf students(i, 6) = j Then '2nd choice
                .Offset(i, j).Interior.Color = vbRed
            ElseIf students(i, 7) = j Then '3rd choice
                .Offset(i, j).Interior.Color = vbGreen
            End If
        Next j
    Next i

```

Next i

End With

End Sub

Sub InitializePop()

'Creates the initial population. The initial population is populated using the  
'student's choices. It is important that the data in the "Students" worksheet  
'be sorted by Major first, and then by GPA. Those student's with the highest  
'GPA will be assigned to their choice projects, if they are not filled, first

Dim k2 As Integer

Dim j2 As Integer

Dim start2 As Integer

Dim finish2 As Integer

Dim Count2B As Integer

Dim Count1B As Integer

Dim CountB As Integer

Dim m2 As Integer

Dim i2 As Integer

Dim projFill() As Integer

Dim not1st As Boolean

Dim not2nd As Boolean

Dim not3rd As Boolean

Dim tempArray() As Integer

Dim temp As Integer

Dim tempCount As Integer

Dim turn As Integer

Dim sort1 As Integer

Dim sort2 As Integer

```
ReDim tempArray(numProjects - 3)
```

```
ReDim projFill(numProjects, diffMajorCount)
```

```
Dim choiceArray(3) As Integer
```

```
For j2 = 1 To popSize
```

```
    flag = False
```

```
    flag1 = True
```

```
    not1st = False
```

```
    not2nd = False
```

```
    not3rd = False
```

```
    tempCount = 1
```

```
    start2 = 1
```

```
    finish2 = 0
```

```
    Count2B = 0
```

```
    Count1B = 0
```

```
    CountB = 0
```

```
For m2 = 1 To diffMajorCount
```

```
    start2 = finish2 + 1
```

```
    CountB = majorCountArray(m2) 'How many students are in each major
```

```
    finish2 = finish2 + CountB
```

```
For i2 = start2 To finish2
```

```
    'Clears out tempArray
```

```
    For p = 1 To numProjects - 3
```

```
        tempArray(p) = 0
```

```
    Next
```

turn = 0

Do Until turn >= 3

turn = turn + 1

flag = False

flag1 = True

'Assigns student to their 1st choice if the max number of majors

'for that project has not been met

If turn = 1 Then

For k2 = 1 To numProjects

If students(i2, 5) = k2 Then

If projFill(k2, m2) < maxMajor(k2, m2) Then

projFill(k2, m2) = projFill(k2, m2) + 1

activeGenArray(i2, k2, j2) = 1

flag = True

turn = 4

k2 = numProjects

End If

End If

Next k2

End If

'Assigns student to their 2nd choice if the max number of majors

'for that project has not been met

If turn = 2 Then

For k2 = 1 To numProjects

If students(i2, 6) = k2 Then

```

    If projFill(k2, m2) < maxMajor(k2, m2) Then
        projFill(k2, m2) = projFill(k2, m2) + 1
        activeGenArray(i2, k2, j2) = 1

        flag = True

        'flag1 = False

        'not2nd = True

        turn = 4

        k2 = numProjects

    End If

End If

Next k2

End If

'Assigns student to their 3rd choice if the max number of majors
'for that project has not been met

