User accessibility optimization using genetic algorithm: aDA

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Abstract:
The aim of this study is the optimization of user accessibility in architectural design using genetic algorithm. In order to define the problematic, literature is surveyed in several steps: (1) Spatial accessibility focusing user movements, (2) Genetic Algorithm and Optimization in architectural design, and (3) Algorithmic Distance Based Accessibility Model (aDA). Spatial accessibility is the concept which allows user to understand function, organization and spatial relationships and welcome them to participate in activities. In order to understand the concept, methods focusing accessibility in design and planning are studied in detail. The mentioned methods here are space layout planning, space syntax and wayfinding. This paper suggests a different look to these methods in the perspective of spatial accessibility, a further question is asked: Is it possible to optimize the user movement depending on these spatial accessibility criteria?

Focusing on user movements, it is aimed to optimize the route of a user to define the distance between two related spaces. Since the architectural space deals with various user types and various functional spaces, optimization is necessary to evaluate the movement. In this respect, genetic algorithm is a useful and well-known method for optimization in architecture. This paper aims to fill the gap in literature to offer a different method as optimization with genetic algorithms in architectural design.

The method introduced briefly here is "Algorithmic Distance Based Accessibility Model (aDA)". It aims to define user and spatial accessibility in architectural design and depending on this, optimization of distances between spaces using genetic algorithm. In this developed model, user and spatial data is scripted depending on a list of criteria and distance optimization is performed by a genetic algorithm. These data are scripted based on a list of criteria that define the scope of the study and evaluated/disevaluated data, as well as tightens the solution pool based on these criteria. The method is evaluated on health campuses, two alternatives are generated and the results are stated.

Keywords: *User and spatial accessibility, genetic algorithm, optimization, architectural design, aDA (Algorithmic Distance Based Accessibility) Model.*

1. Introduction

The user is at the center of architectural design. From a user centric design point of view, the concepts of accessibility and spatial accessibility come to the fore. One of the most important criteria for spatial accessibility is the completion of a movement between two points within the shortest distance. However, shortest distance is a relative term in the context of architectural design that focuses on user accessibility. The shortest distance problem is not a straightforward problem which can simply be defined as the linear distance between two points but a multi parameter problem that takes into account spatial use and different user behaviors. In user centric architectural design, optimization methods that define shortest distance based on user behavior are conveniently utilized.

Genetic Algorithms (GAs) are routinely employed to generate useful solutions to search and optimization problems in the field of informatics. These algorithms adopt the principles of evolutionary process observed in the nature such as the survival of the fittest by natural selection. Given a set of solutions, the best are chosen according to a defined fitness function, and new generations of solutions are populated using the chosen alternatives. The procedure is repeated until an acceptable solution has been reached.

GAs are widely used to solve design problems. Genetic evolutionary design concepts have been applied to the problems in design and architecture and proven to be effective (Gandhi, 2008; Jo andGero, 1998). In the case of architectural design, certain data optimization and user data analysis problems can significantly benefit from the use of GAs. In this respect, the problems related to spatial accessibility which requires arranging spatial relationships to optimize user movement is another area where GAs are the preferred approach.

The main problem addressed in this work is the definition of user centric spatial accessibility in architectural design, and based on this definition, the optimization of distances between spaces by utilizing a genetic algorithm. In order to achieve this, a model called Algorithmic Distance Based Accessibility (aDA) is developed. In this model, spatial and a multi parameter user movement data is scripted following a list of criteria, and distance optimization is performed by a genetic algorithm. The user movement data mentioned consists of; (i) user types, (ii) user speed/distance tables, (iii) daily use hours, (iv) user routes and flow charts, and (v) user density. On the other hand, the spatial data are (i) definition of main and sub spaces, (ii) publicness, security, and emergency levels, (iii) the density and frequency of the use of space, (iv) and other special spatial accessibility parameters.

These data are scripted based on a list of criteria that are defined according to the scope of the study and evaluated/discarded data, as well as tightens the solution pool based on these criteria. Using these data sets, a simple genetic algorithm is designed with a special fitness function. Two components are generated in Rhino Grasshopper interface. First, the user component is utilized to process the user movement data. The user component takes an xml file that includes node data and outputs possible paths which is the initial solution pool for the genetic algorithm. Second, genetic solver component is used to optimize the provided paths. This component takes the user paths and relations as input and outputs the coordinates for spaces using a genetic heuristic. The details of our heuristic are explained in Section 4.

Since spatial accessibility optimization is a large problem domain. The scope of this paper is limited to health campuses in general, thus restricting the user types and functional variety. Ikitelli and Kayseri Health Campuses are used as two case studies. The derived solutions for these campuses are evaluated in focus and a comparative study is discussed. Following the comparison, to test the developed model, three alternate solutions are generated using the Rhino components.

As a result of this work, spatial and user accessibility concepts are concretized and the contribution of genetic algorithm as an effective optimization tool for architectural design is established. With the developed aDA model it is possible to evaluate existing site plans based on user accessibility, and renovations can be offered. At the same time, the new generated site plans can be used in pre-design phase thus helps the designer to start from an optimized scheme. Being one the first studies on health campus planning - which are increasing in number nowadays in Turkey- this work aims at filling the gap in architectural literature. We believe that the results presented here make significant contribution to computational architectural design literature and give direction to future studies in this field. In near future, we plan to develop aDA model suitable for different building types and scales such as university or technology development campuses.

2. Spatial accessibility focusing user movements

In recent years, accessibility has received considerable interest in the architectural community not only to address issues specific to special communities such as the disabled, but also to enhance the functionality of buildings for the general population. "Design for all" concept (Andrade et al., 2012), raised as a result of this approach, is widely considered and practiced for the design of various building typologies.

Accessibility in architecture means equally accessed spaces. Beyond the in-and-out relationships within a space, spatial accessibility is a concept that allows the user to grasp the spatial organization from a functionality point of view. Thus, effective spatial accessibility should lead to more effective use of space and encourage users to participate in activities. One of the most important aspects is the movement of people concerning user and spatial accessibility, therefore to better understand the concept; user and spatial data should be well defined, studied and analyzed. One of the key components of spatial accessibility is the movement of the user within the space. Therefore, an analysis of spatial accessibility requires a clear definition of both the spatial organization data of the space and the movement data of the user within this space.

