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BULANIK MANTIK KULLANILARAK HAREKET YAKALAMA TEKNOLOJİSİ İLE YAKALANAN GÜLEN MİMİK MODELLEME

MODELING OF LAUGHING MIMIC CAUGHT WITH MOTION CAPTURE TECHNOLOGY USING FUZZY LOGIC

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ÖZET

Bu makale, bulanık mantık kullanarak modellemenin gerekliliğini açıklar ve bir gülümsemeyi dijital dünyaya aktarırken en gerçekçi sonuca ulaşılabilmesi için bulanık bir çıkarım modeli oluşturur. Böylece, gülümsemenin en doğru temsilinin oluşturulmasını sağlar. "Hareket yakalama teknolojisi" terimi, tüm insan hareketini dijital alana iletmek için kullanılan teknolojiyi ifade eder. Öte yandan, bu teknolojinin gerçek sonuçlarını elde etmek için kullanılan program dilinde doğruluğu gösteren sayısal veriler kullanılmaktadır. Gerçekliğin tek başına bir bilgisayarın hareket yakalama ile elde edilen bir gülümsemeyi doğru bir şekilde anlaması için yetersiz olduğu gösterilmiştir. Bu araştırmada tartışılan ilk şey bulanık mantık, ardından hareket yakalama, dijital hareket yakalama teknolojisi ve son olarak insan yüzü kaslarıdır. Bulanık mantık teorisinin sorun çözmenin gelişimine yaptığı katkılardan bahsedilmiştir. Daha sonra yüz kaslarından başlayarak dört ana kas, bulanık bir görünüme sahip olacak şekilde grafikler kullanılarak tasarlandı. Sonuç olarak, bulanık mantık teorisinin çözüme yaptığı katkının tartışılması aşağıdadır.

Anahtar Kelimeler: Bulanık Mantık, Hareket Yakalama, Gülümseme, Bilgisayar, Simülasyon, MoCap

ABSTRACT
This article explains the requirement of modeling using fuzzy logic and creates a blurred inference model so that the most realistic result can be reached when transferring a smile to a digital world. This allows for the most accurate representation of the smile to be generated. The term "motion capture technology" refers to the technology that is used in order to transmit the whole of human motion into the digital realm. On the other hand, numerical data that indicates accuracy is employed in the program language that is used in order to achieve the real outcomes of this technology. It has been shown that realism alone is insufficient for a computer to correctly understand a grin that was acquired by motion capture. In this research, the first thing that is discussed is fuzzy logic, followed by motion capture, digital motion capture technology, and finally human face muscles. The contributions that fuzzy logic theory makes to the improvement of issue solving are talked about. Then, beginning with the face muscles, the four primary muscles were designed using graphics so that they had a fuzzy appearance. In conclusion, a discussion of the contribution that the fuzzy logic theory has made to the solution follows.
Keywords: Fuzzy Logic, Motion Capture, Smile, Computer, Simulation, MoCap

1. INTRODUCTION
The technique of digitally capturing and recoding the motions of objects or living beings in space is referred to as motion capture (MoCap for short). The ability to record motion has been realized via the development of a variety of technologies and methods. Triangulating the position of retroreflective rigid bodies that are connected to the subject being targeted may be accomplished with the help of camera-based systems equipped with infrared (IR) cameras, for instance. When projecting light towards an object, depth-sensitive cameras are able to determine its depth based on the amount of time that passes between the light emission and the detection of the backscattered light. There are other tracking systems that can monitor the relative motion of articulated structures. These systems may be based on inertial sensors, electromagnetic fields, or potentiometers. Hybrid systems integrate many distinct MoCap technologies in order to increase accuracy and cut down on the number of instances in which a camera is obscured. Research has also focused on the management and processing of high-dimensional data sets using a variety of analytical methods, such as machine learning, Kalman filters, hierarchical clustering, and many others.
In this specific research study, fuzzy logic is used in conjunction with face capture to imitate a grin. Face capture is one of the fundamental components of a motion capture system. After that, the findings produced were compared to the ones obtained by applying traditional reasoning. In the beginning part, you will find different discussions covering topics such as fuzzy logic, motion capture, and face muscles. The modeling process is described further under the heading for the fuzziness of the grin. The option to give the grin a fuzzy appearance may be found in the graphics and rules menus.

2. Fuzzy Logic
It is a successful approach that does not indicate certainty, does not draw a distinct line of limits, and delivers the most accurate response and answer simulation between solutions and outcomes. This method is known as "fuzzy logic". Fuzzy logic is a successful way that does not specify certainty. The reasoning for this is as follows: the intermediate values are much greater than the net values. By using these values, we are able to eliminate uncertainty and arrive at the solution to the issue by employing logical metrics such as a little, very, very little, and too much (Perry, 1995). Lotfi A. Zadeh is credited as being the first person to present the idea of fuzzy logic (Zadeh, 1965).
In Zadeh's article, he specified the theorem rules as follows:

- There is no certainty in fuzzy logic. There are interim results.
- Numerical data in Fuzzy Logic uses linguistic expressions when it comes to command.

- In Fuzzy Logic, the data range is often evaluated in the range of (0,1).

-In Fuzzy Logic, the connection between linguistic expressions and lexical connections is established. This demonstrates the functionality of the bond.

-Today, all systems made by computer processes can be used with Fuzzy Logic.

The first industrial use of Fuzzy Logic was in 1987 in the metropolitan city of Sendai in Japan (Perry, 1995). In 1988, with the support of Japanese engineers, the Laboratory for International Fuzzy Engineering (LIFE) was established. A total of 48 companies are cooperating in research and development under this structure.

Japanese products with an integrated Fuzzy Logic system include: cleaning brooms, dishwashers, and washing machines. An example of a technologist who uses this technology is the Canon company that integrates this technology into photographic machines (Rathore, 2004). Twenty-five different air conditioners have included the Fuzzy Logic control mechanism (Mendel, 2017). In modern times, the theorem has found a lot of use in robotics. It is commonly used in systems such as those utilized in sound-controlled helicopters, equipment for monitoring heart beats and blood pressure, and systems such as those utilized in elevators.

