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Fuzzy Logic Positioning of a Vehicle in the Movement Direction

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Abstract: Nowadays, applications of unmanned vehicles are increasing rapidly. Unmanned vehicles are used in many areas such as agriculture, transportation and especially military defense systems. In this study; control of the movement direction of a 4-wheeled unmanned land vehicle is studied with fuzzy logic. In our study, the C-based software language was used in the Arduino IDE program. As the input information for the control operation with fuzzy logic, the error value of the movement direction and the previous error value are used. The speed of the motors on the unmanned vehicle is used as the output information. Membership functions for input and output information are created using the triangle membership function. After determination of fuzzy rules, Max-Min method was used to obtain fuzzy inference. As the last step of these processes, the defuzzyfication process weight average method is used. The information obtained by the weight average method is the engine speed information that must be transmitted to the motors used in the vehicle. The engines are applied at this speed and the angle at which the vehicle is to be positioned according to the north point.

Keywords: Fuzzy Logic, Arduino, Direction control

Bir Aracın Hareket Yönüne Konumlanmasının Bulanık Mantık ile Gerçekleştirilmesi

Öz: Günümüzde insansız olarak hareket eden araçların kullanım alanları gün geçtikçe artmaktadır. Özellikle askeri savunma alanı başta olmak üzere tarım, ulaşım gibi birçok alanda insansız araçlar kullanılmaktadır. Bu çalışmamızda; 4 tekerlekli insansız bir kara aracının hareket yönünün bulanık mantık ile kontrolü ele alınmıştır. Çalışmamızda program olarak Arduino IDE programında C tabanlı yazılım dili kullanılmıştır. Bulanık mantık ile kontrol işlemi için giriş bilgileri olarak hareket yönünün hata değeri ve bir önceki hata değeri giriş bilgileri olarak kullanılmıştır. Çıkış bilgisi olarak insansız araç üzerinde bulunan motorların devir sayısı kullanılmıştır. Giriş ve çıkış bilgileri için üyelik fonksiyonları üçgen üyelik fonksiyonu kullanılarak oluşturulmuştur. Bulanık kurallar belirlendikten sonra bulanık çıkarım elde etmek için Max-Min yöntemi kullanılmıştır. Anlatılan bu işlemlerin son basamağı olarak durulama işlemi ağırlık ortalaması yöntemi kullanılmıştır. Ağırlık ortalaması yöntemiyle elde edilen bilgi araçta kullanılan motorlara iletilmesi gereken motor devir bilgisidir. Motorlara bu devir sayısı uygulanarak kara aracının kuzey noktasına göre hangi açıda konumlanacağı ayarlanmaktadır.

Anahtar kelimeler: Bulanık Mantık, Arduino, Yön kontrolü

1. Introduction

The most comprehensive definition of unmanned vehicles is that they do not contain human elements unless they are required to carry out their tasks, and that they are critical technologies that can be controlled remotely or autonomously and perform predetermined tasks. Due to the demands of superiority in battlefield and pre-combat, war against terrorism, security of facilities and buildings, space research, scientific applications and reasons for a wide variety of other demands

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Bu makaleye atıf yapmak için
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and requirements, countries' demand for unmanned vehicles is increasing day by day with technology. The investments made for this purpose increase exponentially every year and the achievements bring important advantages[1].

The first applications of fuzzy logic were generally applied in cement and water treatment systems in the industrial field. Afterwards, it has been seen in applications such as crane, elevator and nuclear reactors. The most important development in the field of fuzzy logic is the system implemented on the subway line in Sendai, northern Japan. After this development, fuzzy logic applications are increased expeditiously. This development reached its peak in the 1990s and has been used in a wide range of applications ranging from fuzzy controlled home appliances to stock exchange portfolio control and cameras to patient monitoring systems. Nowadays, special softwares and hardwares which are written for fuzzy logic control applications become available as packages. For example, Omron produces and commercializes special integrated circuits, which they call fuzzy microprocessors [2].