Previous studies on spatial accessibility addresses the internal and external accessibility problems separately. Here, internal accessibility refers to the horizontal and vertical circulation within the building, while the relationship of the space with the outside environment is considered to be external accessibility. Studies considering internal accessibility focus on accessible design criteria, theoretical and practical knowledge integration, physical environmental data, orientation and user types. On the other hand, studies considering external accessibility focus criteria such as mass housing and layout pattern evaluation.

This paper focuses on internal accessibility measures and user movements through a series of parameters including user speed and distance tables, daily use hours and frequency, user routes and flow charts, publicness, security, and emergency levels. One of the important contributions of this paper is to define novel evaluation criteria for these suggested parameters.

2.1 Methods focusing accessibility in design and planning

There are various application areas of the accessibility concept in design, development and generation of a building. The ones we consider in this work are space layout planning, space syntax and wayfinding.

Space layout planning is the assignment of discrete space elements to their corresponding locations while defining their relationships with one another (Jo, Gero, 1998). The space layout planning problem consists of three important steps: (i) how to formulate the problem, (ii) how to control the generated solutions, (iii) and how to evaluate the solutions depending on specific criteria (Jo, Gero, 1998). Techniques employed for space layout planning include topology based methods utilizing grammars and geometry based on mathematical programming (Medjdoub, Yannou, 2000) and related optimization methods. There is a large body of work focusing on constructive placements, synthesizing layouts using generative grammars and use of genetic algorithms in topographical and geometrical problems (Arvin, House, 2002; Bollmann, Bonfiglio, 2013; Rashid, 2012; Park et al., 2012; Osman et al., 2003).

Space syntax method on the other hand defines the relationships between users and spaces within general theory perspective of building-settlement-city structure (Kubat, 2007, Dursun, 2012). The core of the concept is the people using space as a key to organize for themselves (Bafna, 2003). There are various research on interior space analysis, the topics covered include: (i) the comparison of two distinct office spaces (designed and built) via axial mapping (Bafna, Ramash, 2007), (ii) characterization of a space with graph spectra and plan generation via optimization with genetic algorithm (Hanna, 2007), (iii) an evacuation system proposal stressing spatial, ergonomical and cognitive parameters (Unlu et al., 2007). Additionally there are studies defining and practicing accessibility measures depending on distance and time (Kim et al., 2008). The feasibility analysis of physical and sociological measures and the use of computational methods for this purpose are common in space syntax approach.

One last method proposed in the literature is called wayfinding. Being a concept related to environmental and behavioral studies, wayfinding is defined as the action of starting from a departure point and reaching to a target (Unver, 2006). Therefore wayfinding can be an effective approach to analyze and generate an algorithmic distance based accessibility model. A successful wayfindingbehavior requires knowing the location of and the best route to the target, and then recognizing the target when reached, and finally finding the way back (Bechtel, Churchman, 2002). Studies on wayfinding cover many disciplines; however in this work we specifically take advantage of the works that use the hospitals as a subject (Baskaya et al., 2004).

2.2 Methods focusing on user movements

This section examines the methods for analysis of user movements previously proposed in the literature. Different examples are compared in terms of methods and outcomes. Agent-based design and ant colony

optimization methods are discussed and the use of quadratic assignment problems in architecture is evaluated. As a result of this comparison, similarities and differences are revealed by evaluating the methods in terms of the contribution to this paper's method.

In recent years, new opportunities have emerged in computer-aided design due to the advances in communication and information technologies. Employing genetic algorithms and artificial intelligence methods in the design process provide unlimited possibilities for designers. Agent Based Systems are used both by architects on a building scale and also by city plannerson an urban scale. Such efforts provide solutions to many accessibility problems while also reducing the time required for functional designs.

Various applications and literature studies of agent based design methods are examined in the field of architectural design. Cenani has analyzed the connection between the user and the place utilizing an agent based design method. He developed a model named MallSim that represents the user movements in shopping centers (Cenani, 2007). Aiming for the development of new methods in architectural design, Durmazoglu (2008) proposed an improved agent based system called DROP which is commonly employed in free-form production.

The studies concentrating on human behavior inspired this research. One study exemplifying the comparative approach in real and virtual environments show the results of human movement that effect spatiality (Girginkaya, Cagdas, 2007). In a similar study, a virtual environment is analyzed with wayfinding algorithms and the resulting movements are compared to the cognition data (Haq et al., 2005). The results show us whether in a real or virtual environment, human movement is a key factor to affect the design methodology.

Another agent based approach is Ant Colony Optimization (ACO) which is population-based (Keskinturk, Soyler, 2006) (Dorigo, Gamberdella, 1997). In fact, ACO has been developed by mimicking real ant colonies after observing that ants successfully discovered ideal routes and left a chemical trace behind them called pheromone which serves to communicate these ideal routes to the other ants. Mathematically ACO solves Travelling Salesman problem successfully which can be summarized as the shortest travel distance required between a random set of points (Dorigo, Gamberdella, 1996).

In the literature regarding ACO various approaches and methods are proposed for implementation each with different performance improvements. To date, many systems have been developed including but not limited to the following: Ant System (AS) (Maniezzo, et all., 2004), Ant-Q System (Gambardella, Dorigo, 1995), Rank-based AntSystem (ASrank)(Bıllnheimer et al., 1997), Ant Colony System (ACS) (Dorigo, Gambardelle, 1997), Max-Min Ant System (MMAS) (Stützle, Hoos, 2000), facility layout solving (Lee, 2012).

The last method that needs to be mentioned is the Quadratic Assignment Problem where a generic accesibility problem can be formulated as follows. In a closed space there are a set of p facilities and a set of l locations. For each pair of locations, a distance is specified and for each pair of facilities a

weight is specified. The expected outcome of this formulation is to specify all facilities to different locations with the goal of minimizing the sum of the distances between (http://en.wikipedia.org/wiki/ Quadratic_assignment_ problem).