There are examples of use of the fuzzy system outside Japan,

- used in environmentally friendly automobile engines (Dionova *et al.*, 2020).
- used in automatic landing systems and under control of fuel consumption controls (Carbajal-Hernández *et al.*, 2012).
- Boeing (Committee, 1998), General Motors, Allen-Bradley, Chrysler, Eaton, and Whirlpool benefited from the Fuzzy Logic system in energy-saving vehicles with low power consumption engines (Zhou *et al.*, 1996).
- In 1995, Maytag recognized the smart dishwasher. Fuzzy control was used in this machine (Baker, 1995).
- In the Honda transmission systems, a learning fuzzy control which can adjust itself according to the usage of the driver has been used (Perry, 1995).

3. Motion Capture

With the development of technology in recent years, virtual reality and work on the mimicry of this reality has increased. However, when studies on 3D design are combined with virtual reality, a structure that can not be predicted comes to the fore. One of the advantages that these developments bring to the cinema is the motion capture technology. With this technology, it is now much easier to capture every minute of every move and integrate them into virtual environments.

Motion Capture (MoCap) is a software and hardware system that converts human, animal, and inanimate objects into 3D data. The obtained information is used to give motion to the three-dimensional models in order to perform the motion study. Today, MoCap technology is used a lot in the army and in the field of computer-aided image processing, especially when it comes to health. The first breakthrough in this area was taken by Eadweard Muybridge (1830–1904), a popular English photographer. His first work was that he could not make a study of himself as if a horse had four feet in the air. Muybridge proved that the horse could be in the air on four legs at the moment of running (Latsis, 2015). This is accomplished by recording all the movements of a horse with multiple cameras. Muybridge's first vehicle was a tool called the zoopraxiscope. The purpose of this tool was to sort the pictures taken with different cameras in succession. Zoopraxiscope is the first model of moving picture tools. Muybridge has published two very important books with this technology developed. These are Animals in Motion (1899) and The Human Figures in Motion (1901). Inspired by Muybridge's work, a physiologist named Etienne-Jules Marey designed an advanced camera to record moving picture frames as a film. In the camera shots he designed for Marey's first run, the subject wore a similar outfit of motion capture clothing.

In the years since, an American engineer named Harold Edgerton has developed the vehicle, as well as the stroboscope and the ability to freeze objects (Pastukhov, Vivian-Griffiths and Braun, 2015).
The development of digital MoCap technology has started in the military and health fields since 1970. After 1980, this technology was noticed in terms of computer-aided design. As a result of these advancements, the first 3D animation software, known as Wavefront Tech, was developed in 1985 by the first study to make use of motion capture technology. This research, known as "Brilliance," was made by Robert Abel in 1985 and was intended for use in the Super Bowl. The subject female model is completely painted with cypresses, with 18 points in all joints. Its first use in cinema was in 1990 with "Total Recall". However, due to technical problems, MoCap did not give a successful result. Later, in 1995, this technology was used in the "FX Fighter" and successful results were obtained. The use of this technology on this side has encouraged other companies. After 1990, this technology began to be used in many areas. In the field of sports, it is used to analyze and investigate athlete performance and disability; in the field of design, it is used to understand communication with the moving environment and produce better products; engineers do not associate human movements with robot movements; and trainers conduct research using the performances of actors and dancers (Klaassen *et al.*, 2015).

3.1. Types of MoCap

Today, MoCap systems are divided into 3 groups: optical systems, magnetic systems, and mechanical systems. Each system has its own advantages and disadvantages.

3.1.a. Optical MoCap System

The main purpose of this system is to be used in the health field. The first device to use this system is the Vicon 8 module (Sato and Cohen, 2010). The number of cameras used in this system is between 4 and 32. Vehicles marked for the object to be captured are used. These tools are two-sided; there are passive ones and active ones. The difference between them is whether they are reflective or not. Passive vehicles are made of reflective materials and come in three shapes: sphere, hemisphere, and circle. Their size depends on the resolution of the camera and the size of the object to be captured. In this system, the cameras can capture an average of 30 to 2000 frames per second. At least two cameras must be used on the stage. 3 cameras and more provide the correct shooting for the scene. The maximum usage is 200 signs and 16 cameras. One of the biggest improvements that the system provides is the ability to capture the movement of more than one player at the same time (Sato and Cohen, 2010).
The Vicon IQ system reference talks about the good and bad things about this system.
The advantages of this system are:

- The optical information is high.
- The catch rate gives good quality results.
- Multiple movements are recorded easily.
- The number of signals is not a problem.
- The areas where the signs are placed can easily be changed.
- The skeleton structure of the player can be shaped according to the obtained information.

Cons;

- Processing of the acquired data takes a long time.
- It needs powerful computer systems.
- If the marks on the player cross each other, it causes data loss.
- Control of ambient light is very important. Especially in passive systems.
- The chance of watching real-time data is limited.
- Hardware tools are very expensive.

3.1.b. Magnetic MoCap System

This system, called electromagnetism, works with magnetic trackers. The first areas of use began by monitoring the pilots' movements with the vehicles placed on the helmets of military aircraft pilots. The number of sensors on it varies between 12 and 20. It gives real-time results compared to the other systems. The material of the sensors used consists of metallic parts. Naturally, high concentrations of metals are used in buildings and environments, leading to inaccurate analysis results. Since the sensors used require batteries and energy, they must be recharged within a certain time interval.

The magnetic system is divided into two according to its usage area. One of them is a DC magnetic field and the other is an AC magnetic field. The AC system is aluminum, and the pedestal is susceptible. The DC system is iron and steel. The magnetic system has 144 to 240 images per second. It can capture fewer frames than optical systems and it works louder. But the cost-to-benefit ratio is much lower (Kitagawa and Windsor, 2008).

The advantages and disadvantages of this system are mentioned in MoCap for Artists: Workflow and Techniques.