2. Importance of Study

In a study, fuzzy logic operation is explained with an example and vehicle made an u turn under inspection of fuzzy logic. The aim of this study is to bring the position of the vehicle to the required target and to control the positioning angle of the vehicle [3]. In a study on Altu robot racecourse, position information was calculated and sent to desktop software via bluetooth. The information of target position was sent to desktop software and the direction of route was calculated with the fuzzy logic control method [4]. A new mutation operator for the route finding problems with genetic algorithms for autonomous mobile robot is developed and this new mutation operator was compared with the different mutation operators previously presented in the literatüre [5]. In an environment where there are obstacles in motion and in motion, applications have been made in order to advance the robot to the desired target without hitting the obstacles. For the robots to move around easily to perform any task and reach the desired places in areas where people cannot go into will be possible by not hitting obstacles in that area and fuzzy logic may help to implement this task [6]. In one study, it was aimed to move the autonomous vehicle from the given starting point to the defined target point by calculating a route with depth-priority search algorithm [7]. It is aimed to send the unmanned controlled land vehicle to its destination. Microcontroller, GPS sensor and compass sensor were used for the study. The start and target coordinates are loaded into the memory of the microcontroller. Direction control of unmanned land vehicle was made by making calculations according to coordinate information obtained from GPS and compass sensor [8]. With the development of technology at the present time, it is becoming important to simplify daily routine or to do them without human intervention. As a result, the development of machines that can work unmanned, is rapidly increasing. The basis of our study is to determine the route in which a vehicle moves unmanned. After determining the route in which the vehicle will move unmanned, obtained information is processed by the fuzzy logic system and the cycle information is sent to the wheels of the vehicle so that it can move in a calculated direction. This operation can be used for positioning any moving machine that is intended to move at a determined angle.

3. Fuzzy Logic System Design

Fuzzy logic has begun to be used because classical logic is inadequate for most areas and human intelligence does not fit the way classical logic works. Thus, it can be described as qualitative [10]. Fuzzy logic consists of fuzzy sets. In virtue of fuzzy clustering, the memberships of fuzzy sets are expressed in degrees. In this way, uncertainties of belonging to fuzzy clusters are defined. The gradual expression of membership of fuzzy clusters enables the concepts to become meaningful [11]. The representation of classical clusters and fuzzy clusters is shown in Figure 1. In classical sets, the membership function is 0 or 1, whereas in fuzzy sets, it is in the closed interval of [0, 1].

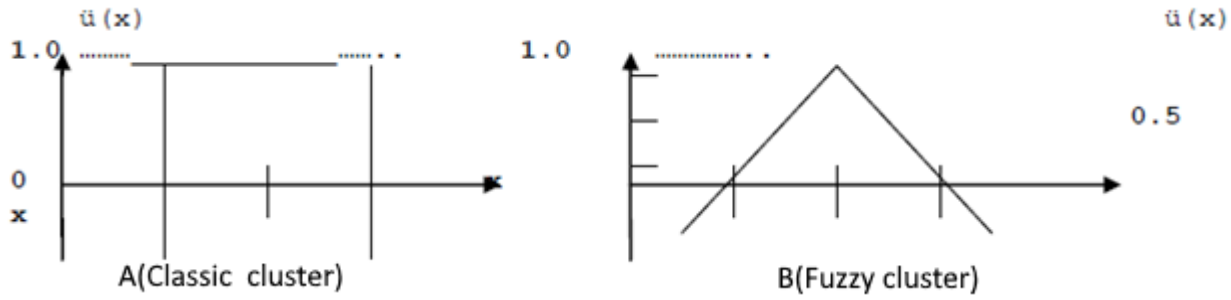

Figure 1. Classic and Fuzzy Cluster Image [12]

3.1. Defining Fuzzy Logic Input Variables

As input information; direction error (e), derivative of direction error (de) is used. In the Arduino program, the software of this information is performed as shown in Figure 2.

```
e=istenenaci-simdikiaci;
de=e-eo;
eo=e;
```

Figure 2. Defining Directional Error and Directional Error Derivative in Arduino

The input variable direction error (e) is obtained by the difference between the instantaneous direction data and the direction in which we want the vehicle to move. The directional error derivative (de) is obtained by the difference between the instantaneous directional error and the previously obtained directional error. This process is expressed as in Figure 2.

3.2. Fuzzy Logic Output Variable

Number of laps in a minute which is sent to vehicle engines, in other words speed value of engine is used as output variable. Speed control of the motors is achieved by using PWM unit in Arduino program. The speed information is between 0 and 255. According to the data obtained from the input information, the required rotation speed is sent to the right and left engines and the target direction of the vehicle is determined. Output variable information of the system we use which means speed data to be added to engine speed will be represented with “du”. Our output variable changes based on the data of direction error (e) and derivative of direction error (de) and fuzzy logic rules.

3.3. Fuzzy Logic Set of Input and Output Variables

In the classical set logic, whether element belongs to cluster is indicated by 0 or 1. In fuzzy cluster, defining of this belonging is explained by the magnitude of the number assigned to the characteristic value in the continuous interval of [0,1] [9].

Input and output variables are expressed in fuzzy logic sets. Fuzzy logic sets are created according to the values of input and output variables. The block representation of the input and output variables in the MATLAB environment is shown in Figure 3.

