Fuzzy Communication and Motion Control by Fuzzy Signatures in Intelligent Mobile Robots

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Abstract. This paper presents two examples for the deployment of fuzzy signatures in the field of intelligent mobile robots. The first shows a complex lateral drift control method base on fuzzy signatures. This method considers the motion system of the robot as a whole, unlike as simple parts of a complex system. The state space is written down by fuzzy signatures which add up flexibility, adaptability and learning ability to the system. In the second experiment a new communication approach is investigated for intelligent cooperation of autonomous mobile robots. Effective, fast and compact communication is one of the most important cornerstones of a high-end cooperating system. In this paper we propose a fuzzy communication system where the codebooks are built up by fuzzy signatures. We use cooperating autonomous mobile robots to solve some logistic problems.

Keywords: fuzzy signatures, fuzzy communication, intention guessing, mobile robotics, motion control.

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1 Introduction

Fuzzy signatures structure data into vectors of fuzzy values, each of which can be a further vector, are introduced to handle complex structured data [3, 5, 7, 8]. This will widen the application of fuzzy theory to many areas where objects are complex and sometimes interdependent features are to be classified and similarities / dissimilarities evaluated. Often, human experts can and must make decisions based on comparisons of cases with different numbers of data components, with even some components missing. Fuzzy signatures were created with this objective in mind. This tree structure is a generalization of fuzzy sets and vector valued fuzzy sets in a way modeling the human approach to complex problems. However, when dealing with a very large data set, it is possible that they hide hierarchical structure that appears in the sub-variable structures.

This paper deals with fuzzy signatures as complex state description method in field of control of mobile robots and robot cooperation. The first example stands near to control theory and gives a new aspect of motion control supervisory systems.

Intelligent cooperation is a new research field in autonomous robotics. If one would plan or build a cooperating robot system which has intelligent behaviors, one could not program the all scenarios which may appear in the life of the robots, and would realize that effective, fast and compact communication is one of the most important cornerstones of a high-end cooperating system. We assume settings where communication itself is very expensive, so generally speaking it is advisable to build up as large as possible contextual knowledge bases and codebooks in the distant on-board robot controller computers [10, 11]. Clearly, this is in order to shorten their communication process. This is appropriate if it significantly reduces the amount of information that must be transmitted from one to another, rather than to concentrate all contextual knowledge in one of them, and then to export its respective parts whenever they are needed in the other(s). It appears to be very important in the cooperation and communication of intelligent robots or physical agents that the information exchange among them is as effective and compressed as possible [4]. In this paper we propose a fuzzy communication system where the codebooks are built up by fuzzy signatures. After an overview of this type of fuzzy communication we will deal with some real scenarios of autonomous mobile robot cooperation. The base idea of this example has come from the partly unpublished research projects at LIFE [6]. The paper presents a cooperation system where a group of autonomous intelligent mobile robots is supposed to solve transportation problems according to the exact instruction given to the Robot Foreman (R_0). The other robots have no direct communication links with R_0 and all others, but can solve the task by intention guessing from the actual movements and positions of other robots, even though they might not be unambiguous.

2 Fuzzy Signatures

The original definition of fuzzy sets was $A : X \to [0,1]$, and was soon extended to *L-fuzzy sets* by Goguen [1]

$$A_s : X \to [a_i]_{i=1}^{k}, a_i = \begin{cases} [0,1] \\ [a_{ij}]_{j=1}^{k_i} \end{cases}, a_{ij} = \begin{cases} [0,1] \\ [a_{ijl}]_{l=1}^{k_{ij}} \end{cases}, \tag{1}$$

$A_L : X \to L$, L being an arbitrary algebraic lattice. A practical special case, *Vector Valued Fuzzy Sets* was introduced by Kóczy [3], where $A_{V,k} : X \to [0,1]^k$, and the range of membership values was the lattice of k-dimensional vectors with components in the unit interval. A further generalization of this concept is the introduction of fuzzy signature and signature sets, where each vector component is possibly another nested vector (right).

Fuzzy signature can be considered as special multidimensional fuzzy data. Some of the dimensions are interrelated in the sense that they form sub-group of variables, which jointly determine some feature on higher level. Let us consider an example. Fig. 1 shows a fuzzy signature structure.