The advantages of this system are:

- The location and position of the sensors can be easily changed.
- Real-time motion tracking can be done.
- Sensors are manufactured from metal parts.
- More than one person and group movement can be recorded.
- Cost is lower than optical systems.

Cons;

- Sensors have a magnetic and electrically charged interface.
- The range of motion is limited due to the short cable connections between the sensors and battery life.
- The number of frames the magnetic sensors record at the moment is lower than the optical systems.
- The motion sensors are difficult to configure.
- According to optical systems, the data space recorded by the magnetic system is less.

3.1.c. Mechanical MoCap System

The sensors that are implanted in the player's joints may be used to control the mechanical MoCap devices. A comparison may be made between this structure and the skeletal system. According to certain other MoCap systems, additional items like gloves are employed. (Mihcin *et al.*, 2021) Real-time operation is possible for mechanical systems. The expenses of the hardware are lower. There is neither a magnetic nor an electrical structure present in it. The fact that it can be carried about easily is the single most valuable characteristic. The fact that the technology is unable to deliver consistent results while the feet are in the air is the most significant shortcoming of the device. If the player is bouncing about, the system will not be able to identify it, and the player will be required to display the position once again. Only by including magnetic sensors into this system will this problem be able to be fixed.

Another limitation that restricts the player's movements is that the players placed in the joints of the player are sensitive to the player's ability to move and to break (Ling *et al.*, 2020).

The advantages and disadvantages of this system are mentioned in Motion Capture Fundamentals.

The advantages of this system are:

- Real-time results.
- Cost is lower than other systems.
- There is no blockage in the system.
- The magnetic sensors do not use electric sensors.

- Easy to carry.
- Has a large image capture area.

Cons;

- It does not give correct results on a global scale.
- The movement restricts the movement of the player and the observer.
- It has sensors that can break easily.
- It takes time to adjust the sensor settings.
- Can record at low frames per second.

In the NRC report "Modeling and Simulation-Linking Entertainment and Defense" published in 1997, it is predicted how difficult it is to imitate virtual reality with the methods and technologies of that period, but on the other hand, it is predicted that this will lead to more inviolable, more realistic, and more successful results in the future (Zyda, 2005).

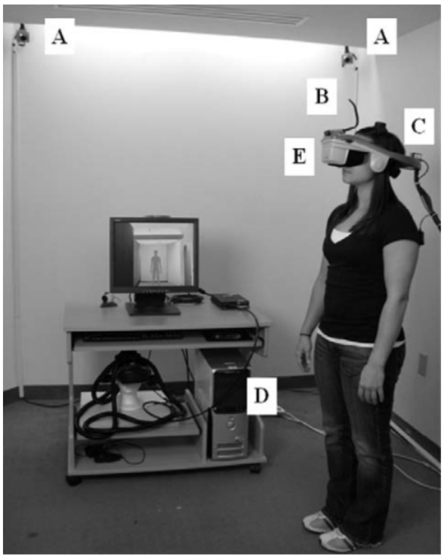

Figure 1. Sample virtual reality hardware components (A) optical sensor, (B) the position of the player in the room, (C) speedometer, (D) processing of the player's head movements as data and transferring them to the computer, (E) size field (Fox, Arena and Bailenson, 2009)

In today's cinema, with the use of these developing technologies, thanks to the increased sense of reality, all the scenes that are impossible on the white screen can be animated by the virtual heroes. In this respect, cinema and the visual arts have reached a different dimension. Along with the technological innovations that have evolved, not only the moving computer but also the transfer of the same quality shows the technological point where the cinema has come to today.
Motion capture (MoCap) is a system that moves moving objects into the computer environment by matching them to the point of origin. Although it is used mostly in the military, entertainment, and sports fields, it is also integrated into cinema and game productions today. The movements of the human actors are used in the transition phase of digital characters in 2D and 3D. This transition has 3 distinct structures. face, fingers, and areas to be caught.

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Figure 2. Motion Capture Process (Perales, 2001)

The motion capture system has many advantages over traditional animation. The most important ones are: (Pfeifer and Relancio, 2022).

- Low latency, nearest shots, easy optimization of captured data. Very little data can be captured in a short time.
- Depending on the quality of the data obtained and the quality of the human actor, much better results can be obtained.
- Even the hardest movements to capture can be recorded easily and transferred to the computer very quickly.
- Providing free support as software significantly reduces the cost of the production run.

Figure 3. Motion Capture Process (Sharma and Sharma, 2013)

In this work, a smile is simulated with fuzzy logic through face capture, which is one of the most basic features of motion capture structure. Face capture is the whole process that allows the person to capture the facial movements and mimics through the cameras, transfer them to the electronic center, and re-process them on the computer. It is feasible to capture the greatest quality detail on any sort of platform, whether it is real or 3D, as long as it enables you to blend genuine face motions into the structure. This is true whether the platform is actual or 3D.

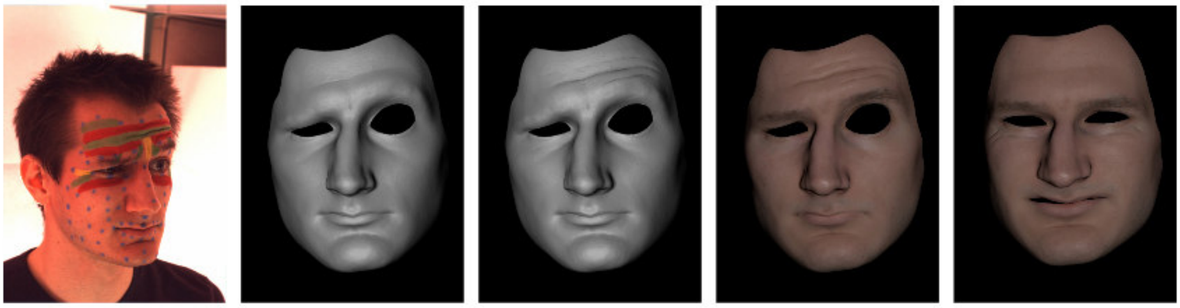

Figure 4. Face Capture Workflow (Bickel *et al.*, 2007)

Each point placed on the surface is used to easily match the mimes between the real actor and the virtual actor. There are a total of 43 muscles in the human face. In this study, these 17 subjects were gathered under 4 main structures and their state of smile of these 4 muscles on face control was simulated with fuzzy logic (Smith, 2003).
Orbicularis oris, risorius, depressor anguli oris, zygomaticus, and the short book of muscles (Skipper, 2003).