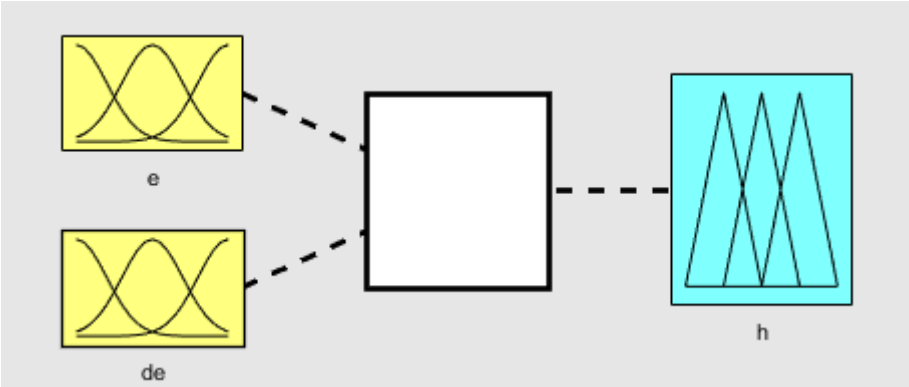

Figure 3. Fuzzy Logic Input and Output Sets

7 fuzzy logic sets are defined for system input variables which are direction error (e) and derivative of direction error (de). Data of clusters is same for both variables. The names and value ranges of these sets are given in Figure 4, which shows the membership functions below. Triangular membership function is used for membership functions of input variables.

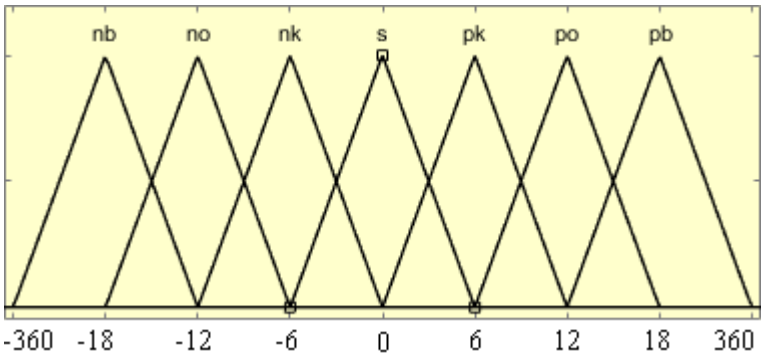

Figure 4. Directional Error and Derivative of Directional Error Fuzzy Logic Sets

There are 7 fuzzy logic sets for motor speed (du) which is output variable of the system. The names and intervals of these sets are given in Figure 5, which shows the membership functions below. Triangular membership function is used for membership functions of output variable.

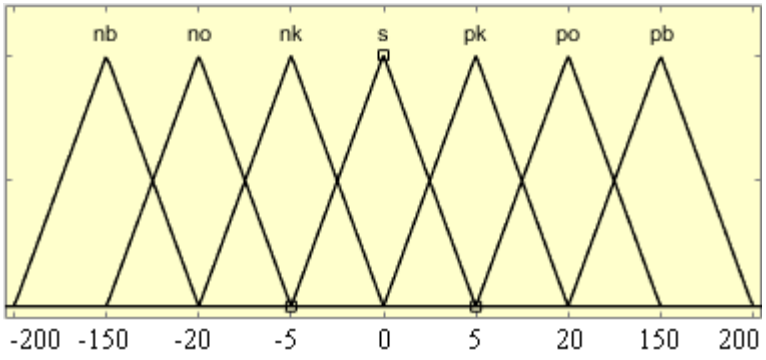

Figure 5. Fuzzy Logic Sets of Motor RPM Output Information

The input and output set variable values are transferred to the required variables in the Arduino program. The weighting sub-program for the input variables is shown in Figure 6. The weight value in clusters ranges from 0 to 1.

```
double bulanik(double dusuk, double orta, double yuksek, double giris){
  double yy;

  if( (giris>dusuk) && (giris<orta) )
    yy=(giris-dusuk)/(orta-dusuk);
    else if(giris==orta)
      yy=1.0;
        else if( (giris>orta) && (giris<yuksek) )
          yy=(giris-yuksek)/(orta-yuksek);
            else
              yy=0.0;

      return yy;
}
```

Figure 6. Arduino Subprogram for Determination of Input Variables' Membership Degree in Fuzzy Logic Set

3.4. Fuzzy Control Order Chart

As the output variable, 7 sets are created for the speed variable to be transferred to the engines of the vehicle and a fuzzy control table is prepared for the fuzzy logic operation by using these sets.