All these methods mentioned above shows that there are multifold driving forces to achieve an enhanced building accessibility. Among these forces, user data is highly significant which requires matching the generative process to the architectural design process. Better analysis and evaluation of user movement will improve the quality of spatial accessibility, and will directly contribute to preliminary design and project evaluation phases. The acquisition of accessible spaces and measuring the accessibility will contribute to interdisciplinary fields as well.

3. Genetic algorithm and optimization in architectural design

In the previous section we provided a brief summary of techniques that are employed to solve optimization problems in architectural design domain. Being one of these techniques, GAs are chosen in this work because of their compatibility to the problem formulation in our case. Mimicking the natural selection process in the nature, GAs provide easy to implement and intuitive selection and search heuristics. We employ GAs to define spatial relationships for a given set of spatial elements while optimizing user movements between these elements. We believe effective adaptation of GAs in the field of architectural design, especially for user data optimization tools that ensure consistency, will significantly contribute to the field.

3.1 Evolutionary design concept and computational paradigm

The goal of architectural design is to produce creative and sustainable solutions to ill-defined spatial arrangement problems (Giaccardi, Fischer, 2008). The reflection of the design problem on problem solving process dates back to Ptolemy's Almagest in astronomy field in AD 100-170 and Copernic's De revolutionibusorbiumcoelestium in 1543 (Liddament, 1999). Later, epistemological problems that indicate both difficulties and weaknesses of computational theory have emerged with Kurt Godel who develops computational theory and Alan Turing who invents Turing machine. Computational theory has taken on new dimension with the invention of early computers by Charles Babbage (1792- 1871). In other words, computers have played an important role in the design of computational paradigm (Liddament, 1999). Focusing of the design problems on computer-based calculation methods brings to mind a significant question: Will these techniques improve the internal model of design or will they imitate the design process of real designers?

Evolution, which forms the basis of evolutionary design, is a general-purpose optimization problem solving method that creates the most remarkable and successful designs in nature (Bentley, 1999). In this respect, the process of evolution and design are similar to each other and the method called Evolutionary Design Process emanates from this similarity. For Aristotle this combination can be termed as a "productive logic" and is kind of a re-creation bringing different alternatives together; for Dawkins, it is a combination of random pieces (Dawkins, 1986); for Boden, finding the new and creative one by bringing known ideas in an unknown way (Boden, 1991).

The concept of evolutionary design is analyzed basically in 4 groups: Evolutionary design optimization, creative evolutionary design, evolutionary art and evolutionary artificial intelligence (Bentley, 1999). This work especially focuses on evolutionary design optimization.

In addition to the solution of optimization problems, evolutionary algorithms can also be used as a design tool. Evolutionary approach is a productive test method that can be used in evaluation and the synthesis of design process (Marin et al., 2008). Characteristics of this approach are:
- Being a population rather than a single result in design solution,
- Selecting individuals according to their fitness function,
- Improvement of new generations with mutations and crossovers,

While looking at the development of evolutionary algorithms in history we come across many significant sources in the literature including but are not limited to the following: Genetic Algorithms by J. H. Holland in 1975; Revolutionary Strategies by P. Bienert, I. Rechenberg and H. P. Schwefel in 1960; Revolutionary Programming by L.F. Fogel in 1966; Concept of Genetic Programming by J. Koza in 1992. These sources define GAs as the most well-known of evolutionary search algorithms.

3.2 Use of genetic algorithms in optimization problems in architecture
As noted earlier, GAs are search and optimization methods based on the principles of natural selection. The basic idea is based on creating an ideal population by adapting of organisms to the external environment as in the case of natural adaptive systems. Genetic algorithms, working in accordance with the rules of probability, scan a specific part of the solution space rather than the entire solution with an objective function (Emel, Taskin, 2002). In this way, they reach the solution in a shorter period of time by efficiently reducing time required for search (Goldberg, 1989).

Recent studies reveal the success of GAsin solving optimization problems in a simple but powerful way (Jo andGero, 1998). The reason that makes the use of generative tools difficult is the difficulty of identifying evaluation criteria to determine an acceptable solution. Since the architectural design problems are "ill-defined problems", defining evaluation criteria is even more challenging for this field (Caldas, Norford, 2002). Hence, the most significant initial step is to turn the "ill-defined problems" of architectural design into "well-defined" ones.

Joe and Gero have used genetic optimizations techniques on space layout planning (Jo andGero, 1998). Space layout planning is based on placing of different place elements according to their connections with each other. These connections include topology and geometry unlike the linear assignment problems. Geometric problems are solved by using mathematical programming and optimization techniques whereas topology problems use shape grammar. Topological space planning is based on topological relations of space elements (Jo andGero, 1998). Relations diagram that shows the spaces with bow and arrow (Miller, 1971), balloon diagram (Korf, 1977), a rectangular dissection (Grason, 1971; Gilleard, 1978), optimization of hospital design (Gandhi, 2008) can be seen among such studies. Geometric space planning is a measurement problem of space elements and plans according to their geometric characteristics (Mitchell et. al., 1976; Gero, 1978; Balachandran and Gero, 1987).

4. Algorithmic distance based accessibility model (aDA)

The main problem in this paper is the definition of user and spatial accessibility in architectural design and depending on this, optimization of distances between spaces using genetic algorithm (Ozer et al., 2012). In this respect, a model called aDA (Algorithmic Distance Based Accessibility) is developed. In this developed model, user and spatial data is scripted depending on a list of criteria, and distance optimization is performed by a genetic algorithm. The user data mentioned here are; (i) user types, (ii) user speed/distance tables, (iii) daily use hours, (iv) user routes and flowcharts, and (v) user density. On the other hand, spatial data are; (i) definition of main and sub spaces, (ii) publicness/ security/ emergency levels, (iii) space use density and time and (iv) evaluation of spatial accessibility parameters (Figure 1). These data are scripted based on a list of criteria that define the scope of the study and evaluated/discarded data, as well as tightens the solution pool based on these criteria. In this case, the criteria are defined so as to evaluate health campuses.

4.1 Evaluation parameters

Evaluation parameters are defined as *spatial value (r)* and *relationship value (d).* Spatial value (r) states the properties of the space.   The data pointing this (r) value are; user route flowcharts, publicness-emergency-security levels, spatial use time and density. In the evaluation, the value is shown as radius of a circle (Figure 2). Relationship value (d) states the relationship between two locations. In the evaluation, the value is shown as the distance between two points, namely locations (Figure 2). The data pointing this (d) value are spatial value, and publicness-emergency-security levels. The correlation between these data and value parameters are defined as shown in below Table 1.