3.2. Muscle Types

3.2.a. Orbicularis Oris

It is the greatest convention of movement within the facial muscles in structure. It can handle complex forms with opening and closing. It covers the entire periphery of the dewar at the top and bottom. Orbicularis oris is not formed by a single muscle tissue. More than one partition is allocated. This includes the outer, red lip, and portions. The direction of movement of the muscles is from left to right and from right to left. The structure of the muscles moves from four different spots, which results in a mimic being formed on the surface of the mouth. In addition to the role that Orbicularis oris plays in laughing, rage, aggressiveness, ambition, and other related emotions ('Human anatomy for artists: the elements of form', 1992).

3.2.b. Risorius

The name given to the case is a box extending from the cheeks toward the mouth. There are people on both sides of your face. It works in forward and backward motion. The weak point is that you can not stretch as much as this muscle during conversation. It is one of the most important muscles in general. Risorius' greatest contribution to mimicry is to make the smile action happen ('Human anatomy for artists: the elements of form', 1992).

3.2.c. Depressor Anguli Oris

In the lower region of the dusk, the face is located on both sides of the opposite. Depressor anguli oris comes from two different intentional channels. It shows the greatest effect on the mimics of sadness. Apart from that, grief, depression, and disgust are also seen in the mimics ('Human anatomy for artists: the elements of form', 1992).

3.2.d. Zygomaticus

The zygomatic stands on the surface of the bone on the exterior of the skull. The muscles of the anguli oris operate along with those of the risorius and depressor. It travels in a left-to-right, upward, and downward direction. It is one hundred times longer than any of the other muscles. Zygomaticus is the mimic with the maximum activity ('Human anatomy for artists: the elements of form', 1992).

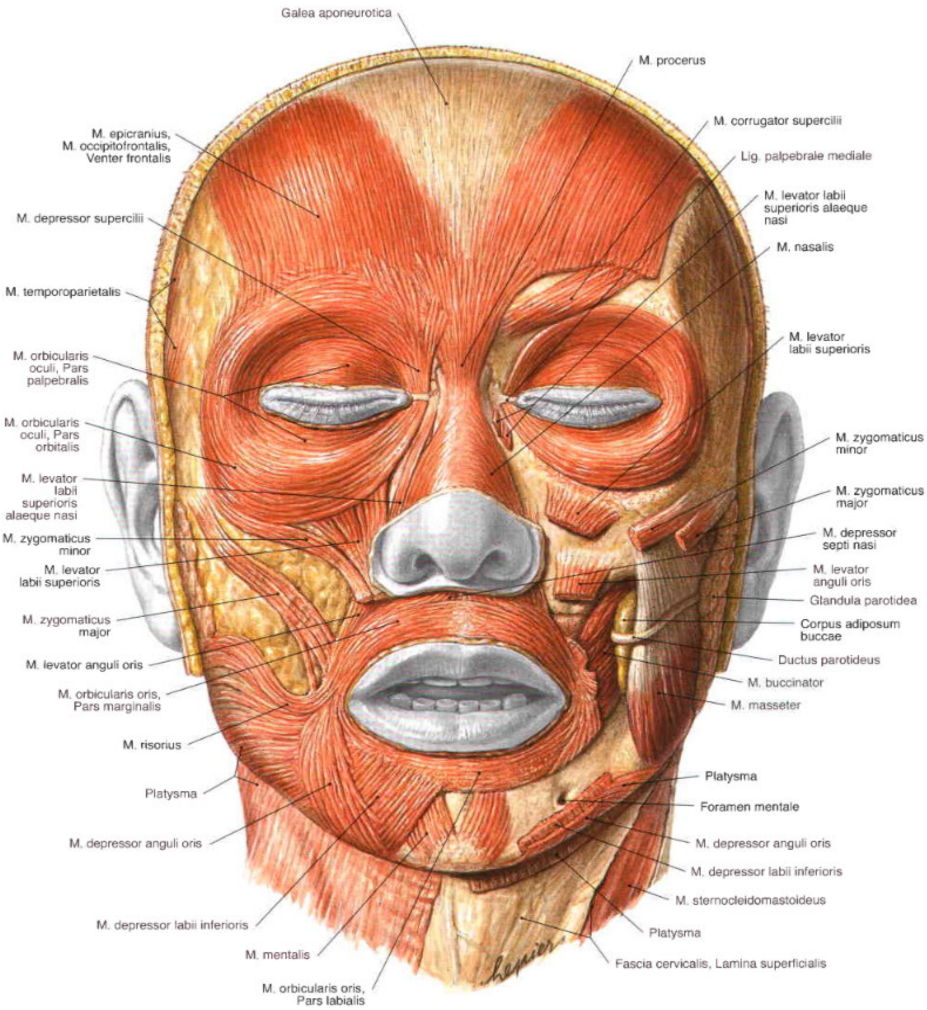

Figure 5. Facial Muscle System (Paulsen.J, 2010)

It has been determined that these 4 motion points are moving and stretched along a natural line ('The handy psychology answer book', 2011). These structures are;