If turn = 3 Then

    For k2 = 1 To numProjects

        If students(i2, 7) = k2 Then

            If projFill(k2, m2) < maxMajor(k2, m2) Then

                projFill(k2, m2) = projFill(k2, m2) + 1

                activeGenArray(i2, k2, j2) = 1

                flag = True

                'flag1 = False

                'not3rd = True

                turn = 4

                k2 = numProjects

            End If

        End If

    End If

End If

```

Next k2

End If

If turn = 4 Then

choiceArray(1) = students(i2, 5)

choiceArray(2) = students(i2, 6)

choiceArray(3) = students(i2, 7)

For j = 1 To 3

For i = 1 To 2

If choiceArray(i) > choiceArray(i + 1) Then

sort1 = choiceArray(i)

choiceArray(i) = choiceArray(i + 1)

choiceArray(i + 1) = sort1

End If

Next

Next

End If

Loop

'If all three student choices are not available, then

'the remaining projects are listed in a temporary array, tempArray

If flag = False Then

tempCount = 1

For k2 = 1 To numProjects

'tempCount = 1

If tempCount <= numProjects - 3 Then

    If choiceArray(1) = k2 Then

        ElseIf choiceArray(2) = k2 Then

            ElseIf choiceArray(3) = k2 Then

                Else

                    tempArray(tempCount) = k2

                    tempCount = tempCount + 1

            End If

        End If

    Next k2

If a student has not been assigned to a project yet

q = numProjects - 3

flag1 = False

flag = True

Do Until flag1 = True

    rndNum = WorksheetFunction.RandBetween(1, q)

    temp = tempArray(rndNum)

    If projFill(temp, m2) < maxMajor(temp, m2) Then

        projFill(temp, m2) = projFill(temp, m2) + 1

        activeGenArray(i2, temp, j2) = 1

        flag = True

        flag1 = True

    End If

For t = rndNum To numProjects - 4

    tempArray(rndNum) = tempArray(rndNum + 1)

    rndNum = rndNum + 1

```
        Next
        If q > 1 Then
            q = q - 1
        Else
            flag1 = True
        End If
    Loop
End If
Next i2
Next m2
Next j2
End Sub
```

```
Sub CopyActivePopToOffspring()
```

```
'Copy the present generation's population of chromosomes into the offspring array
```

```
numOffspring = popSize
```

```
ReDim offSpringArray(numStudents, numProjects, numOffspring)
```

```
For j = 1 To popSize
```

```
    For i = 1 To numStudents
```

```
        For k = 1 To numProjects
```

```
            offSpringArray(i, k, j) = activeGenArray(i, k, j)
```

```
        Next
```

```
    Next
```

```
Next
```

```
End Sub
```

```
Sub Crossover1()
```

Count = 0

Do Until Count = chance

Count = Count + 1

Randomize

rndNum = Rnd()

'If a randomly generated number is less than or equal to the probability of crossover

'(crossoverProb), then perform crossover

If rndNum <= crossoverProb1 Then

ReDim tempOffspring(numStudents, numProjects, 4)

'Randomly select two Parent chromosomes from the population

For m = 1 To 2

rndNum1 = WorksheetFunction.RandBetween(1, popSize)

For j = 1 To numStudents

For i = 1 To numProjects

tempOffspring(j, i, m) = activeGenArray(j, i, rndNum1)

Next i

Next j

Next m

'Randomly select a crossover point

rndNum2 = WorksheetFunction.RandBetween(1, numStudents)

'Perform crossover at crossover point on two Parent chromosomes

For m = 1 To 2

For i = 1 To numProjects

```

    For j = 1 To rndNum2
        tempOffspring(j, i, 3) = tempOffspring(j, i, 1)
        tempOffspring(j, i, 4) = tempOffspring(j, i, 2)
    Next j

    For j = rndNum2 + 1 To numStudents
        tempOffspring(j, i, 3) = tempOffspring(j, i, 2)
        tempOffspring(j, i, 4) = tempOffspring(j, i, 1)
    Next j

Next i

Next m

'Increase the number of offspring by two and increase size of
'offSpringArray by 2
numOffspring = numOffspring + 2
ReDim Preserve offSpringArray(numStudents, numProjects, numOffspring)

'Copy two new offspring into the offSpringArray
For j = 1 To numStudents
    For i = 1 To numProjects
        offSpringArray(j, i, numOffspring - 1) = tempOffspring(j, i, 3)
        offSpringArray(j, i, numOffspring) = tempOffspring(j, i, 4)
    Next i
Next j