The fuzzy signature structure shown in Fig. 1 can be represented in vector form as follow:

$$x = \begin{bmatrix} \begin{bmatrix} x_{11} \\ x_{12} \end{bmatrix} \\ \begin{bmatrix} x_{21} \\ \begin{bmatrix} x_{221} \\ x_{222} \\ x_{223} \end{bmatrix} \\ x_{23} \end{bmatrix} \\ \begin{bmatrix} x_{31} \\ x_{32} \end{bmatrix} \end{bmatrix}^T \tag{2}$$

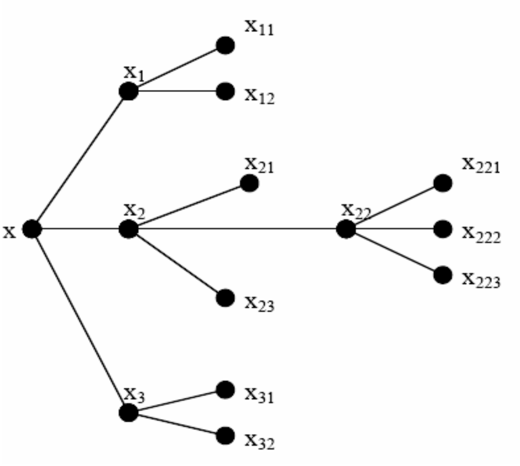

Fig. 1. A Fuzzy Signature Structure

Here $[x_{11}\ x_{12}]$ from a sub-group that corresponds to a higher level compound variable of x_1. $[x_{221}\ x_{222}\ x_{223}]$ will then combine together to form x_{22} and $[x_{21}\ [x_{221}\ x_{222}\ x_{223}]\ x_{23}]$ is equivalent on higher level with $[x_{21}\ x_{22}\ x_{23}] = x_2$. Finally, the fuzzy signature structure will become $x = [x_{221}\ x_{222}\ x_{223}]$ in the example.

The relationship between higher and lower level is governed by the set of fuzzy aggregations. The results of the parent signature at each level are computed from their branches with appropriate aggregation of their child signature. Let a_1 be the aggregating associating x_{11} and x_{12} used to derive x_1, thus $x_1 = x_{11}a_1x_{12}$. By referring to Fig. 1, the aggregations for the whole signature structure would be a_1, a_2, a_{22} and a_3. The aggregations a_1, a_2, a_{22} and a_3 are not necessarily identical or different. The simplest case for a_{22} might be the min operation, the most well known t-norm. Let all aggregation be min except a_{22} be the averaging aggregation. We will show the operation based on the following fuzzy signature values for the structure in the example.

Each of these signatures contains information relevant to the particular data point x_0; by going higher in the signature structure, less information will be kept. In some operations it is necessary to reduce and aggregate information obtained from another source (some detail variables missing or simply being locally omitted). Such a case occurs when interpolation within a fuzzy signature rule base is done, where the fuzzy signatures flanking an observation are not exactly of the same structure. In this case the maximal common sub-tree must be determined and all signatures must be reduced to that level in order to be able to interpolate between the corresponding branches or roots in some cases [8].

$$x = \begin{bmatrix} \begin{bmatrix} 0.3 \\ 0.4 \end{bmatrix} \\ \begin{bmatrix} 0.2 \\ \begin{bmatrix} 0.6 \\ 0.8 \\ 0.1 \end{bmatrix} \\ 0.9 \end{bmatrix} \\ \begin{bmatrix} 0.1 \\ 0.7 \end{bmatrix} \end{bmatrix}^T \tag{3}$$

After the aggregation operation is performed to the lowest branch of the structure, it will be described on higher level as:

$$x = \begin{bmatrix} 0.3 \\ \begin{bmatrix} 0.2 \\ 0.5 \\ 0.9 \end{bmatrix} \\ 0.1 \end{bmatrix}^T \tag{4}$$

Finally, the fuzzy signature structure will be:

$$x = \begin{bmatrix} 0.3 \\ 0.2 \\ 0.1 \end{bmatrix}^T \tag{5}$$

3 Mobil Robot Motion Control System

The differentially steered drive system used in many robots is essentially the same arrangement as that used in a wheelchair. Thus, steering the robot is just a matter of varying the speeds of the drive wheels. At least two independent driving chains are used in most of differentially steered drive system. Each driver wheel has the own controller in a traditional motion system, which give a hard tuned, rigid arrangement. In this paper we propose a complex lateral drift control method base on fuzzy signatures. This method inspects the motion system as a whole, unlike as simple parts of a complex system. The state space is written down by fuzzy signatures which add up flexibility, adaptability and learning ability to system.