- Orbicularis oris
- Risorius
- Depressor anguli oris
- Zygomaticus

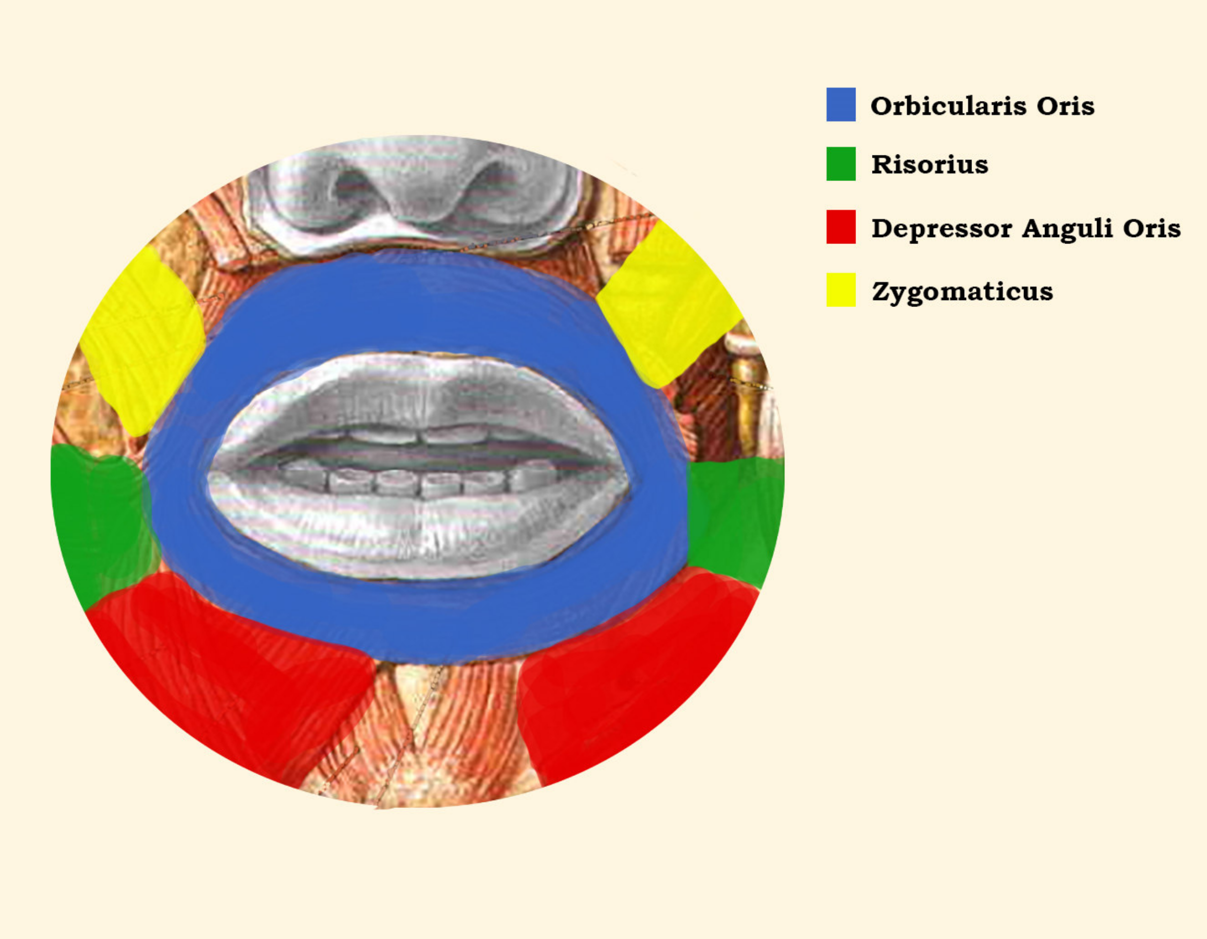

Figure 6. Four Points of View on Face (Paulsen.J, 2010).

The movements of the facial muscles in this area were taken from the book "Anatomy of Movement" (Kerr, 1997).
The facial muscles (mimic muscles) are the muscles that connect the facial parts of the face and neck from the skin layers and allow facial movements to occur. All facial muscles are underpowered by N. facialis, the 7th cranial nerve.
The M. epicranius part that actually moves the head skin is actually M. occipitofrontalis + M. temporoparietalis comes in two intentional channels. M. occipitofrontalis starts from the occiput at the back and extends to the forehead, while M. temporoparietalis starts at the top of the ear and ends at the galea aponeurotica. The two muscle parts also connect to the aponeurosis connective tissue and cover the skull. The leading part of Epicranius is to lift the eyebrows upward and wrinkle the forehead horizontally.
M. auricularis posterior, anterior, and superior muscles wrap around the ear and move the ear forward, backward, and upwards.
In facial expressions, M. orbicularis oculi comes to the delusion of 3 parts to provide the cover of the eye. The M. corrugator is located deep in the median half of the M. orbicularis oculi in the median half of the eyebrows, bringing the eyebrows closer together when contracted. The M. depressor, located on the medial side of the M. corrugator supercilii, pulls down the inside of the brow.
From the muscles around the nose, M. procerus is a small pyramid, and when it contracts it brings wrinkles to the nose root. The M. nasalis comes in two parts intentionally and is responsible for opening and closing the nose wings.

The M. levator labii superior muscle, located around the mouth and extending inwardly from the fibers, allows the upper limb to be pulled upwards. M. zygomaticus major and minor muscles pull the sides of the lip up and to the side during laughing. M. risorius has a whistling motion, M. depressor labii inferior lower lips pulling muscle, M. depressor anguli oris mouth corner pulling muscle, M. orbicularis oris lips closing muscle, and M. buccinator has a smile.