End If

Loop

End Sub

Sub Crossover2()

```

Count = 0

Do Until Count = chance

Count = Count + 1

Randomize

rndNum = Rnd()

'If a randomly generated number is less than or equal to the probability of crossover

'(crossoverProb), then perform crossover

If rndNum <= crossoverProb2 Then

ReDim tempOffspring(numStudents, numProjects, 4)

'Randomly select two Parent chromosomes from the population

For m = 1 To 2

rndNum1 = WorksheetFunction.RandBetween(1, popSize)

For j = 1 To numStudents

For i = 1 To numProjects

tempOffspring(j, i, m) = activeGenArray(j, i, rndNum1)

Next i

Next j

Next m

'Randomly select a crossover point

rndNum2 = WorksheetFunction.RandBetween(1, numProjects)

'Perform crossover at crossover point on two Parent chromosomes

For m = 1 To 2

For i = 1 To numStudents

```

For j = 1 To rndNum2
    tempOffspring(i, j, 3) = tempOffspring(i, j, 1)
    tempOffspring(i, j, 4) = tempOffspring(i, j, 2)
Next j

For j = rndNum2 + 1 To numProjects
    tempOffspring(i, j, 3) = tempOffspring(i, j, 2)
    tempOffspring(i, j, 4) = tempOffspring(i, j, 1)
Next j

Next i

Next m

'Increase the number of offspring by two and increase size of
'offSpringArray by 2
numOffspring = numOffspring + 2
ReDim Preserve offSpringArray(numStudents, numProjects, numOffspring)

'Copy two new offspring into the offSpringArray
For j = 1 To numStudents
    For i = 1 To numProjects
        offSpringArray(j, i, numOffspring - 1) = tempOffspring(j, i, 3)
        offSpringArray(j, i, numOffspring) = tempOffspring(j, i, 4)
    Next i
Next j

End If

Loop

End Sub

Sub Mutation1()

```

Count = 0

Do While Count <> chance

Count = Count + 1

Randomize

rndNum = Rnd()

'If a randomly generated number is less than or equal to the probability of  
'mutation operator #1(mutationProb1), then perform mutation operator #1

If rndNum <= mutationProb1 Then

ReDim tempOffspring(numStudents, numProjects, 3)

'Randomly select one Parent chromosome from the population

rndNum1 = WorksheetFunction.RandBetween(1, popSize)

For j = 1 To numStudents

For i = 1 To numProjects

tempOffspring(j, i, 1) = activeGenArray(j, i, rndNum1)

tempOffspring(j, i, 2) = activeGenArray(j, i, rndNum1)

Next

Next

'Randomly select two students from Parent chromosomes

rndNum1 = WorksheetFunction.RandBetween(1, numStudents)

rndNum2 = WorksheetFunction.RandBetween(1, numStudents)

'Randomly swap student assignments

For i = 1 To numProjects

tempOffspring(rndNum1, i, 2) = tempOffspring(rndNum2, i, 1)

Next i

```
For i = 1 To numProjects
```

```
    tempOffspring(rndNum2, i, 2) = tempOffspring(rndNum1, i, 1)
```

```
Next i
```

```
'Increase the number of offspring by two and increase size of
```

```
'offSpringArray by 1
```

```
numOffspring = numOffspring + 1
```

```
ReDim Preserve offSpringArray(numStudents, numProjects, numOffspring)
```

```
'Copy two new offspring into the offSpringArray
```

```
For j = 1 To numStudents
```

```
    For i = 1 To numProjects
```

```
        offSpringArray(j, i, numOffspring) = tempOffspring(j, i, 2)
```

```
    Next
```

```
Next
```

```
End If
```

```
Loop
```

```
End Sub
```

```
Sub Mutation2()
```

```
    Count = 0
```

```
    Do While Count <> chance
```

```
        Count = Count + 1
```

```
        Randomize
```

```
        rndNum = Rnd()
```

```
'If a randomly generated number is less than or equal to the probability of
```

'mutation operator #2(mutationProb2), then perform mutation operator #2

If rndNum <= mutationProb2 Then

ReDim tempOffspring(numStudents, numProjects, 3)

'Randomly select one Parent chromosome from the population

rndNum1 = WorksheetFunction.RandBetween(1, popSize)

For j = 1 To numStudents

For i = 1 To numProjects

tempOffspring(j, i, 1) = activeGenArray(j, i, rndNum1)

Next

Next

'Randomly select a student and a project from Parent chromosomes

rndNum1 = WorksheetFunction.RandBetween(1, numStudents)

rndNum2 = WorksheetFunction.RandBetween(1, numProjects)

For i = 1 To numProjects

If tempOffspring(rndNum1, i, 1) = 1 Then

q = i

End If

Next i

'Swap the assigned project for a student with a randomly selected project

tempOffspring(rndNum1, q, 1) = 0

tempOffspring(rndNum1, rndNum2, 1) = 1

'Increase the number of offspring by two and increase size of

'offSpringArray by 1