3.1 Lateral Drift Control Method

We propose a motion control method which treats the robot locomotion as whole, without inspection of drive and other system separately. The base of this method is the lateral drift measure. Every sampling time the sensors collect information about the difference between the theoretical trajectory and the real trajectory or position as Fig. 2 shows. For the sake of simplicity let us assume that the followed lane is parallel with the x-axis and linear. The $e(T_1)$ is the measured error (lateral drift) on the T_1 sampling time.

Essentially, this implementation attempts to control a secondary effect, the overall locomotion behavior of the robot, rather than a primary effect (individual motor speed).

Theoretically the measured error and changing of the error (speed and direction) give enough information to control and correct the lane-following of the robot. We built fuzzy signature base control algorithms to cope this relatively complex control problem.

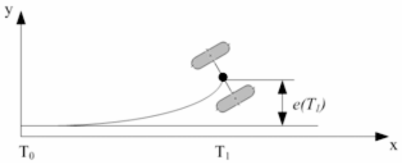

Fig. 2. Track of the robot on a Cartesian coordinate plane

3.2 Fuzzy Signature-Based Motion Control

In the lateral drift motion control method the controlled robot is a complex system which can be handled by fuzzy signatures based supervisory regulator [9]. The *reference* sub-tree (R_e) is the base of the controller, which depicts the state of the robot trajectory drift. Equation (6) and Fig. 4 show the scheme of fuzzy signature for R_e , where *e* is the measure of lateral error and *de/dt* is the velocity of error changing. A new branch appears on higher level: the Δe, the error changing between two sampling, signs the success of preview manipulation of controller. The Δe is very important for self-diagnosis and latter adaptation.

$$R_e = \begin{bmatrix} D \\ \Delta e \end{bmatrix} = \begin{bmatrix} \begin{bmatrix} e \\ \dfrac{de}{dt} \end{bmatrix} \\ \Delta e \end{bmatrix} \tag{6}$$

The used linguistic value in signatures are:

$$e = \begin{Bmatrix} \textit{Negative Big}, \textit{Negative Small}, \textit{Zero}, \\ \textit{Positive Small}, \textit{Positive Big} \end{Bmatrix}$$

$$\frac{de}{dt} = \begin{Bmatrix} \textit{Fast DownGrade}, \textit{DownGrade}, \textit{Zero}, \\ \textit{UpGrade}, \textit{Fast UpGrade} \end{Bmatrix}$$

$$\triangle e = \begin{Bmatrix} \textit{Negative Big}, \textit{Negative Small}, \textit{Zero}, \\ \textit{Positive Small}, \textit{Positive Big} \end{Bmatrix}$$

The above described fuzzy signature can build a basic reference for motion control. If we want use a more sophisticated system then the fuzzy signature is had to complement some new branches or sub-trees. This is a real advantage over classical control structure, where the whole system is had to change in this case.

Let us add a behavior sub-tree (B) to our system. Here the behavior means the control strategy of trajectory following. For example, if the following behavior is soft then the controller softly correct the lateral drift from theoretical trajectory (Fig. 3).

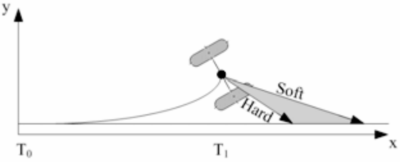

Fig. 3. Track correction behaviors

The motion control fuzzy signature complemented with controller behavior is the following:

$$C = \begin{bmatrix} R_e \\ B \end{bmatrix} = \begin{bmatrix} \begin{bmatrix} \begin{bmatrix} e \\ \frac{de}{dt} \end{bmatrix} \\ \Delta e \end{bmatrix} \\ B \end{bmatrix} \tag{7}$$

where the behavior is $B = \{\textit{Soft}, \textit{Moderate}, \textit{Hard}\}$.

The relationship between higher and lower level is govern by the set of fuzzy aggregations. The results of the parent signature at each level are computed from their branches with appropriate aggregation of their child signature. The fuzzy signature behavior is highly influenced by the chosen aggregations. In our case we use simple fuzzy aggregations, on lowest or leaf level *max*, on the second and third level *average* and on the highest level the *production* aggregation methods are used.