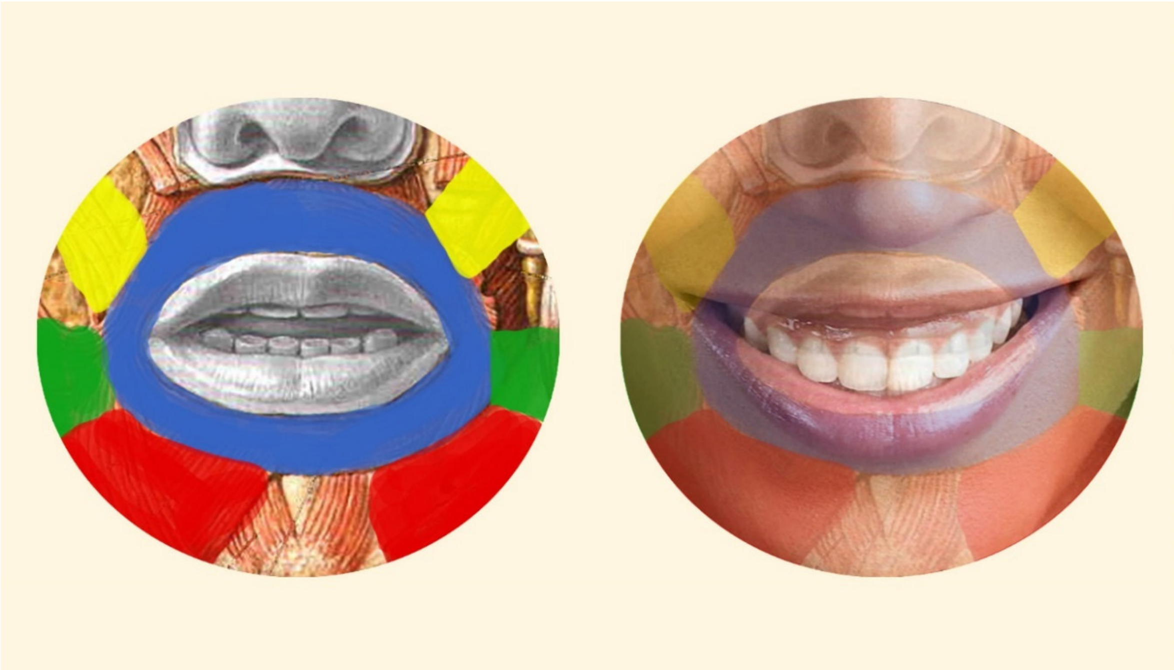

Figure 7. Smile Change of Four Movement Points on the Face (Paulsen.J, 2010)

4. FUZZIFICATION OF THE SMILING

We now have a total of 43 muscles. At the time of the smile, only 17 of them were acting. These 17 muscles can be represented by 4 basic groups. The 4 basic muscle groups (orbicularis oris, risorius, depressor anguli oris, zygomaticus) that perform laughing actions on the human face are blurred as follows. The values in Figure 8 are expressed proportionally. Because the value of each person is different.

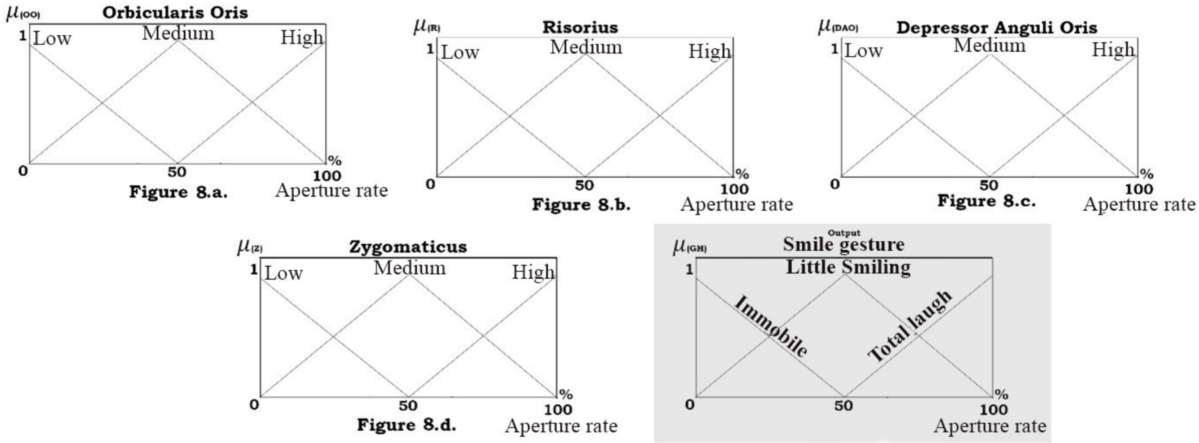

Figure 8.a. Figure 8.b. Figure 8.c. Figure 8.d. Figure 8.e.

Figure 8.a.: This cluster is Orbicularis Oris. It is indicated by the expression OO. Orbicularis oris has been blurred to a low, medium, or high degree. This is expressed by the ratio of opening distance. The opening distance is shown in the horizontal axis. **Figure 8.b:** Risorius is the name of this cluster. R is indicated by the expression. Risorius's low, medium, and high are blurred. The opening distance is shown in the horizontal axis. **Figure 8.c**.: This cluster is the Depressor Anguli Oris. DEO is shown by the expression. Depressor Anguli Oris's low, medium, and high states are blurred. The opening distance is shown in the horizontal axis. **Figure 8.d**.: This cluster is Zygomaticus. Z is indicated by the expression. Zygomaticus's low, medium, and high states are blurred. The opening distance is shown in the horizontal axis. **Figure 8.e.**: This set is the output set. It is shown by the GH expression. The output cluster shows 3 results. These are: Immobile, Little Smiling, and Total Laugh. This is expressed by the ratio of opening distance. The opening distance is shown in the horizontal axis.

4.1. Rules

In fuzzy systems that are governed by rules, hazy clusters are expected to be linked to one another at all times. The concept of smile is based on 24 principles that use fuzzy logic. These rules are either linked to one another or to other related systems that are capable of operating independently from one another. The results of the laughing motion are given in the rule base below. We now have a total of 43 muscles. At the time of the smile, only 17 of them were acting. These muscles are concentrated on 4 main structures (Smith, 2003). In this book, these rules are written by looking at the definitions of muscle structure and laughing. A smile model was implemented using the Matlab Fuzzy toolbox.