Table 1. Fuzzy Logic Order Table

de \ e	nb	no	nk	s	pk	po	pb
nb	nb	nb	nb	nb	nb	nb	nb
no	nb	nb	no	no	nk	s	pk
nk	no	no	nk	nk	s	pk	pk
s	no	nk	nk	s	pk	pk	po
pk	nk	nk	s	pk	pk	po	po
po	nk	s	pk	po	po	pb	pb
pb	pb	pb	pb	pb	pb	pb	pb

After the fuzzy control table is prepared, it is assigned to the variables as a value so that it can be used by the program.

```
int nb=150;
int no=20;
int nk=5;
int ss=0;
int pk=-5;
int po=-20;
int pb=-150;
double merkez[7][7]={  nb, nb, nb, nb, nb, nb, nb,
                       nb, nb, no, no, nk, ss, pk,
                       no, no, nk, nk, ss, pk, pk,
                       no, nk, nk, ss, pk, pk, po,
                       nk, nk, ss, pk, pk, po, po,
                       nk, ss, pk, po, po, pb, pb,
                       pb, pb, pb, pb, pb, pb, pb};
```

Figure 7. Display of Fuzzy Logic Order Table in Arduino Program

3.5. Fuzzyfication of Input Variables

Min_Max fuzzy comparison method is used for fuzzyfication of input variables. Two input information is used as input variables. Our input information is defocused with direction error (e) and derivative of direction error (de) in Arduino program with fuzzyfication subprogram which is shown in Figure 8.

```
void kuralbul(){
  int k=0, m=0;
  for(k=0;k<7;k++){
    for(m=0;m<7;m++){
      p[k][m]=0;
      }
    }
  for(k=0;k<7;k++){
    for(m=0;m<7;m++){
      p[k][m]=min(ua[k], ub[m]);
        }
    }
}
```

Figure 8. Sub-Program with Min-Max Method in Arduino Program

3.6. Obtaining Fuzzy Inference by Weight Average Method

In order to obtain the value resulting from fuzzyfication and order finding processes, fuzzy inference is required. Fuzzy inference makes fuzzy information meaningful. A sub-program called defuzzyfication is used for this process. The center of weight method is used in the defuzzyfication process. As a result of the defuzzyfication process, the speed information which will be transferred to engines of the vehicle is obtained. The speed information is transmitted to the right and left motor groups by adding or subtracting the required ratio. In this way, the direction of movement of the vehicle is controlled.

```
double durulama(){
  double q=0.0, qq=0.0;
  int k=0, m=0;

  for(k=0;k<7;k++){
    for(m=0;m<7;m++){
      q=q+(p[k][m]*merkez[k][m]);
      qq=qq+p[k][m];
      }
    }
    if(qq!=0)
    return du=q/qq;
}
```

Figure 9. Arduino Subprogram for Fuzzy Logic Center of Weight Method

The engine speed information (du) obtained as a result of the defuzzyfication process is transmitted to the vehicles' moving components. Since the vehicle we use in our study is a tracked vehicle, this information is transferred to the right and left engine groups.

4. Conclusion

In the experiments carried out on the land vehicle, the target angle is calculated according to target coordinate information and the movement of the vehicle in the calculated direction is provided.

When vehicle moves, its coordinate changes as well. The target angle is calculated instantaneous for the vehicle. The control of the motion was carried out with fuzzy logic operation. The position information of the vehicle and the angle for target position are shown in Table 2.

Table 2. Location and Target Angle Information

	4010.688 North 3451.286 East **Movement to Position route**		4010.692 North 3451.284 East **Movement to Position route**	
1	4010.685 North 3451.265 East	78.81°	4010.676 North 3451.278 East	32.68°
2	4010.683 North 3451.266 East	75.65°	4010.678 North 3451.278 East	37.69°
3	4010.682 North 3451.266 East	71.77°	4010.683 North 3451.280 East	48.65°
4	4010.683 North 3451.270 East	75.38°	4010.684 North 3451.282 East	43.36°
5	4010.685 North 3451.273 East	76.93°	4010.684 North 3451.284 East	23.96°
6	4010.684 North 3451.275 East	65.38°	4010.684 North 3451.286 East	0°
7	4010.686 North 3451.279 East	72.76°	4010.687 North 3451.287 East	-63.43°
8	4010.688 North 3451.282 East	90°	4010.689 North 3451.286 East	180°
9	4010.688 North 3451.285 East	90°	4010.688 North 3451.286 East	0°
10	4010.688 North 3451.286 East	0°		

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