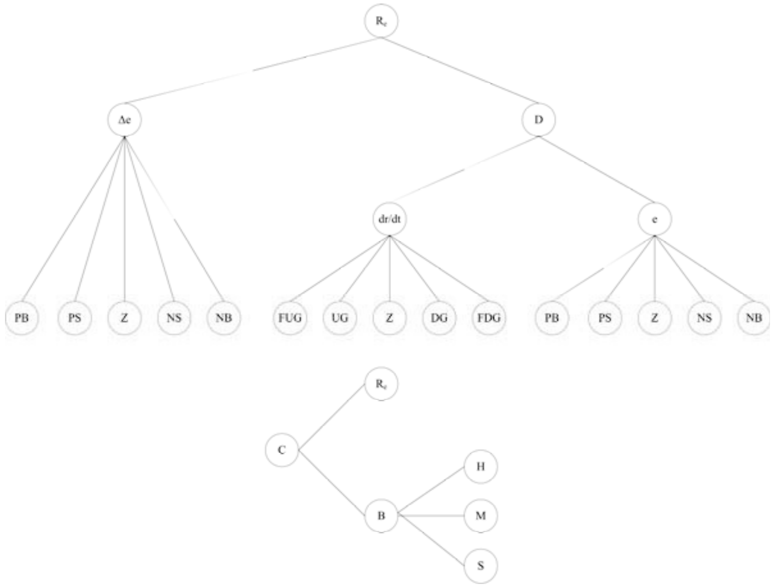

Fig. 4. R_e and the final C fuzzy signatures

This fuzzy signature writes down the state of the robot locomotion in every sampling time and makes a reference signal for control decision. The controller can work with a very simple fuzzy rule base because the fuzzy signature prepares the data for it.

Let us take an example with linguistic values and numerical signatures:

$$C_1 = \begin{bmatrix} \begin{bmatrix} \begin{bmatrix} \textit{Negative Big} \\ \textit{UpGrade} \end{bmatrix} \\ \textit{Positive Small} \end{bmatrix} \\ \textit{Moderate} \end{bmatrix} \rightarrow \begin{bmatrix} \begin{bmatrix} \begin{bmatrix} 0.1 \\ 0.6 \end{bmatrix} \\ 0.7 \end{bmatrix} \\ 0.5 \end{bmatrix} \tag{8}$$

After the low level aggregation the higher level will be described as:

$$C_1 = \begin{bmatrix} \begin{bmatrix} 0.3 \\ 0.7 \end{bmatrix} \\ 0.5 \end{bmatrix} \tag{9}$$

Finally, the fuzzy signature structure will be:

$$C_1 = \begin{bmatrix} 0.5 \\ 0.5 \end{bmatrix} \rightarrow \begin{bmatrix} 0.25 \end{bmatrix} \tag{10}$$

Therefore the C_1 control parameter is *Negative Small*, and the manipulation is taken according to this state and behavior fuzzy signature, the robot tend to go back to track with moderate characteristic.

4 Fuzzy Communication of Cooperating Robots

One of the most important parameters of effective cooperation is efficient communication. Because communication itself very expensive, it is much more advisable to build up as large as possible contextual knowledge bases and codebooks in robot controllers in order to shorten their communication process. That is, if it essentially reduces the amount of information that must be transmitted from one to another, than to concentrate all contextual knowledge in one of them and then to export its respective parts whenever they are needed in other robot(s). It appears to be very important in the cooperation and communication of intelligent robots or physical agents that the information exchange among them is as effective and compressed as possible [4].

4.1 The System in Hand

Let us examine a subset of our overall robot cooperation problem work in practice. There is a warehouse where some square boxes wait for ordering. Various configurations can be made from them, based on their color and tags. We have a group of autonomous intelligent robots which try to build the actual order of boxes according to the exact instructions given to the R_0 (foreman) robot. The other robots have no direct communication links with R_0, but they are able to observe the behavior of R_0 and all others, and they all posses the same codebook containing the base rules of storage box ordering. Every box has an identity color and tag on one side of it. The individual boxes can be shifted or rotated, but always two robots are needed for actually moving a box, as they are heavy. If two robots are pushing the box in parallel the box will be shifted according the joint forces of the robots. If the two robots are pushing in opposite directions positioned at the diagonally opposite ends, the box will turn around the center of gravity. If two robots are pushing in parallel, and one is pushing in the opposite direction, the box will not move or rotate, just like when only a single robot pushes. Under these conditions the task can be solved, if all robots are provided with suitable algorithms that enable intention guessing from the actual movements and positions, even though they might be unambiguous.

