Electromanyetik Silahlı Terörle Mücadele Robotu
Electromagnetic Weaponed Anti Terrorism Robot

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***Özetçe*— Bu makale, elektromanyetik silahların bir robota entegrasyonunu, elektromanyetik silahlı bir robotun tasarımını ve yapımını, elektromanyetik silahla olası hedeflerin otonom olarak hedeflenmesini ve bir elektromanyetik silahlı güvenlik robotunun sahip olması gereken özellikleri önermektedir. Bu çalışmada adı geçen robot, geleneksel kullanıcı hedefli saha güvenlik robotu yaklaşımlarından farklı olarak, görev alanındaki potansiyel tehditleri görüntü işleme ve yapay zeka teknikleriyle tespit ederek, kullanıcı kontrollü hedeflemeye ihtiyaç duymadan hedefleri doğru bir şekilde belirleyip otonom olarak hedef almasını sağlamaktadır. Günümüz silahlı robotlarından farklı olarak, yeni bir literatür çalışması olacak elektromanyetik silahlı bir robot, bir referans yol oluşturmak için geliştirilmiştir. Robot tarafından taşınabilen elektromanyetik bir silah üretilip robota entegre edilerek elektromanyetik silahlı yeni bir silahlı robot yaklaşımı tanıtılmıştır. Elektromanyetik silahların menzil sınırlaması ve robot kullanıcısının olası hedefleme hataları dikkate alınarak çeşitli yöntemler önerilmektedir. Hedef takibi için robot ve kullanıcının dinamik kısıtlamaları altında en uygun hedeflemeye sahip olacak şekilde bir kontrol algoritması geliştirilmiştir. Prototipleme ve deneyler, otonom bir hedefleme sistemine sahip otonom bir güvenlik robotunun kullanıcı sorunlarını ve hedefleme sorunlarını giderme yeteneğini göstermektedir. Ayrıca sahada çalışan elektromanyetik silahlı bir güvenlik robotunun sahip olması gereken özellikler için çeşitli yöntemler ve öneriler sunulmaktadır.**

Anahtar Kelimeler— İnsansız kara aracı; Elekromanyetik silah; Drone; Askeri robot; Savunma sistemleri.

***Abstract*— This article proposes the integration of electromagnetic weapons on a robot, design and construction of an electromagnetic armed robot, autonomous targeting of possible targets with the electromagnetic weapon, and the features a electromagnetic armed safety robot should have. Unlike traditional user-targeted field security robot approaches, the robot mentioned in this study detects potential threats in the task area with image processing and artificial intelligence techniques, so the user can accurately identify and autonomously target targets without the need for controlled targeting. Unlike today's armed robots, an electromagnetic armed robot, which will be a new literature study, has been developed to create a reference path. An electromagnetic weapon that can be carried by a robot is produced and integrated into the robot and a new armed robot approach with electromagnetic weapon is introduced. Various methods are proposed considering the range restriction of electromagnetic weapons and possible targeting errors of the robot user. A control algorithm has been developed to have the most appropriate targeting under the dynamic constraints of the robot and user for target tracking. Prototyping and experiments show the ability of an autonomous security robot with an autonomous targeting system to troubleshoot user problems and targeting problems. In addition, various methods and recommendations are provided for the features that a electromagnetic armed security robot working in the field should have.**

Keywords— Unmanned vehicle; Electromagnetic weapon; Object targeting; Military robot; Defense systems.

I. INTRODUCTION

Today, unmanned armed war platforms are used in defense industry areas. Unmanned armed vehicles are safe and cheap systems preferred in dangerous missions. Many countries aim to improve their defense and military capabilities by working on this issue. An unmanned vehicle developed in terms of software and hardware will be able to function effectively in the field. Studies are foreseen for future applications of unmanned vehicles[1].

Armed unmanned vehicles are generally controlled by an operator. Users aim manually with the remote control to identify a potential enemy and aim at it. If there is any task, this task is done with human decisions and commands. When these systems carrying a heavy weapon platform above them fire, high noise, light and vibration occur. While high noise and light enables this vehicle to be detected by the enemy, the vibration caused by the gun firing also makes it difficult to aim at the target. It is extremely important for an unmanned war platform to remain silent and hidden on the field. Because a vehicle that is hidden and silent on the field can successfully perform its duty without being noticed by others. However, since the determination of possible targets in the field is done by people, the success of these human-dependent systems depends on the users using these tools.