```

numOffspring = numOffspring + 1

ReDim Preserve offSpringArray(numStudents, numProjects, numOffspring)

'Copy two new offspring into the offSpringArray

For j = 1 To numStudents
    For i = 1 To numProjects
        offSpringArray(j, i, numOffspring) = tempOffspring(j, i, 1)
    Next i
Next j

End If

Loop

End Sub

Sub FitnessValueInitialPop()

'Determine the fitness value for each chromosome in the offspring array
'ReDim offSpringArrayFV(numOffspring)

For j = 1 To popSize
    fV = 0

    For i = 1 To numStudents
        For k = 1 To numProjects
            fV = fV + activeGenArray(i, k, j) * weightsArray(i, k)
        Next
    Next

    activeGenArrayFV(j) = fV

Next

End Sub

Sub FitnessValue()

'Determine the fitness value for each chromosome in the offspring array

```

```

ReDim offSpringArrayFV(numOffspring)

For j = 1 To numOffspring
    fV = 0
    For i = 1 To numStudents
        For k = 1 To numProjects
            fV = fV + offSpringArray(i, k, j) * weightsArray(i, k)
        Next
    Next
    offSpringArrayFV(j) = fV
Next
End Sub

```

```

Sub Feasibility()
    'Checks for feasibility, assigns awards and penalties

    Dim i1 As Integer
    Dim j1 As Integer
    Dim k1 As Integer
    Dim m1 As Integer
    Dim p1 As Integer
    Dim t1 As Integer
    Dim CountA As Integer
    Dim Count1A As Integer
    Dim Count2A As Integer
    Dim start1 As Integer
    Dim finish1 As Integer
    Dim infeasIndex() As Integer
    Dim total As Integer

```

total = 0

For k = 1 To numOffspring

For i = 1 To numStudents

For j = 1 To numProjects

'For student, check to make sure that they have not been

'assigned to more than one project

If offSpringArray(i, j, k) = 1 Then

ReDim Preserve infeasIndex(total + 1)

infeasIndex(total + 1) = j

total = total + 1

End If

Next

'If a student is assigned to more than one project, then

'randomly select a project for which the student is assigned

'and remove that assignment. Continue this process until

'the student is only assigned to one project

If total > 1 Then

Do Until total = 1

rndNum = WorksheetFunction.RandBetween(1, total)

offSpringArray(i, infeasIndex(rndNum), k) = 0

total = total - 1

Loop

End If

'If a student is not assigned to any project, then randomly select a project

If total = 0 Then

rndNum = WorksheetFunction.RandBetween(1, numProjects)

offSpringArray(i, rndNum, k) = 1

```

    End If

    total = 0

Next
Next

For j1 = 1 To numOffspring
    For k1 = 1 To numProjects

        start1 = 1

        finish1 = 0

        Count2A = 0

        CountA = 0

        If k1 <> numProjects Then

            For m1 = 1 To diffMajorCount

                start1 = finish1 + 1

                CountA = majorCountArray(m1) 'How many students are in each major

                finish1 = finish1 + CountA

                For i1 = start1 To finish1

                    If offSpringArray(i1, k1, j1) = 1 Then

                        Count2A = Count2A + 1

                    End If

                Next i1

            For p1 = k1 + 1 To numProjects

                For t1 = start1 To finish1

                    If offSpringArray(t1, k1, j1) = 1 Then

                        If t1 = start1 Then

                            feasibilityBestIndex = start1          'student number

```

```

        feasibilityBestProjNum = p1          'project number
        feasibilityBestWeight = weightsArray(t1, p1) 'weight
    Else
        y = t1          'student number
        z = p1          'project number
        x = weightsArray(t1, p1) 'weight
    End If