4.2 Scripting and optimization

The Genetic Algorithm parameter selection criteria are the chromosome, addition mutation, multiplication mutation, crossover, fitness function and selection. Chromosome is defined by an array of doubles that represent x and y values of points. X and y values are stored consequently for each point. The objective of the algorithm is to maximize the fitness function through generations. The findings show that the algorithm successfully increases the fitness value. However most of the times there is no "perfect solution" therefore it gives an approximation result with fitness values lower then 1. Since the fitness function tries to make the results closer to relation degrees, end product is ideally a set of tangent circles, where every circle represents degree of usage (spatial value, r). Genetic algorithm runs with specified population size until the specified generation. After the algorithm terminates, the genetic solver component writes the coordinate values as output. These values are the optimized distance values which are considered to be relationship value (d) (Table 1 and Figure 2).

4.3 Scripting grasshopper components

Using this data set, a simple genetic algorithm is designed with a special fitness function. Two components are generated in Rhino Grasshopper interface (Figure 3); user component (Table 2) is used to process user movement data and takes an xml file that includes node data and generates paths. On the other hand, genetic solver component (Table 3) is used to optimize the routes. It takes the user paths and relations and creates the coordinates for spaces using a genetic algorithm.
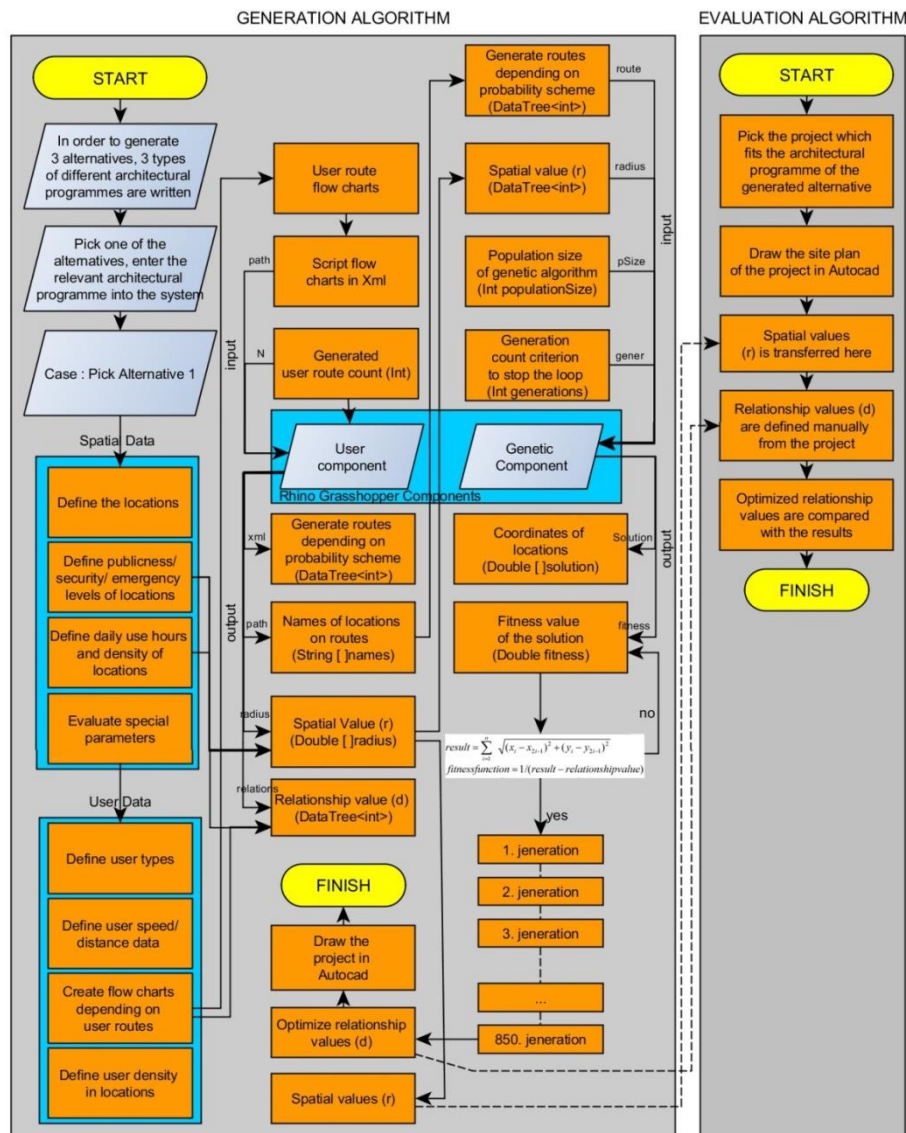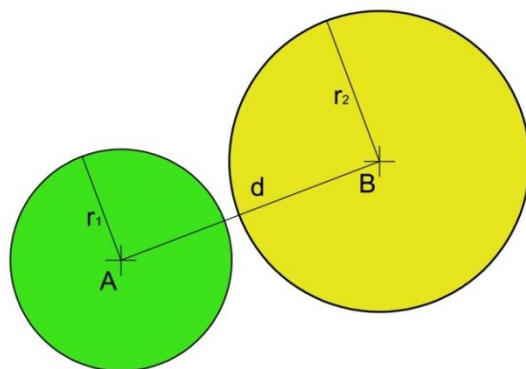
Figure 1. *aDA generation and evaluation algorithm.*

4.4 Evaluation of fitness function

Any two points (referring to locations) will be compared due to design criteria that are defined. In each step the new child is compared with its parents. If the fitness value is lower than before, the parent which has higher fitness value is picked for the generation, and continues that way.

Figure 2. *Spatial value (r) and relationship value (d) parameters between location A and B.*

The aim of this algorithm is to increase the fitness

value through generations. As a result of the findings of this study, the fitness value was successfully increased in the algorithm, but didn't reach the perfect level and stayed below 1 (Figure 4). Since the aim of the fitness functions is to get closer to the *relationship values (d)*, the end results are becoming adjacent circles. The center of the circle is the place of the location (x,y coordinate) and the radius of the circle indicates *spatial value (r)*. It is important to mention here, relationship values (d) are physical distances between locations, but spatial values (r) do not indicate the physical size, but refers to the density.