Fig. 5 presents some example of how eleven boxes can be arranged. The robots would move or push the boxes, so one box has max two neighbors on their opposite sides. The tag of the box, which is always on the Relative-North side of the box (as we will see below), must be visible (so do not adjoin any other object), so the box can touch others only the East or/and West sides.

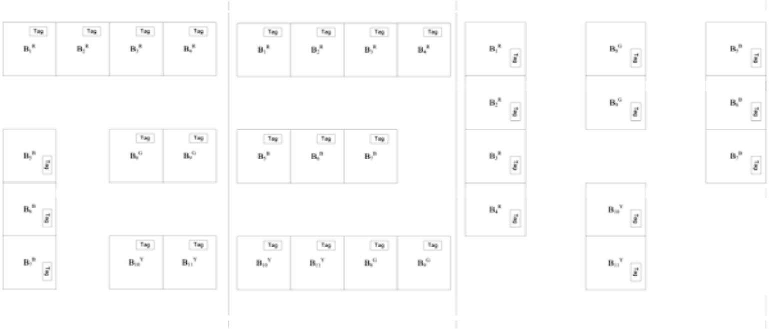

Fig. 5. Examples for box arrangement

In the description two direction sign systems are used, the absolute direction with letters N, E, S, W as in the usual sense for North, East, South and West. The second direction sign system is a box relative system where the sides of a box are N_B, E_B, S_B and W_B respectively (Fig. 6). The position of the objects (boxes and robots in this case) always can be described by the absolute course, latitude and longitude of the object. One object relative position to a box is described by the box relative system, i.e. which side of the box is touched by that object.

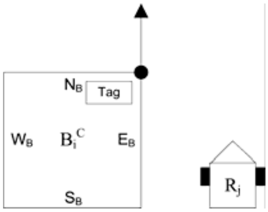

Fig. 6. Symbols of boxes and robots

The box has a B^c_i sign which means that is the i^{th} Box with C color (e.g.: R for red). Fig. 3 depicts the features of a box and robot. The R_j is the sign of the j^{th} robot. The R_0 is a distinct one, namely it is the robot foreman, the only robot that exactly knows the task on hand.

There are just a few essentially different robot positions allowed. Because two robots are needed for pushing or turning a box, at each side of the boxes, two spaces are available for the robots manipulating them: the "counterclockwise position" and the "clockwise position" (see Fig. 7). The position is described by

$P_r^b = [S, T]$ where r is the number of the robot, b is the number of the box, S is the side of the box where the robot touch it (N_B, E_B, S_B and W_B respectively) and the T is the turning position that means "counterclockwise position" or "clockwise position" (CC or CW).

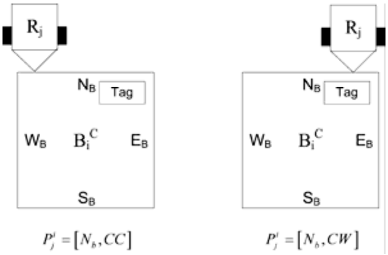

Fig. 7. Robot positions at the N_B side of the box

The cooperating combination of robots is denoted by $C_{i,j,(k)}^b$ where *i, j* and *k* is the number of the robots (*k* appears only in stopping combinations), and *b* is the number of the box. There are three essentially different combinations (Fig. 8), $C_{1,2}^i = P$ is the "pushing or shifting combination", when two robots (R_1 and R_2) are side by side at the same side of the table; $C_{1,2}^i = RC$ stands for "counterclockwise rotation combination"; and $C_{1,2}^i = RW$ denotes "clockwise rotation combination". In the first case R_1 and R_2 are in the relative North (N_B) position, in the other two, North (N_B) and South (S_B). Of course, all the other three directions are similarly allowed. Any other combination of two robots is illegal, except see the next paragraph ("stopping combination"). The three essentially different combinations can be seen in Fig. 8.

