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Research Article

NSGA-II Algorithm For The Reallocation Problem In Land Consolidation[1]

Zeynep Ortaçay[1**], Harun Uğuz[1], Hüseyin Haklı[2]

[1] Department of Computer Engineering, Konya Technical University, 42075 Konya, Turkey (ORCID: 0000-0003-3563-0435)
[2] Department of Computer Engineering, Necmettin Erbakan University, 42140 Konya, Turkey

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Abstract

To solve problems encountered in real life, we sometimes need optimization algorithms. Some of these problems have single objective, while others have multiple objectives. If there is a single objective, the problem is defined as a single-objective optimization problem and if there are more than one objective it is called multi-objective optimization problem.
Today, lands are fragmented and scattered. This makes agriculture difficult and costly. To prevent these problems, Land Consolidation (LC) studies are being carried out. The reallocation stage, which is part of LC, can be defined as a multi objective optimization problem.
In this study, one of the multi objective optimization techniques, NSGA-II algorithm, is applied to the reallocation problem. The results are comparable with the studies in the literature.

Keywords: Multi-Objective optimization algorithm, NSGA-II, Land Consolidation, Reallocation.

Arazi Toplulaştırma Çalışmasındaki Dağıtım Problemi Içın NSGA-II Algoritması

Öz

Gerçek hayatta karşımıza çıkan problemlerin çözümleri için bazen optimizasyon algoritmalarına ihtiyaç duyarız. Bu problemlerin bazıları tek bir amaca sahip olurken bazıları da birden fazla amaca sahiptirler. Eğer tek bir amaç varsa, problem "tek amaçlı optimizasyon problemi" birden fazla amaç var ise "çok amaçlı optimizasyon problemi" olarak tanımlanır.
Günümüzde arazilere parçalı ve dağınık haldedirler. Bu da tarım yapmayı zor ve maliyetli hale getirmektedir. Bu sorunların önüne geçmek için Arazi Toplulaştırma (AT) çalışmaları yapılmaktadır. AT aşamalardan biri olan dağıtım aşaması da çok amaçlı optimizasyon problemi olarak tanımlanabilir.
Bu çalışmada dağıtım problemine çok amaçlı optimizasyon tekniklerinden biri olan NSGA-II algoritması uygulanmıştır. Literatürde yapılan çalışmalar ile kıyaslanabilir sonuçlar elde edilmiştir.

Anahtar Kelimeler: Çok Amaçlı Optimizasyon Algoritması, NSGA-II, Arazi Toplulaştırma, Dağıtım.

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[**] Sorumlu Yazar: Konya Teknik Üniversitesi, Mühendislik ve Doğa Bilimler Fakültesi, Bilgisayar Mühendisliği Bölümü, Konya, Türkiye, ORCID: 0000-0003-3563-0435, zortacay@ktun.edu.tr

1. Introduction

Most of the problems we encounter in real life are problems that has multiple objectives(Konak, Coit, & Smith, 2006). It is difficult to find a single and specific solution to such problems (Konak et al., 2006). If there are conflicts in the objectives of the question, that is, if one objective is minimized and the other is maximized, the complexity increases further.

Multi-Objective Optimization (MOO) Algorithms seek to find a good balance between such conflicting objectives. The MOO algorithms generate an acceptable set of solutions, taking all the objectives of the problems with multiple objectives into account (Deb, 2014). There is no single solution in MOO algorithms, they output a data set with different acceptable solutions called Pareto optimal solutions (Deb, 2014). Pareto optimal solution set consists of solutions that are noninferior to other solutions(Gao et al., 2008). The decision-maker makes a selection from these acceptable solutions (Sağ & Çunkaş 2009). This decision maker can be a method or someone who is an expert of the subject. Therefore, in multi objective optimization, there are 2 important processes: An optimization process to find pareto optimal solutions and a decision process to select one of the solutions (Deb, 2014). In recent years, many MOO algorithms have been proposed (Deb, Agrawal, Pratap, & Meyarivan, 2000). Some of these algorithms are VEGA(Schaffer, 1986), MOGA(Murata & Ishibuchi, 1995), NPGA(rey Horn, Nafpliotis, & Goldberg, 1994), NSGA-II(Deb, Pratap, Agarwal, & Meyarivan, 2002), SPEA2 (Zitzler, Laumanns, & Thiele, 2001), MSOPS (Hughes, 2003) and OMOEA-II (Zeng, Yao, Kang, & Liu, 2005). NSGA-II algorithm has been applied to the problems such as LC Interview (Ozsarı 2018), multi-period inventory-redundancy allocation in a series-parallel system(Alikar, Mousavi, Ghazilla, Tavana, & Olugu, 2017), supply chain (Bandyopadhyay & Bhattacharya, 2013; Bhattacharya & Bandyopadhyay, 2010; Javanshir, Ebrahimnejad, & Nouri, 2012) , green vehicle routing(Jemai, Zekri, & Mellouli, 2012), facility location (Bhattacharya & Bandyopadhyay, 2010).