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Table 1: Rule Base of the results of the laughing motion

IF	*OO=low*	Or	*R=low*	Or	*DAO=low*	Or	*Z=low*	**Then**	*GH = Stable*
IF	*OO=medium*	Or	*R=low*	Or	*DAO=low*	Or	*Z=low*	**Then**	*GH = Stable*
IF	*OO=high*	Or	*R=low*	Or	*DAO=low*	Or	*Z=low*	**Then**	*GH = Stable*
IF	*OO=low*	Or	*R=medium*	Or	*DAO=low*	Or	*Z=low*	**Then**	*GH = Stable*
IF	*OO=low*	Or	*R=high*	Or	*DAO=low*	Or	*Z=low*	**Then**	*GH = Stable*
IF	*OO=medium*	Or	*R=medium*	Or	*DAO=low*	Or	*Z=low*	**Then**	*GH = smiling*
IF	*OO=medium*	Or	*R=high*	Or	*DAO=low*	Or	*Z=low*	**Then**	*GH = smiling*
IF	*OO=high*	or	*R=medium*	or	*DAO=low*	or	*Z=low*	**Then**	*GH = smiling*
IF	*OO= high*	Or	*R=high*	Or	*DAO= low*	Or	*Z= low*	**Then**	*GH = full laugh*
IF	*OO= low*	Or	*R= low*	Or	*DAO= medium*	Or	*Z= low*	**Then**	*GH = Stable*
IF	*OO= low*	Or	*R= low*	Or	*DAO= high*	Or	*Z= low*	**Then**	*GH = Stable*
IF	*OO= medium*	Or	*R= low*	Or	*DAO= medium*	Or	*Z= low*	**Then**	*GH = little smiling*
IF	*OO= medium*	Or	*R= low*	Or	*DAO= high*	Or	*Z= low*	**Then**	*GH = little smiling*
IF	*OO= high*	Or	*R= low*	Or	*DAO= medium*	Or	*Z= low*	**Then**	*GH = little smiling*
IF	*OO= high*	Or	*R= low*	Or	*DAO= high*	Or	*Z= low*	**Then**	*GH = full laugh*
IF	*OO= low*	Or	*R= low*	Or	*DAO= low*	Or	*Z= medium*	**Then**	*GH = Stable*
IF	*OO= low*	Or	*R= low*	Or	*DAO= low*	Or	*Z= high*	**Then**	*GH = Stable*
IF	*OO= medium*	Or	*R= low*	Or	*DAO= low*	Or	*Z= medium*	**Then**	*GH = smiling*
IF	*OO= medium*	Or	*R= low*	Or	*DAO= low*	Or	*Z= high*	**Then**	*GH = smiling*
IF	*OO= high*	Or	*R= low*	Or	*DAO= low*	Or	*Z= medium*	**Then**	*GH = smiling*
IF	*OO= high*	Or	*R= low*	Or	*DAO= low*	Or	*Z= high*	**Then**	*GH = full laugh*
IF	*OO= medium*	Or	*R= medium*	Or	*DAO= medium*	Or	*Z= medium*	**Then**	*GH = smiling*
IF	*OO= high*	Or	*R= high*	Or	*DAO= high*	Or	*Z= high*	**Then**	*GH = full laugh*
IF	*OO= medium*	Or	*R= high*	Or	*DAO= medium*	Or	*Z= high*	**Then**	*GH = full laugh*

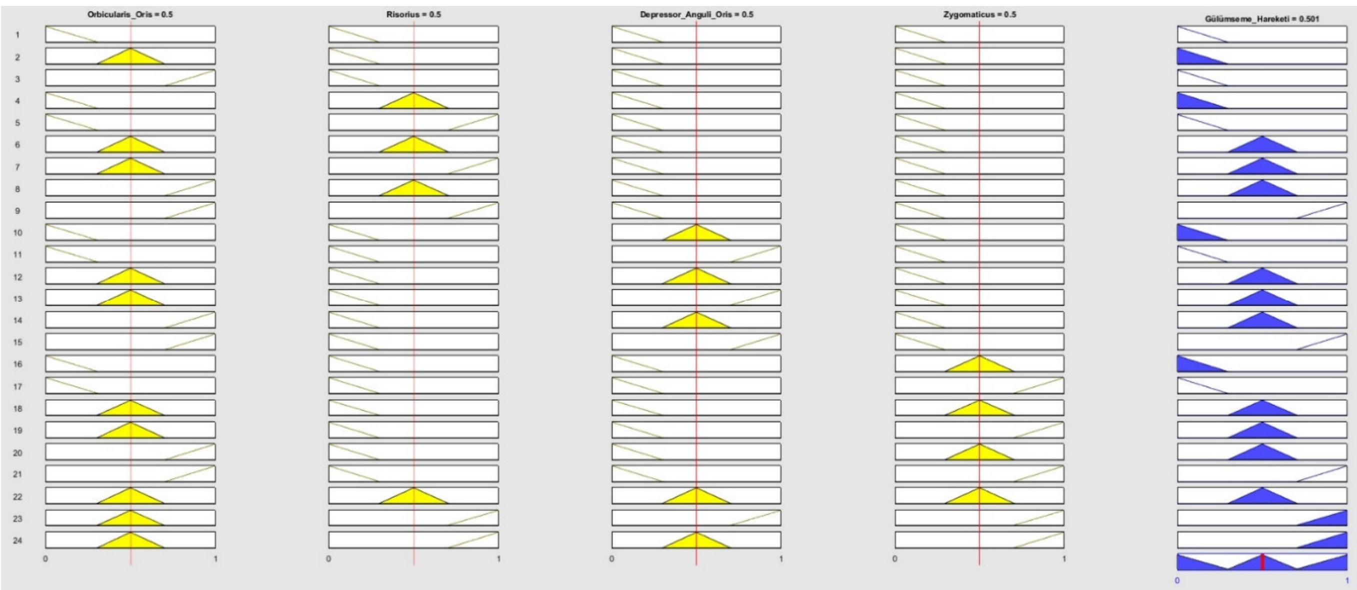

Figure 9. Smile model on Matlab Fuzzy toolbox

Figure 10. A: Technology without fuzzy logic, B: Technology laughing simulation using fuzzy logic