Eventually, in Fig. 9, the combinations are shown where two robots intend to do a move operation (shift or rotate), and another robot that has recognized the goal box configuration positions itself to prevent a certain move. $C_{1,2,3}^i = ST$ is essentially a three robot combination, where either R_1 and R_2 are attempting a shift and R_3 positions itself to prevent it, or R_2 and R_3 / R_1 and R_3 are starting a rotation and R_1 and R_2 prevent it, knowing that the intended move is wrong from the point of view of the goal configuration.

However, in $C_{1,2,3}^i = ST$ it is sufficient that R_1 takes up its $P_1^i = [N_B, CC]$ position if R_3 is aware that both the shift and the rotate counterclockwise combinations would be wrong from the point of view of the goal, thus R_3 immediately stops the maneuver by assuming the $P_3^i = [S_B, CW]$ position, thus preventing both shift and clockwise rotation.

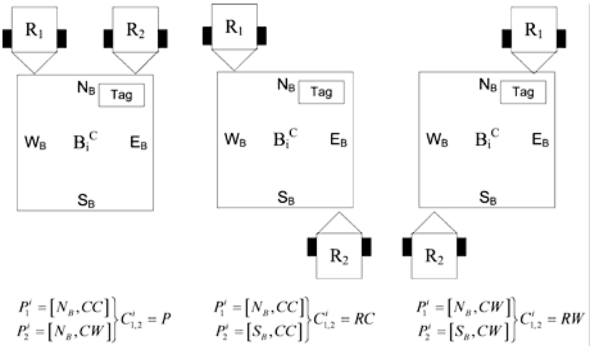

Fig. 8. Allowed combinations of two robots for moving the table

This is an exception where a two robot combination other than the ones listed in Fig. 8 is legal as a temporary combination, clearly signalizing "stop this attempt as it is in contrary to the goal". A symmetrical pair of the three robot combination but for stopping shift to the South or a counterclockwise rotation can be seen in the second part of Fig. 9.

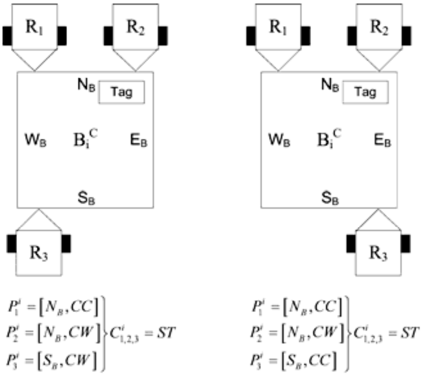

Fig. 9. Three and two robot stopping configurations

4.1.1 Fuzzy Signature Classes

On basis of the features of the boxes the robot can build a fuzzy signature for each box. This signature built up on a template or class, and every box has its own instance of the Box fuzzy Signature Class (BSC). This signature records the position, the arrangement, the dynamic and the robots working on the actually box. Let us see the construction of this fuzzy signature class. As can be seen in Eq. (11), the main signature has three sub-signatures.

$$B_i^c = \begin{bmatrix} P \\ AR \\ DY \end{bmatrix} \tag{11}$$

The first is the position (*P*) sub-signature which describes the actual fuzzy position of the box (e.g.: Nearly North). It has four leaves namely the points of the compass, North, East, South and West. The box is "in direction" if its reference side lays near to any main compass direction (Fig. 10).

It is important that the real position of a box has two other parameters: the latitude and the longitude of its reference point, but it does not have any importance to decision making only in navigation, so we abandon these parameters here.

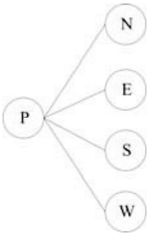

Fig. 10. Box position fuzzy signature

The second branch of box fuzzy signature is the arrangement that describes the box's connections to other boxes. As it was described above, a box can connect to none, one or two other boxes. Therefore the signature has two main branches for the no connection case, and for the connected case, which has two other branches for connect to one, connect to two boxes. The leaves describe the side of connection. As we see this signature we can observe that there are some surprising permitted connect positions in it (e.g.: North or tag side). These are very useful for decision making about wrong positions and wrong dynamic of the box. Fig. 11 presents the arrangement signature (*AR*) where *AL* is the "alone" (no connection) branch, *NB* are the neighbor boxes: one or two and the direction of the join.