The aim of this study is to obtain optimum solution for the reallocation problem, which is a part of land consolidation, by using NSGA-II algorithm. The performance of this algorithm is compared with the results obtained by the technician and the results of the Haklı thesis (Haklı, 2017) . The multi-objective optimization algorithms used in this study, search solutions according to two objectives. These objectives are to have less overflow in the blocks and place the parcels to their preferences.

The following sections of the study are identified as follows: In the second part, NSGA-II and its algorithm are explained. In the third chapter, basic information about the MOO problem, reallocation step of land consolidation, is given. In the fourth chapter, the formulation of the problem is explained. In the fifth chapter, the results are given and compared with results of other studies.

2. Material and Method

2.1. Material

In Turkey, lands are fragmented, small and shapeless, disorganized. Due to this reason it is diffucult and costly to do agriculture in these lands. There are many precautions to prevent these problems. One of the most important of them is the land consolidation study(Takka, 1993). The main purpose of this study is to enable farmers to produce more easily, which plays an important role in the development of the country (Girgin, 1982). Land consolidation process basically consists of 6 steps: Rating, Block Planning, Interview, Reallocation, Parceling, Reporting.

In this study, reallocation step of LC is discussed. Reallocation is the process of placing each parcel in blocks, considering the preferences made during the interview phase. Some pre-processing operations are performed before proceeding with the method. These operations are as follows:

1. Parcels with fixed facility remain in place. They are not included in reallocation.
2. The parcels that can be placed in their first preferences are directly placed in block and are not included in the method.
3. After the first 2 steps, the remaining parcels are merged.

Performing the reallocation process should be in accordance with the preferences and the blocks should not exceed their capacity. If all parcels are placed in their preferred locations, excessive overflows occur in the blocks. Therefore, some parcels are placed in their preference, while others are not. Here, the block overflow and preference balance must be well done.In this study Üçhüyük, which is in Çumra distrcit of Konya province, and Ekinözü, which is in Karaman province, lands were determined as the area to be studied. General information about these lands is given in Table 1.

Table 1. General information of Ekinözü and Üçhüyük lands

	ÜÇHÜYÜK	**EKİNÖZÜ**
Enterprises	275	409
Blocks	17	99
Parcels	407	1689
Facilities	71	115
Total Area (ha)	875.69	3177.68

Ekinözü village is about three times larger than Üçhüyük village. Üçhüyük village has 17 blocks while Ekinözü village has 99 blocks. Thus it can be easily observed how the algorithms used will behave according to the size of the data.

2.2. Method

NSGA-II ALGORİTHM

Various algorithms are designed to solve multi-objective optimization problems using Genetic Algorithm (Agarwal & Nanavati, 2016). One of the most reliable and widely used algorithm is Non-dominated Sorting Genetic Algorithm (NSGA-II) (Deb et al., 2002). This algorithm was proposed in 2002, to elimate computational complexities and weaknesses during the individual selection of the original NSGA algoritm proposed by Srinivas and Deb (Deb et al., 2002). With three important features that guides the literature, NSGA-II algorithm is one of the most popular MOO algorithms (Sağ, 2008).