Genetic algorithm runs at a defined size of population to a defined number of generations. When the algorithm stops, genetic component prints out the coordinate values. These coordinates are printed as a schematic campus site plan.

Table 1. *Spatial (r) and relationship value (d) definitions.*

| Value parameters		Explanations
Spatial value: r (radius)	r increases if density of usage in location "A" increases	r increases; if any location is passed by
		r increases; if publicness value increases, security value decreases, emergency degree increases.
		r increases; if location use density and time increases.
		r decreases; if the mean distance value between spaces increases
Relationship value: d (distance)	d decreases if relationship between location "A" and "B" increases	d decreases; if spatial value (d) increases
		d decreases; if connection between two locations increases
		d increases; if publicness value decreases, security value increases, emergency degree decreases.
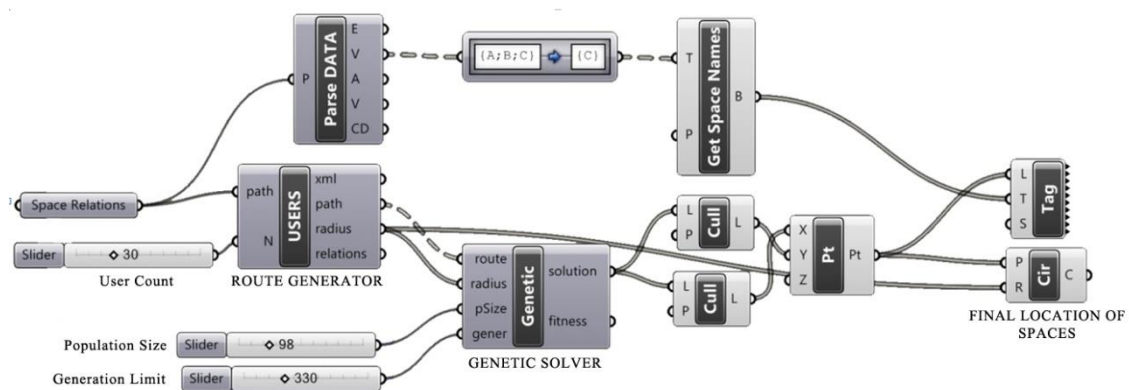
Figure 3. *aDA grasshopper user interface.*

4.5 Generation of the health campuses
Due to its complex architectural program and functional varieties, health campuses are studied in detail. Two solutions are generated at different scales; first solution is generated to have seven hospitals and second solution is generated to have five hospitals (Table 4). By this method we would like to test which size is suitable for a more accessible health campus.
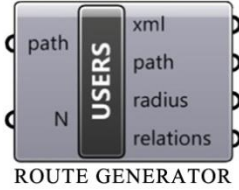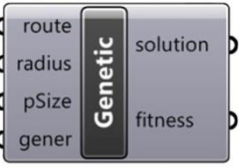
Table 2. *User component input and output.*

Visualization	Input	Notation	Definition
	XmlDocument	path	*Xml file*
	Int	N	Generated user route count
ROUTE GENERATOR	*Output*		
	Data Tree\<int\>	xml	Generated route based on probability scheme
	String[ ] names	path	Names of the locations on the route
	Double[ ] radius	radius	Spatial value (r) of the locations
	Data Tree\<int\>	relations	Relationship value (d) of the locations

Table 3. *Genetic component input and output.*

| Visualization	Input	Notation	Definition
	Data Tree\<int\>	route	Generated route based on probability scheme
	Data Tree\<int\>	radius	Spatial value (r) of the locations
	Int population Size	pSize	Population size of the genetic algorithm
	Int generations	gener	Generation count criteria to stop the loop
GENETIC SOLVER	*Output*		
	Double[ ] solution	Solution	Coordinates of the locations
	Double fitness	fitness	Fitness value of the solution
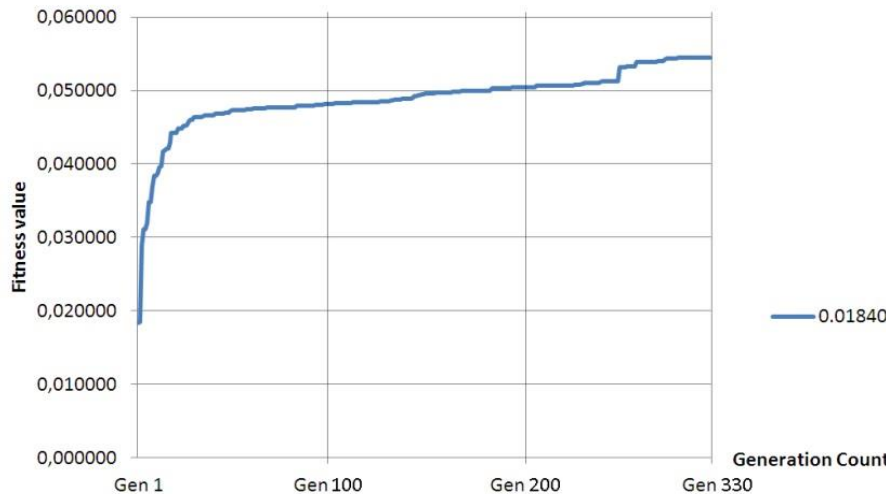
Figure 4. *Fitness function and generations.*

In Solution 1; after 330 generations, the results come up to be in the figure (Figure 5a). After the result is analyzed, we used basic campus schemes to produce an architectural site plan which fits our solution (Figure 5b). In this case, we aim to get a solution which satisfies the below:

1. Placement of CU in a central location accessible from the other hospitals; GH, RH, PH, KDCH, KDH, ONH, and OH.
2. Close relation between ONH and RH for functional necessities,
3. Far relation between RH and CU, because RH is an independent hospital,

4. Close relation of SC with main campus entrance and the other hospitals.
5. Close relation of campus service entrance with hospital service entrances.
6. Closer relation of GH with campus main entrance because of being the most populated hospital.