    If x > feasibilityBestWeight Then
        feasibilityBestWeight = x
        feasibilityBestIndex = y
        feasibilityBestProjNum = z
    End If

End If

Next t1

Next p1

Next m1

End If

Next k1

Next j1

```

\*\*\*Reward

Dim k2 As Integer

Dim j2 As Integer

Dim start2 As Integer

Dim finish2 As Integer

Dim Count2B As Integer

Dim Count1B As Integer

Dim CountB As Integer

Dim m2 As Integer

Dim i2 As Integer

For j2 = 1 To numOffspring

For k2 = 1 To numProjects

start2 = 1

finish2 = 0

Count2B = 0

Count1B = 0

CountB = 0

For m2 = 1 To diffMajorCount

start2 = finish2 + 1

CountB = majorCountArray(m2) 'How many students are in each major

finish2 = finish2 + CountB

For i2 = start2 To finish2

If offSpringArray(i2, k2, j2) = 1 Then

Count2B = Count2B + 1

End If

Next i2

'For each project, if at least the minimum number of a major has been assigned,

'then reward chromosome

If Count2B >= minMajor(k2, m2) Then

offSpringArrayFV(j2) = offSpringArrayFV(j2) + projects(k2, 3) \* 1 ' <--2

End If

Next m2

Next k2

Next j2

\*\*\*Penalty

Dim j3 As Integer

Dim k3 As Integer

Dim start3 As Integer

Dim finish3 As Integer

Dim Count2C As Integer

Dim CountC As Integer

Dim m3 As Integer

Dim i3 As Integer

For j3 = 1 To numOffspring

For k3 = 1 To numProjects

start3 = 1

finish3 = 0

Count2C = 0

CountC = 0

For m3 = 1 To diffMajorCount

start3 = finish3 + 1

CountC = majorCountArray(m3) 'How many students are in each major

finish3 = finish3 + CountC

For i3 = start3 To finish3

If offSpringArray(i3, k3, j3) = 1 Then

Count2C = Count2C + 1

End If

Next i3

```

'For each project, if the more than the maximum number of a major
'has been assigned, then penalize chromosome

If Count2C > maxMajor(k3, m3) Then
    If offSpringArrayFV(j3) >= projects(k3, 3) Then
        offSpringArrayFV(j3) = offSpringArrayFV(j3) - projects(k3, 3) * 1 '<--3
    Else
        offSpringArrayFV(j3) = 0
    End If
End If

Next m3

Next k3

Next j3
End Sub

```

```

Sub SelectBestFromOffspring()
'Select best chromosome from offSpring array and store in History Array
bestFV = offSpringArrayFV(1)
bestFVIndex = 1
For m = 2 To numOffspring
    If bestFV < offSpringArrayFV(m) Then
        bestFV = offSpringArrayFV(m)
        bestFVIndex = m
    End If
Next m

For i = 1 To numStudents
    For j = 1 To numProjects
        historyArray(i, j, gen) = offSpringArray(i, j, bestFVIndex)
    
```

```
historyArrayFV(gen) = offSpringArrayFV(bestFVIndex)
```

```
If gen = 1 Then
```

```
    historyBestFV = historyArrayFV(gen)
```

```
    historyBestFVIndex = gen
```

```
ElseIf historyArrayFV(gen) > historyBestFV Then
```

```
    historyBestFV = historyArrayFV(gen)
```

```
    historyBestFVIndex = gen
```

```
End If
```

```
Next j
```

```
Next i
```

```
End Sub
```

```
Sub NextGen()
```

```
    'Select next generations chromosomes
```

```
    For k = 1 To popSize
```

```
        rndNum1 = WorksheetFunction.RandBetween(1, numOffspring)
```

```
        For n = 1 To 2
```

```
            rndNum2 = WorksheetFunction.RandBetween(1, numOffspring)
```

```
            For j = 1 To numProjects
```

```
                For i = 1 To numStudents
```

```
                    If offSpringArrayFV(rndNum1) > offSpringArrayFV(rndNum2) Then
```