- Fast non-dominated sorting approach.
- Fast crowding distance computation
- Crowd comparison operator

The NSGA-II algorithm starts with random population generation. Then the fitness values of each individual in the population are calculated. Sorting according to the domination criterion is performed by using these fitness values. After that, the parent pool is created for cross-over and mutation. For this purpose, tournament selection is made with the help of crowding distance prediction procedure. Next, two point crossover (Figure 1) and single point mutation (Figure 2) are performed. The resulting new population is combined with the existing population, sorted according to the domination criterion, and crowding distance estimates are calculated. Afterwards with the help of these values, individuals that will pass to the next generation are selected. This process is repeated until the stopping criterion is met.

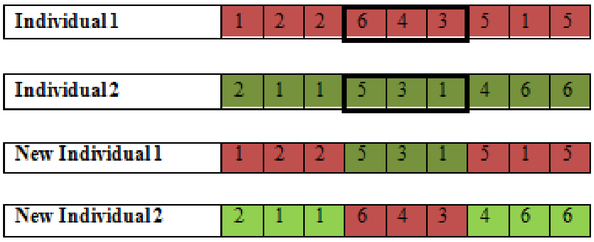

Figure 1.Two point crossover

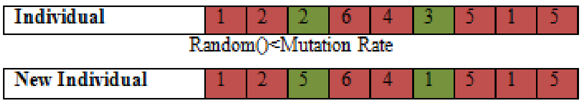

Figure 2. Single point mutation

SOLUTION OF REALLOCATION PROBLEM USING NSGA-II

Since the reallocation process, which is a step of LC, has more than one objectives as block occupancy rate and preferences, it can be defined as a multi objective optimization problem. The overflowing or empty areas of the blocks is one objective and the preferences of the parcels is another. The smaller the absolute values of the overflowing and empty areas of the blocks, the better the suitability. And if the blocks to which the parcels are assigned are among the preferences of that parcel the suitability is better. The objective functions used in this study are as follows.

First objective function: Returns the ratio of the absolute sums of the overflow or empty areas to the number of blocks, as shown in Equation (2).

$$TA(j) = BA(j) - \sum_{i=1}^{b} PA(j)(i)) \qquad (1)$$

$$Obj_1 = sum(TA(j)/BA(j)) \qquad (2)$$

b: Number of parcels placed to jth block

TA(j): Increased or decreased area of jth block after placement

PA(j)(i): total of area of parcels placed in jth block

Second objective function: Table 2 shows the penalties for each parcel according to how they are placed to their preferences. According to this table, the mathematical formula of the second objective function is given in Equation 3.

Table 2. Preference Penalties

PREFERENCE	PENALTİES
1. Preference	0
2. Preference	0.1
3. Preference	0.3
None	1

$$Obj_2 = \left(\sum_{i=1}^{PS} PPP(i)\right)/PN \qquad (3)$$

PN : Number of parcels

PPP(i): Penalty points of ith parcel.

The second objective function is the division of total penalties that parcels take according to whether they are placed to their preferences or not, to the number of parcels. The population generated for land reallocation is as in Figure 3. Which parcel placed in which block is shown in population.

Figure 3. Chromozome Structure

3. Results

Interview lists of Üçhüyük and Ekinözü lands were filled by the enterprises themselves. The NSGA-II algorithm was run 30 times for 1000 and 2500 iterations. The number of individuals was defined as 100, the mutation rate was 0.08 and the crossing rate was 0.9. As the result of experimental studies, these are the most suitable values. In the results, the average preference success percentages were shown as pre-method (TBY1) and post-method (TBY2). In addition, the results of Genetic Algorithm(GA),Scatter Search(SS) and Differential Evolution (DE) in Haklı's doctoral dissertation, which he completed in 2017, were compared with obtained results[19]. In this study, the expert system included in the thesis of Haklı is used to reset the overflow areas in the blocks as a result of the reallocation process [19].

3.1. Üçhüyük Land

Üçhüyük is a small village compared to Ekinözü in terms of area and number parcels. The results of 1000 and 2500 iterations for Üçhüyük land are given in Table 3.When these results were examined, DE is the most successful algorithm for both 1000 and 2500 iterations in pre-method. Right after are, SS and NSGA-II algorithms. But for post-method, DE algorithm is in the first place as of preference success while NSGA-II algorithm is in second. GA algorithms success is always worse than other two.