Table 4. *Architectural program of the generated health campus solutions.*

Solution 1: 7 Hospitals	M2	Solution 2 : 5 Hospitals	M2
General Hospital (GH)	34000	General Hospital (GH)	34000
Rehabilitation Hospital (RH)	34000	Rehabilitation Hospital (RH)	34000
Psychiatric Hospital (PH)	17000	Psychiatric Hospital (PH)	17000
Obstetrics and pediatrics Hospital (KDCH)	68000	Obstetrics and pediatrics Hospital (KDCH)	68000
Cardiovascular disease Hospital (KDH)	25500	Forensic Psychiatric Hospital (YGPH)	17000
Orthopedic and neurological hospital (ONH)	38250		
Oncology Hospital (OH)	25500		
Central Units (CU)	120000	Central Units (CU)	120000
Social Center (SC)	31565	Social Center (SC)	31565

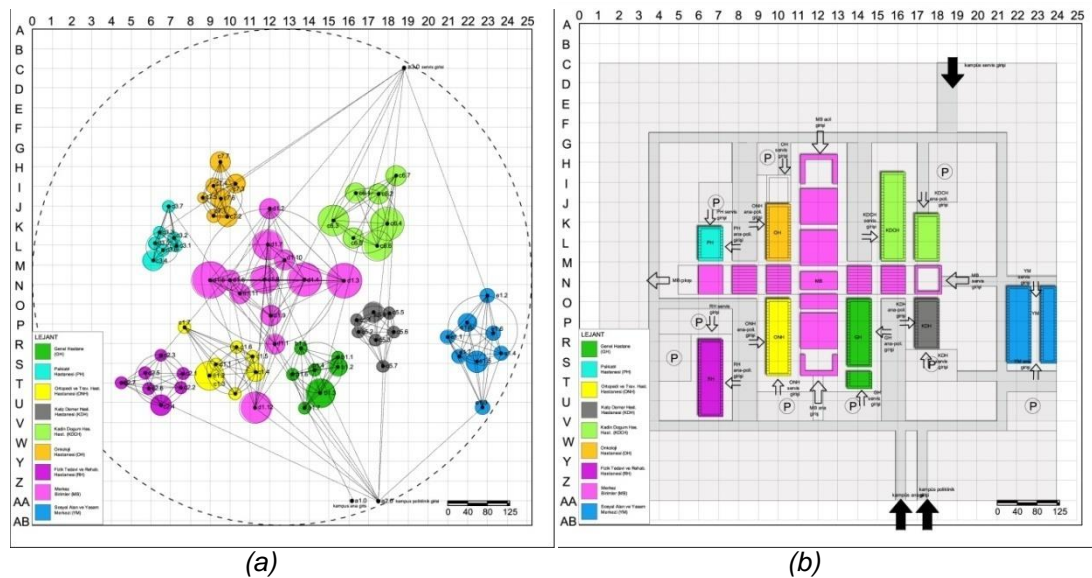(a)   (b)

Figure 5. *Images from the solution 1, (a) spatial relationship scheme of a health campus (b) schematic site plan of the same campus.*

In Solution 2; same as above solution, the results come up to be in the figure (Figure 6a). It is also produced based on centralized campus scheme (Figure 6b). In this case, we aim to get a solution which satisfies the below:
1. Placement of CU in a central location accessible from the other hospitals; GH, RH, PH, and KDCH.
2. Close relation between PH and YGPH for functional necessities,

3. Far relation between YGPH and other hospitals due to security conditions,
4. Close relation of SC with main campus entrance and the other hospitals.
5. Close relation of campus service entrance with hospital service entrances.
6. Closer relation of GH with campus main entrance because of being the most populated hospital.
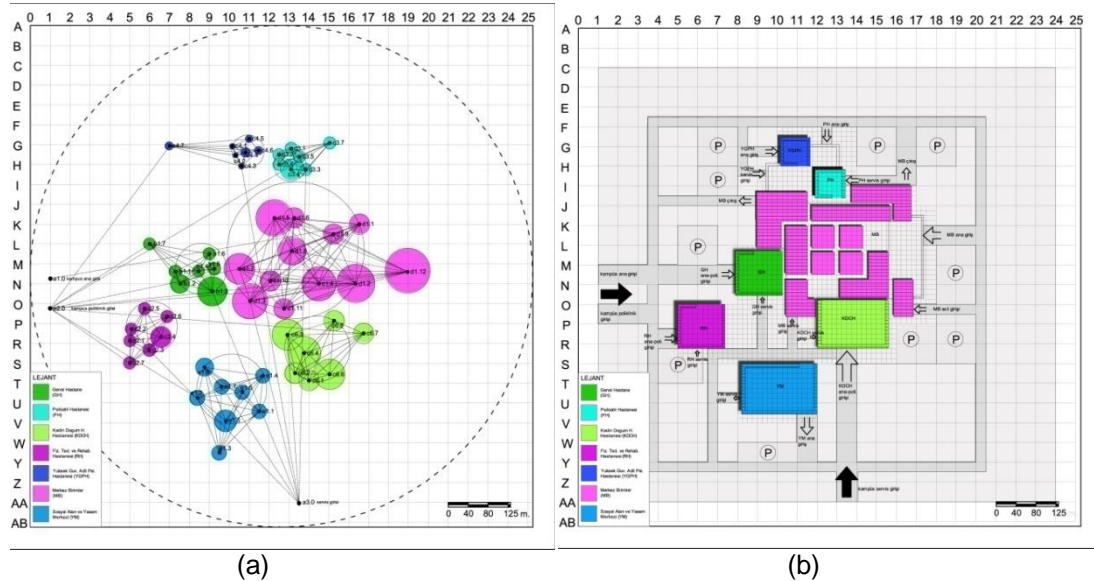

(a)   (b)

Figure 6. Images from the solution 2, (a) spatial relationship scheme of a health campus (b) schematic site plan of the same campus.