```
                        activeGenArray(i, j, popSize) = offSpringArray(i, j, rndNum1)
```

```
                    Else
```

```
                        activeGenArray(i, j, popSize) = offSpringArray(i, j, rndNum2)
```

```
                    End If
```

```
                Next i
```

```
            Next j
```

```

        rndNum1 = rndNum2

    Next n

Next k

End Sub

Sub PrintAbsoluteBest()

    Dim number As Integer

    Dim Addup As Integer

    ActiveWorkbook.Worksheets("Output").Range("A1:XD1000").Clear

    With ActiveWorkbook.Worksheets("Output").Range("C5")

        Count = 0

        With .Offset(-1, Count - 1)

            .Value = "Fitness Value = "

            .Font.Bold = True

            .Columns.AutoFit

        End With

        With .Offset(-1, 0)

            .Value = historyBestFV

            .Font.Bold = True

            .Columns.AutoFit

        End With

        With .Offset(0, Count)

            .Value = "Last Name"

            .Font.Bold = True

            .Columns.AutoFit


```

End With

With .Offset(0, Count + 1)

.Value = "First Name"

.Font.Bold = True

.Columns.AutoFit

End With

With .Offset(0, Count + 2)

.Value = "GPA"

.Font.Bold = True

.Columns.AutoFit

End With

With .Offset(0, Count + 3)

.Value = "Major"

.Font.Bold = True

.Columns.AutoFit

End With

For i = 1 To numStudents

With .Offset(i, Count)

.Value = students(i, 1) 'last name

.Columns.AutoFit

End With

With .Offset(i, Count + 1)

.Value = students(i, 2) 'first name

.Columns.AutoFit

End With

With .Offset(i, Count + 2)

.Value = students(i, 3) 'GPA

```

.NumberFormat = "0.0"

Columns.AutoFit

End With

With .Offset(i, Count + 3)

.Value = students(i, 4) 'Major

.Columns.AutoFit

End With

Count = Count + 3

For j = 1 To numProjects

With .Offset(0, j + 3)

.Value = "P" & j

.Font.Bold = True

End With

With .Offset(i, Count + j)

.Value = historyArray(i, j, historyBestFVIndex)

If historyArray(i, j, historyBestFVIndex) = 1 Then

.Font.Bold = True

End If

End With

If students(i, 5) = j Then '1st choice

With .Offset(i, Count + j).Interior

.Pattern = xlSolid

.PatternColorIndex = xlAutomatic

.ThemeColor = xlThemeColorAccent1

.TintAndShade = 0.399975585192419

.PatternTintAndShade = 0

End With

```

ElseIf students(i, 6) = j Then '2nd choice

With .Offset(i, Count + j).Interior

.Pattern = xlSolid

.PatternColorIndex = xlAutomatic

.ThemeColor = xlThemeColorAccent2

.TintAndShade = 0.399975585192419

.PatternTintAndShade = 0

End With

ElseIf students(i, 7) = j Then '3rd choice

With .Offset(i, Count + j).Interior

.Pattern = xlSolid

.PatternColorIndex = xlAutomatic

.ThemeColor = xlThemeColorAccent3

.TintAndShade = 0.399975585192419

.PatternTintAndShade = 0

End With

End If

Next j

Count = 0

Next i

End With

With ActiveWorkbook.Worksheets("Output").Range("B4")

With .Offset(1, 6 + numProjects)

.Value = "Check"

.Font.Bold = True

End With

For i = 1 To numStudents

```

Addup = 0

For j = 1 To numProjects
    Addup = Addup + .Offset(i + 1, j + 4)

    If j = numProjects Then
        .Offset(i + 1, numProjects + 6).Value = Addup
    End If

Next j

Next i

End With

With ActiveWorkbook.Worksheets("Output").Range("B4")

With .Offset(numStudents + 3, 4)
    .Value = "Sum = "
    .HorizontalAlignment = xlRight
    .Font.Bold = True
End With