5. CONCLUSION

Fuzzy logic is used in this work to represent the grin that a person has on the inside. By using fuzzy logic, this model has the potential to develop grin mimics that are more lifelike than those produced by previous methods. In the beginning, we talk about fuzzy logic, motion capture, digital motion capture technology, and the human face muscles. The four primary facial muscles were used as the input for this process. More careful scrutiny has been applied to the parameters of the output. In this article, the authors highlight the merits of employing fuzzy logic theory rather than more traditional methods to problem solving. The advantages of having face muscles are going to be covered in the next part, along with some graphic representations of the four basic facial muscles. In order to model each of the four basic muscle types that have just been explained, fuzzy logic is employed as a simulation tool. Rule-based metrics are not governed by any rules since there are none left. These rules are defined by a total of twenty different rules. In conclusion, a discussion of the contribution that the fuzzy logic theory has made to the solution follows. As a consequence of this, the technologies that make use of fuzzy logic are contrasted with those that do not make use of fuzzy logic. In addition to this, fuzzy logic may be used to a wider range of locations to produce a greater number of muscle motions. Because of these processes, the use of fuzzy logic has contributed to an improvement in the speed of computer-related business. Linguistic variables are easier to express than other kinds. It has been noticed that the findings obtained utilizing fuzzy logic are more accurate when compared to those acquired using traditional logic.

REFERENCES

Baker, A. (1995) ‘Intelligent dishwasher outsmarts dirt’, *Design News (Boston)*.

Bickel, B. *et al.* (2007) ‘Multi-scale capture of facial geometry and motion’, *ACM Transactions on Graphics*. doi: 10.1145/1276377.1276419.

Carbajal-Hernández, J. J. *et al.* (2012) ‘Assessment and prediction of air quality using fuzzy logic and autoregressive models’, *Atmospheric Environment*. doi: 10.1016/j.atmosenv.2012.06.004.

Committee, S. (1998) *IEEE Standard for Software Verification and Validation IEEE Standard for Software Verification and Validation*, *IEEEInstitute of Electrical and Electronics Engineers*.

Dionova, B. W. *et al.* (2020) ‘Environment indoor air quality assessment using fuzzy inference system’, *ICT Express*. doi: 10.1016/j.icte.2020.05.007.

Fox, J., Arena, D. and Bailenson, J. N. (2009) ‘Virtual Reality: A Survival Guide for the Social Scientist’, *Journal of Media Psychology*. doi: 10.1027/1864-1105.21.3.95.

‘Human anatomy for artists: the elements of form’ (1992) *Choice Reviews Online*. doi: 10.5860/choice.29-5499.

Kerr, K. (1997) ‘Anatomy of Movement Exercises’, *Physiotherapy*. doi: 10.1016/s0031-9406(05)65618-0.

Kitagawa, M. and Windsor, B. (2008) *MoCap for Artists Workflow and Techniques for Motion Capture*, *Journal of Chemical Information and Modeling*.

Klaassen, B. *et al.* (2015) 'A full body sensing system for monitoring stroke patients in a home environment', in *Communications in Computer and Information Science*. doi: 10.1007/978-3-319-26129-4_25.

Latsis, D. (2015) 'Landscape in motion: Muybridge and the origins of chronophotography', *Film History: An International Journal*. doi: 10.2979/filmhistory.27.3.1.

Ling, H. Y. *et al.* (2020) 'Character controllers using motion VAEs', *ACM Transactions on Graphics*. doi: 10.1145/3386569.3392422.

Mendel, J. M. (2017) *Uncertain Rule-Based Fuzzy Systems*, *Uncertain Rule-Based Fuzzy Systems*. doi: 10.1007/978-3-319-51370-6.

Mihcin, S. *et al.* (2021) 'Wearable motion capture system evaluation for biomechanical studies for hip joints', *Journal of Biomechanical Engineering*. doi: 10.1115/1.4049199.

Pastukhov, A., Vivian-Griffiths, S. and Braun, J. (2015) 'Transformation priming helps to disambiguate sudden changes of sensory inputs', *Vision Research*. doi: 10.1016/j.visres.2015.09.005.

Paulsen.J, W. F. ; (2010) 'Sobotta Atlas of Human Anatomy: Head, Neck and Neuroanatomy', *15th Edition*.

Perales, F. (2001) 'Human motion analysis and synthesis using computer vision and graphics techniques. State of art and applications', *Proc. World Multiconf. on systemics, cybernetics.*

Perry, T. S. (1995) 'Lotfi A. Zadeh [fuzzy logic inventor biography]', *IEEE Spectrum*. doi: 10.1109/6.387136.

Pfeifer, C. and Relancio, J. J. (2022) 'Deformed relativistic kinematics on curved spacetime: a geometric approach', *European Physical Journal C*. doi: 10.1140/epjc/s10052-022-10066-w.

Rathore, A. K. (2004) 'Improved performance of fuzzy logic based direct field oriented controlled induction motor', in *International Power Electronics Congress - CIEP*. doi: 10.1109/ciep.2004.1437568.

Sato, H. and Cohen, M. (2010) 'Using motion capture for real-time augmented reality scenes', *Proceedings of the 13th International Conference on ….*

Sharma, Ashish and Sharma, Anima (2013) 'Motion Capture Process , Techniques and Applications', *Internation Jornal on Recent and Innovation Trends in Computing and Communication*.

Skipper, L. (2003) 'The Concise Book of Muscles', *Physiotherapy*. doi: 10.1016/s0031-9406(05)60186-1.

Smith, G. (2003) 'Customers are People ... The Human Touch', *Interactive Marketing*. doi: 10.1057/palgrave.im.4340237.

'The handy psychology answer book' (2011) *Choice Reviews Online*. doi: 10.5860/choice.48-6591.

Zadeh, L. A. (1965) '1965 J(Zadeh) Fuzzy Sets.pdf', *Information and Control*.

Zhou, Y. *et al.* (1996) 'Fuzzy logic control of a four-link robotic manipulator in a vertical plane', *Intelligent Engineering Systems Through Artificial Neural Networks*.

Zyda, M. (2005) 'From visual simulation to virtual reality to games', *Computer*. doi: 10.1109/MC.2005.297.