Results for Solution 1 (Table 5):

- GH is planned as a 200 bed hospital. Since all other criteria are satisfied, Criterion 3, the distance to the campus service entrance is more than desired. Overall evaluation is 10/11 (91%).
- RH is planned as a 100 bed hospital. All other criteria are satisfied, but Criterion 3 and Criterion 9, distance to the SC is more than desired. Since this hospital is planned to be an independent hospital, Criteria 6-7-8 are not related. Overall evaluation is 6/8 (75%).
- PH is planned as a 100 bed hospital. Criterion 2, distance of the car park to the main campus entrance, and Criterion 9 is more than desired. Criterion 10 is not related since it is not closely related to any other hospital. Overall evaluation is 8/10 (80%).
- KDCH is planned as a 400 bed hospital. Only Criterion 2 is not satisfied for this hospital. Criterion 10 is not related since it is not closely related to any other hospital. Overall evaluation is 9/10 (90%).
- KDH is planned as a 150 bed hospital. Only Criterion 3 is not satisfied for this hospital. Overall evaluation is 10/11 (91%).
- OH is planned as a 150 bed hospital. Criterion 2, distance of the car park to the main campus entrance, and Criterion 9 is more than desired. Criterion 10 is not related since it is not closely related to any other hospital. Overall evaluation is 9/11 (82%).
- Central Unit (CU), serving six hospitals, is planned as a successful

solution. The distances between campus main entrance and service entrance are satisfied.

Results for Solution 2 (Table 5):

- GH is planned as a 200 bed hospital. All the criteria are satisfied for this hospital. Overall evaluation is 11/11 (100%).
- RH is planned as a 100 bed hospital. Since this hospital is planned to be an independent hospital, Criteria 6-7-8 and 10 are not related. Overall evaluation is 7/7 (100%).
- PH is planned as a 100 bed hospital. Criteria 2, 3 and 9 are more than desired. Criterion 10 is not related since it is not closely related to any other hospital. Overall evaluation is 8/11 (73%).
- KDCH is planned as a 400 bed hospital. Only Criterion 2 is more than desired. Criterion 10 is not related since it is not closely related to any other hospital. Overall evaluation is 9/10 (90%).
- YGPH is planned as a 50 bed hospital. Only Criterion 3 is more than desired. Since this hospital is planned to be an independent hospital, Criteria 6-7-8 and 10 are not related. Overall evaluation is 7/8 (88%).
- Central Unit (CU), serving four hospitals, is planned as a successful solution. The distances between campus main entrance and service entrance are satisfied.
- If we compare the two solutions, we can see Solution 2 is better in both conditions. If we only compare the common hospitals (GH, RH, PH, KDCH) Solution 1 is evaluated 84%, Solution 2 is 91%. Even if we compare the total campus the results are similar. Therefore, since Solution 2 is better, we can conclude that five hospital campusesare more suitable for accessibility purposes.
- The criteria that are not satisfied commonly are Criteria 2, 3 and 9. These results show us in this type of central organizations, it is impossible to improve the above-mentioned criteria.

5. Results and prospective studies

We used user movement diagrams and aimed to generate new planimetric possibilities towards an optimized behavior of a schematic configuration in site plan scale. We developed a script based tool that works as a component running in Rhino Grasshopper. This work focuses mostly on those aspects related to the user movement inside spaces. The capability of producing optimized solutions and effective use of computational techniques for the given set of user data proves the utility of the developed model.

In the scope of this paper, health campuses are studied in general, with the derived solutions Ikitelli and Kayseri Health Campuses are evaluated in focus, a comparative study is discussed. Later on, to test the developed model, two alternate solutions are generated. Since spatial accessibility optimization is a large problem domain, the scope is limited to health campuses in this paper, due to its various user types and functional variety. The developed model is accepted to generate schematic site plans suitable to different architectural programs, to shed light on and give direction to future studies.

As the result of this paper, spatial and user accessibility and the contribution of genetic algorithm as an optimization tool to architectural design field is well defined. With the developed aDA model it is possible to evaluate

existing site plan designs based on user accessibility, and renovations can be offered. At the same time, the generated schematic site plans can be used in pre-design phase and make important contribution to pre-design phase. In further studies, the aDA model is planned to be developed on different building types and different building scales, such as education or university campuses.

Table 5. Comparison of the generated solutions depending on the design criteria.

	Solution 1							Solution 2				
	GH	RH	PH	KDCH	KDH	OH	ONH	GH	RH	PH	KDCH	YGPH
Criterion 1. Hospital area qualification	+	+	+	+	+	+	+	+	+	+	+	+
Criterion 2. Qualification of distance of hospital car parks to campus main and polyclinic entrances	+	+	-	-	+	-	+	+	+	-	-	+
Criterion 3. Qualification of distance of the hospital to campus emergency/service entrance	-	-	+	+	-	+	-	+	+	-	+	-
Criterion 4. Relationship of hospital car parks to each other	+	+	+	+	+	+	+	+	+	+	+	+
Criterion 5. Relationship of campus main entrance, polyclinic and emergency/service entrance	+				+			+				+
Criterion 6. Relationship to Laboratory- Radiology Department (CU)	+	NR*	+	+	+	+	+	+	NR	+	+	NR
Criterion 7. Relationship to Emergency Department (CU)	+	NR	+	+	+	+	+	+	NR	+	+	NR
Criterion 8. Relationship to Surgery Department (CU)	+	NR	+	+	+	+	+	+	NR	+	+	NR
Criterion 9. Relationship to Social Center (SC)	+	-	-	+	+	-	-	+	+	-	+	+
Criterion 10. Relationship of related hospitals to each other	+	+	NR	NR	+	NR	+	+	NR	+	NR	+
Criterion 11. Qualification of relationship value (d)	+	+	+	+	+	+	+	+	+	+	+	+
Final Evaluation	10/11 (%91)	6/8 (%75)	8/10 (%80)	9/10 (%90)	10/11 (%91)	8/10 (%80)	9/11 (%82)	11/11 (%100)	7/7 (%100)	8/11 (%73)	9/10 (%90)	7/8 (%88)
Total	%84				%84			%91				%88

*NR= Not related

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Kullanıcı erişilebilirliği optimizasyonunda genetik algoritma kullanımı: aDA