For i = 1 To numProjects
    Addup = 0

    For j = 1 To numStudents
        Addup = Addup + .Offset(j + 1, i + 4)

        If j = numStudents Then
            .Offset(numStudents + 3, i + 4).Value = Addup
        End If

    Next j

Next i

End With

```

```
With ActiveWorkbook.Worksheets("Output").Range("B4")  
    Range(.Offset(0, 0), .Offset(10000, 1000)).Columns.AutoFit  
End With
```

```
End Sub
```

```
Sub SolutionSummary()
```

```
    Dim number As Integer
```

```
    Dim number2 As Integer
```

```
    ActiveWorkbook.Worksheets("Solution Summary").Range("A1:XD1000").Clear
```

```
    With ActiveWorkbook.Worksheets("Solution Summary").Range("A1")
```

```
        With .Offset(0, 0)
```

```
            .Value = "Solution Summary"
```

```
            .Font.Size = 14
```

```
            .Font.Bold = True
```

```
        End With
```

```
        Count = 0
```

```
        number = 0
```

```
        number2 = 0
```

```
        For j = 1 To numProjects
```

```
            With .Offset(j + number + 1, Count)
```

```
                .Value = "Project Number: " & j
```

```
                .Font.Bold = True
```

```
            End With
```

```
With .Offset(j + number + 2, Count)

    .Value = "Project Name: " & projects(j, 1) 'name

    .Font.Bold = True

End With

With .Offset(j + number + 3, Count)

    .Value = "Project Sponsor: " & projects(j, 2) 'sponsor

    .Font.Bold = True

End With

With .Offset(j + number + 4, Count)

    .Value = "Project Weight: " & projects(j, 3) 'weight

    .Font.Bold = True

End With

With .Offset(j + number + 6, Count + 1)

    .Value = "Last Name"

    .Font.Bold = True

End With

With .Offset(j + number + 6, Count + 2)

    .Value = "First Name"

    .Font.Bold = True

End With

With .Offset(j + number + 6, Count + 3)

    .Value = "GPA"

    .Font.Bold = True

End With

With .Offset(j + number + 6, Count + 4)

    .Value = "Major"

    .Font.Bold = True
```

End With

With .Offset(j + number + 6, Count + 5)

.Value = "Choice?"

.Font.Bold = True

End With

number = number + 6

For i = 1 To numStudents

If historyArray(i, j, historyBestFVIndex) = 1 Then

number2 = number2 + 1

With .Offset(j + number + number2, Count + 1)

.Value = students(i, 1) 'last name

.Columns.AutoFit

End With

With .Offset(j + number + number2, Count + 2)

.Value = students(i, 2) 'first name

.Columns.AutoFit

End With

With .Offset(j + number + number2, Count + 3)

.Value = students(i, 3) 'GPA

.NumberFormat = "0.0"

.Columns.AutoFit

End With

With .Offset(j + number + number2, Count + 4)

.Value = students(i, 4) 'Major

.Columns.AutoFit

End With

```
If students(i, 5) = j Then '1st choice
    With .Offset(j + number + number2, Count + 5)
        .Value = "1st"
        .Columns.AutoFit
    End With

ElseIf students(i, 6) = j Then '2nd choice
    With .Offset(j + number + number2, Count + 5)
        .Value = "2nd"
        .Columns.AutoFit
    End With

ElseIf students(i, 7) = j Then '3rd choice
    With .Offset(j + number + number2, Count + 5)
        .Value = "3rd"
        .Columns.AutoFit
    End With

Else
    With .Offset(j + number + number2, Count + 5)
        .Value = "--"
        .Columns.AutoFit
    End With

End If

End If

Next i

Count = 0

number = number + number2
```

number2 = 0

Next j

End With

With ActiveWorkbook.Worksheets("Solution Summary").Range("A1")

Range(.Offset(0, 0), .Offset(1000, 25)).Columns.AutoFit

End With

End Sub

- 
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  3. Vergara, Khouja, and Michalewicz, "An evolutionary algorithm for optimizing material flow in supply chains," *Computers and Industrial Engineering* 43 (3) pg 407- 421, 2002