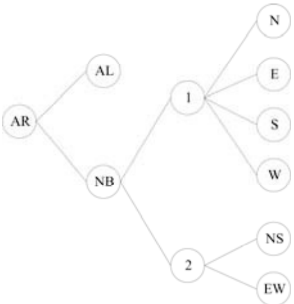

Fig. 11. Box arrangement fuzzy signature

The next branch is the dynamic feature (*DY*) of the box, which is valid if robots work on the box and records what the robots are doing: push or rotate, and in which direction. This signature includes all the valid combinations of robots, and all valid movements of boxes. This is shown in Fig. 12, with the number of robots at a box (*1R, 2R, 3R* respectively), the effect of this combination of robots (*SH* as shift and *R* as rotate) and the direction.

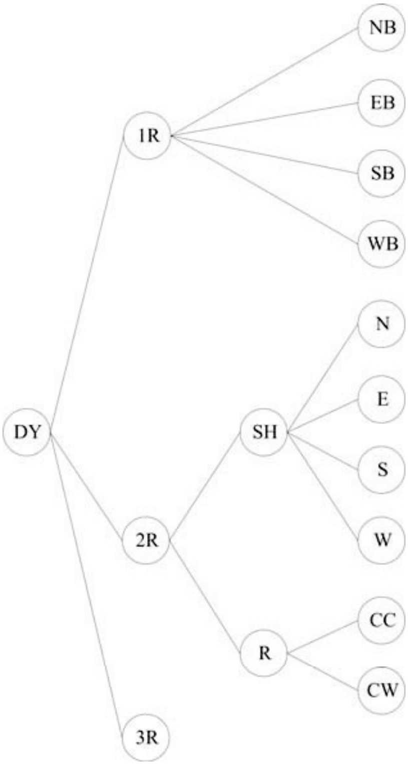

Fig. 12. Dynamic fuzzy signature

These three output fuzzy signatures are able to describe the actual states of the box and give a basis for the fuzzy decision process in the robot control. Every robot builds its actual knowledge-base from the fuzzy signature classes and then boxes are assigned individual signatures in each individual robot controller.

The second necessary fuzzy signature class is the Robot state fuzzy Signature Class (RSC), which describes the state of each robot. This represents the dynamic and working behavior of the robot. In this paper we do not consider the robot signatures in detail because they do not have an important role in the primary decision making.

4.1.2 Fuzzy Decision

The above described fuzzy signatures enable robots to recognize a situation in the warehouse, and then the robots use their codebooks to take action accordingly. Let us see the codebook, namely a hidden fuzzy decision tree, in the robot controller. For simplicity we have cut the decision tree to sub-trees, then arranged them in a logical sequence. The robot takes decisions from some simple cases to more complex ones. The Fig. 13 shows the entry point of the decision process. This figure depicts the steps of decision making based on fuzzy signatures, where the diamond shaped objects denote the elementary decisions (decision milestones) and hide the fuzzy signatures that are used. The used and hidden signatures are presented by a grey arrow with the signature name.

It is important to mention here this is only a local task and the final decision making needs the global signatures and other robot signatures, but these are beyond the scope of this paper. The first step in the local decision is to search for the nearest box, after which the box signature is built up or updated. In the next level, the position of the box is investigated which is described by the *P* signature. If the membership value of any good direction (N, E, S or W) is high enough, then the decision process steps to the next level and takes the arrangement (*AR*) and dynamic (*DY*) signatures of the box, if not then there is a simple decision: the box must rotate. Which direction? This is dependent on the global state of system, which is described by global signatures.

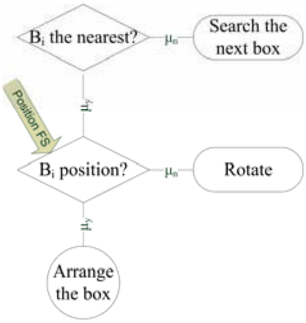

Fig. 13. Entry point of decision task

The arrangement and dynamic signatures are used in a partially parallel way. Fig. 14 shows the whole decision task from this point. The robot analyzes the arrangement and dynamic of the box. If three robots work on it then there is a Stop combination and our robot (R_i) does not have any task on this box, it must search the next box. If two robots work on it and the guessed result points to higher order then R_i leaves it and searches the next near box. If the box has one or two neighbors in a good combination then the membership degree of “on the place” is raised and any dynamic (shift or rotate) is forbidden so if there any robot combination the R_i should go to the Stop position. Of course, if the neighbors of the box are not in a good place then more analysis is necessary to take the appropriate decision. If one robot waits for help there, then R_i decides which is a good position for pushing or turning the box and goes to this position. The most complex decision problem appears when any robot is not at the box; in this case R_i needs to take a decision about the box alone. This higher level problem is not covered in this paper.