Mimari tasarımın merkezinde kullanıcı yer alır. Mekânların ön tasarım, avam proje, uygulama, kullanım sonrası analizlerini kullanıcı odaklı olarak gerçekleştirmek esastır. Kullanıcı söz konusu olduğunda; erişilebilirlik kavramı ve buna bağlı olarak da mekânsal erişilebilirlik ön plana çıkmaktadır. Mekânın kullanıcı açısından en önemli kriterlerinden biri ise en kısa mesafede hareketin tamamlanabilmesidir. Fakat mimari tasarımda kullanıcı erişilebilirliği kapsamında en kısa mesafe kavramı göreceli bir tanımdır. En kısa mesafe problemi iki nokta arasındaki en kısa mesafe gibi basit bir problem değil, mekân kullanım özellikleri ve farklı kullanıcı özellikleri göz önüne alınarak değerlendirilmesi gereken çok parametreli bir problemdir. Bu nedenle çok kullanıcılı mekânlar için en kısa mesafe tanımının yapılabilmesi için optimizasyon gereklidir. Bunun sonucu olarak mimarlık alanında kullanıcı hareketine bağlı mesafe optimizasyonu üzerine yapılacak bilimsel çalışmalara ihtiyaç duyulmaktadır.

Bilişim alanının optimizasyon yöntemlerinden biri olan genetik algoritmalar, doğal evrimsel süreci taklit eden benzer bir şekilde çalışmayı prensip olarak kabul eden, arama ve eniyileme yöntemidir. Belirlenen uygunluk fonksiyonlarına göre eniyilerin hayatta kaldığı bu sistemde, sürekli olarak uygunluğu artan yeni nesiller üretilir. Bu nedenle, kullanıcı hareketlerinin optimizasyonu ve mekânsal ilişkilerin tanımlanabilmesi için genetik algoritmalar bir yöntem olarak benimsenmekte ve bu alanda eksik olan literatüre katkı koymak hedeflenmektedir.

Bu çalışmada belirlenen ana problem, mimari tasarımda kullanıcı ve mekân erişilebilirliğinin tanımlanması ve buna bağlı olarak mekânlar arası uzaklığın genetik

algoritma ile optimizasyonudur. Bu problem ışığında aDA (Algoritmik Mesafe Tabanlı Erişilebilirlik) modeli geliştirilmiştir. Geliştirilen bu modelde elde edilen kullanıcı ve mekân tabanlı veriler, belirlenen kurallar dizinine göre kodlamaya aktarılmakta, genetik algoritma ile mesafe optimizasyonu yapılmaktadır. Burada ele alınan kullanıcı tabanlı veriler; (i) kullanıcı tiplerinin tanımlanması, (ii) kullanıcıların hız/mesafe verilerinin eldesi, (iii) günlük kullanım saatlerinin belirlenmesi, (iv) kullanıcı rotalarının ve buna bağlı akış diyagramlarının oluşturulması ve (v) kullanıcı kullanım yoğunluğu verileridir. Ele alınan mekân tabanlı veriler ise; (i) mekânların tanımlanması ve kodlanması, (ii) kamusallık/ güvenlik / aciliyet derecelerinin belirlenmesi, (iii) mekân kullanım yoğunluğu ve uzunluğunun belirlenmesi ve (iv) yapıya ait özel parametrelerin değerlendirilmesidir. Bu verilerin kodlamaya aktarılmasında belirleyici rol oynayan kurallar dizini; hem çalışmanın kapsamını, değerlendirilen ve göz ardı edilen verileri belirlemekte, hem de belirlediği kurallar çerçevesinde sonuç kümesinin kapsamını daraltmaktadır. Kodlama aşamasında ise RhinoGrasshopper yazılımı üzerinde rota üretici ve genetik çözümleyici bileşenleri kodlanmakta, uygunluk fonksiyonu değerlendirilmesi ile birlikte optimize edilmiş final çıktılar elde edilmektedir.

Bu çalışma kapsamında ele alınan yapı tipi olan sağlık kampüsleri genelinde, modeli test etmek amacı ile 2 farklı vaziyet planı alternatifi üretilmekte, karşılaştırmalı sonuçlar değerlendirilmektedir. Çok geniş bir problem alanı olan mekânsal erişilebilirlik optimizasyonu bu makale kapsamında oldukça farklı kullanıcı tipi ve işlevsel çeşitlilik gösteren sağlık kampüsleri ile sınırlandırılmaktadır. Modelin, farklı mimari ihtiyaç programlarına uygun vaziyet planları ortaya koyması ve bu çalışmanın yapılacak ileriki çalışmalara ışık tutması ve yön vermesi beklenmektedir.

Sonuçların karşılaştırılmasında, mekânların kullanım yoğunluğunu ifade eden mekânsal değer (r) parametresi ve mekânlararası uzaklığı ifade eden ilişki değeri (d) parametresi ölçülmektedir. Bu parametrelerden (r) parametresi sanal olarak daire büyüklüğü ile ifade edilmekte, (d) parametresi ise gerçek olarak uzaklık belirtmektedir. İki parametre arasında ters orantı ortaya çıkmakta, yani (r) arttıkça (d) azalmaktadır.

Bu çalışma sonucunda, mekân ve kullanıcı erişilebilirliği net olarak tanımlamakta ve bir optimizasyon aracı olarak genetik algoritmaların tasarım alanına katkısı ortaya konulmaktadır. Geliştirilen aDA modeli ile var olan vaziyet planı tasarımlarını kullanıcı erişilebilirliğine bağlı olarak değerlendirmek mümkün olmakta, yapılabilecek iyileştirmeler ortaya koyulabilmektedir. Aynı zamanda geliştirilen model ile üretilen yeni vaziyet planı alternatifleri, ön tasarım aşamasında kullanılmakta ve mimari tasarımda bilişim literatürüne önemli katkı sağlamaktadır. Diğer yandan bu çalışma ülkemizde yeni geliştirilen ve gün geçtikçe sayıları artan sağlık kampüsü tasarımlarının değerlendirilmesi ve üretilmesi üzerine yapılmış ilk çalışmalardan biri olup, bu alandaki önemli bir boşluğu doldurmayı hedeflemektedir. İleriki araştırmalarda geliştirilen bu modelin farklı yapı ve kampüs tipleri üzerinde geliştirilmesi, farklı yapı ölçekleri ve eğitim kampüsleri gibi alanlarda uygulanması planlanmaktadır.