Table 3. Results of Üçhüyük land's preference success

	GA(Haklı, 2017)		DE(Haklı, 2017)		SS(Haklı, 2017)		NSGA-II	
	TBY1(%)	TBY2(%)	TBY1(%)	TBY2(%)	TBY1(%)	TBY2(%)	TBY1(%)	TBY2(%)
1000	71.85	73.38	91.35	89.48	86.99	85.01	84.5	86.3
2500	74.89	75.88	91.4	89.7	88.72	86.73	86.11	89

Reallocation with minimum number of parcels obtained as a result of 30 runs with 2500 iterations, is discussed. The results of the single objective optimization method presented in the Haklı's thesis were compared with these results. These comparisons are presented in Table 4. In this table, post-method number of parcels and average parcel sizes are given. As the result of the land reallocation process, it is aimed to decrease the number of parcels and to increase the average parcel size. When the results in Table 4 are examined, NSGA-II algorithm has the most successful result with 233 parcels and average parcel size as 29228.1. GA method has the least successful results of all methods.

Table 4. Average parcel number of Üçhüyük land and comparison of parcels according to parcel size

	Cadastre Status (Haklı, 2017)	GA(Haklı, 2017)	DE(Haklı, 2017)	SS(Haklı, 2017)	NSGA-II
Number Of Parcels	265	255	236	236	233
Average Parcel Size	28025.31	26706.47	28856.57	28856.57	29228.1

3.2. Ekinözü Land

Ekinözü is a big village compared to Üçhüyük village. The results of 1000 and 2500 iterations for Ekinözü land are given in Table 5.For Ekinözü land, SS algorithm is the most successful algorithm for pre-method preference with 1000 and 2500 iterations. Then comes the NSGA-II algorithm. In this field, GA algorithm gave the least successful results.NSGA-II algorithm is seen as the most successful algorithm in terms of post-method preference success. It is followed by the SS algorithm. Multi objective optimization algorithm has been observed to give better results in large-scale terrains.

Table 5. Results of Ekinözü land's preference success

	GA(Haklı, 2017)		DE(Haklı, 2017)		SS(Haklı, 2017)		NSGA-II	
	TBY1 (%)	TBY2 (%)	TBY1 (%)	TBY2 (%)	TBY1 (%)	TBY2 (%)	TBY1 (%)	TBY2 (%)
1000	67.61	70.68	76.6	74.94	78.06	76.45	76.9	77.43
2500	68.11	70.59	76.27	74.07	80.64	78.56	78.31	79.41

Reallocation with minimum number of parcels obtained as a result of 30 runs with 2500 iterations is discussed. The results of the single-objective optimization method presented in the Haklı's thesis are compared with these results. These comparisons are presented in Table 6. In this table, the number of parcels and average parcel sizes after the method are given. According to the results in Table 6, the SS algorithm has the most successful result with 483 parcels and 48932.03 average parcel size. The NSGA-II algorithm is the second successful algorithm with a parcel number of 511 and average parcel size of 46250.82. The GA algorithm has the worst success with 534 parcels.

Table 6. Results of Ekinözü land's preference success

	Cadastre Status (Haklı, 2017)	GA (Haklı, 2017)	DE (Haklı, 2017)	SS (Haklı, 2017)	NSGA-II
Number Of Parcels	1130	534	517	483	511
Average Parcel Size	20915.19	44258.75	45714.07	48932.03	46250.82

3. Conclusion

In this study, the basic NSGA-II algorithm was applied to the reallocation problem which is one of the LC stages. Also, for the first time in the literature a multi-objective optimization algorithm has been applied on this problem.

Comparable results with studies that applies the single objective optimization to solve the reallocation problem on Ekinözü and Üçhüyük lands, have been obtained. In the results of the comparison, the NSGA-II method is generally in the first or second place. In future studies, this problem and results can be analyzed by using different multi objective algorithm.

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