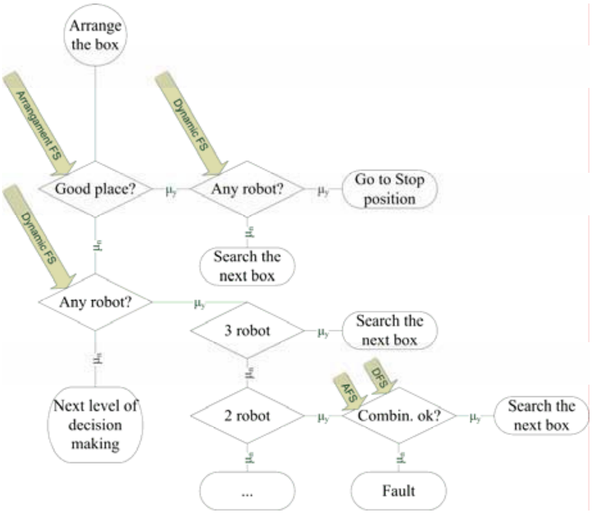

Fig. 14. The decision task

Based on the above considerations it is possible to build some elements of the context and codebook for cooperating robots. It takes the form of a decision tree, where the inputs are the fuzzy signatures of the observations, the first level outputs are intention guesses and the second level outputs the concrete actions of the corresponding robot.

5 Future Works

Research towards extending this fuzzy communication method to more complex robot cooperation is going on currently. We will build further algorithms for fuzzy communication which will be tested and developed in a simulation environment.

We have some micro-sized autonomous mobile robots as Fig. 15 shows. These robots can move, avoid collision and perform the simple shifting tasks of the nature we describe in this paper in a well-defined environment. At the next stage these robots will be used as a real cooperating system. In other works we are investigating scenarios in which the foreman is directly controlled by a human (in a game-like environment, this is effectively a human controlled agent), in particular extending the use of eye gaze to allow the assistant robots to better predict human intentions [2].

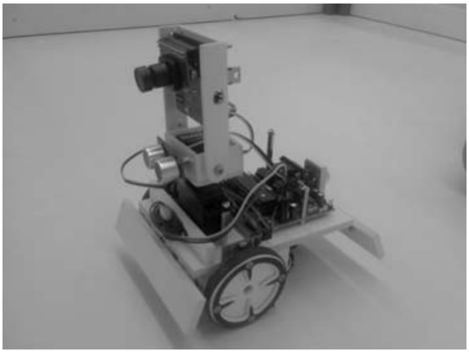

Fig. 15. The B-bot Micro

6 Conclusions

In this paper we presented the usage of fuzzy signature based algorithms on field of mobile robotics. These methods were used in totally other level of robot control. The motion control stays the lower layer of control hierarchy than the cooperation system which is a high level strategy control algorithm. We could see the applicability of fuzzy signatures on these two layers of mobile robot control.

We experimented with a new fuzzy signature based motion control system for a differentially driven mobile robot, which gives more flexibility and modularity on the control level with less computational complexity.

Fuzzy communication contains vague or imprecise components and it might lack abundant information. If two robots are communicating by a fuzzy channel, it is necessary that both ends possess an identical part within the codebook. The codebook might partly consist of common knowledge but it usually requires a context dependent part that is learned by communicating. Possibly it is continuously adapting to the input information. If such a codebook is not available or it contains too imprecise information, the information to be transmitted might be too much distorted and might lead to misunderstanding, misinterpretation and serious damage. If however the quality of the available codebook is satisfactory, the communication will be efficient i.e. the original contents of the message can be reconstructed. At the same time it is cost effective, as fuzzy communication is compressed as compared to traditional communication. This advantage can be deployed in many areas of engineering, especially where the use of the communication channels is expensive in some sense, or where there is no proper communication channel available at all.

Here we illustrate clearly that the communication among intelligent robots by intention guessing and fuzzy evaluation of the situation might lead to effective cooperation and the achievement of tasks that cannot be done without collaboration and communication.

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