This article describes the operation and modeling of an unmanned vehicle with electromagnetic weapon powered by electricity, as an alternative to unmanned ground vehicles with conventional gunpowder guns. Electromagnetic weapons are systems that launch bullets directly with electrical energy without using any flammable materials such as gunpowder. When the electromagnetic gun fires, it does not produce any sound, light and vibration. This means that these weapons will bring innovation and superiority to today's traditional armed ground vehicles. A vehicle with an electromagnetic weapon will undoubtedly be more quiet, secret and effective in the field than vehicles with gunpowder guns. In addition, in this study, autonomous target detection and object targeting methods, which can be a solution to human controlled vehicles, are also explained. As a solution to the failures especially in long-range firing, a new aiming method was explained on this study. A vehicle with autonomous target detection and targeting system can detect targets and aim at the target without the need for human commands, this will be a solution to the negativities arising from human errors and deficiencies in today's armed vehicles. In this study, after the modeling and prototyping of a field robot with an electromagnetic weapon, motion detection, face recognition, object recognition, and the integration of autonomous target tracking software and its methods are explained. With these studies, it is aimed to bring new solutions for future armed unmanned vehicles.

II. UNMANNED LAND VEHICLES

Unmanned land vehicles, which are frequently used in areas such as surveillance and intelligence gathering, are technology platforms that have emerged as a result of various electronic developments, especially communication and imaging devices. These vehicles are the solution for tasks that endanger human life and where human access is not possible[2,3]. These unmanned land vehicles can be customized with various equipment mounted on them according to the areas where they will be used[4]. Various researches are being carried out on the use of unmanned land vehicles to ensure human and field safety[5-7]. They can be produced in various sizes according to the need and the type of task they will carry out and their designs are shaped accordingly. Smaller design models use electric motors, while larger models use internal combustion engines that produce more power and run on fuel[8]. Today, these vehicles are mainly used in exploration and surveillance, equipment transportation, first aid and rescue, live search in natural disasters, chemical and scientific research, military field and many other areas. Only for surveillance and short range vehicle applications, solutions are limited[9]. In most cases, the images from the camera need to be analyzed and intervened without the need for people. Instead, vehicle applications with long range, various sensors, equipped with a weapon system and working with smart software will be more functional and successful in the duty field. With the development of technology and weapon systems, the production of weapon integrated land vehicles has been realized. These armed vehicles can function by carrying weapons of various sizes. Generally, armed land vehicles are needed in situations that may endanger human life in battlefields and it is aimed to perform manned missions safely and cost-effectively with these vehicles[10,11]. Today, most of these platforms are managed manually by a user who manages them without smart software (Fig. 1).

Figure 1. Remote-controlled military vehicles using traditional weapons

These vehicles serve with hundreds of kilos of weapons. When these vehicles fire with the gun on them, loud noise, gunpowder and vibration emerges. Since the vibration created by the gun causes the whole vehicle to shake, the operator has difficulty in controlling the vehicle and the gun and aiming at the target. The resulting noise and gunpowder fumes cause the location of the vehicle to be understood. To overcome such problems, new systems and methods must be introduced to the vehicle operator and unmanned vehicle.

III. EWATR

EWATR (Electromagnetic Weaponed Anti Terrorism Robot) is designed as an armed unmanned land vehicle, which is the type of unmanned land vehicles used in the battlefields. Unlike armed unmanned land vehicles, it incorporates today's technological innovations and software. It has border security, reconnaissance-observation, intelligence gathering, armed intervention to possible target, enemy identification, face recognition and automatic aiming. Unlike today's conventional weapons, the electromagnetic weapon prototype is integrated on the robot. Electromagnetic weapons are high-capacity capacitors and electrically operated systems[12,13]. Unlike conventional gunpowder guns, EWATR uses a quieter, more effective and lighter electromagnetic weapon system that works with high capacity capacitors and compared to other guns. Research on electromagnetic launcher, which may be an alternative to traditional weapons used today, has been going on for years[14,15]. In the coming years, as the electromagnetic weapon systems develop, it is likely to be used in unmanned vehicles, a new competitive environment will arise and countries will update their military equipment with this weapon system. EWATR has 4 wheels, 4x4 off-road traction system and an independent suspension system that enables it to move on difficult terrain. The wheeled system has been preferred due to the inability to move due to pallet breakage in tracked vehicles and the disadvantage of various hardware problems[16]. EWATR's weapon system, which will use its electromagnetic weapon in contact with potential enemies, is located in the front of the vehicle (Fig. 2). With its design and features, EWATR is manufactured to be capable of performing silent and secret missions in the military field.

Figure 2. Electromagnetic weapon system

IV. ELECTROMAGNETIC WEAPON

A smaller but more effective electromagnetic weapon was designed to use the electromagnetic weapon in EWATR than the electromagnetic weapon in the literature. In order for the gun to be stronger, the number of copper windings in it was increased, and more electrical current was provided from the electromagnetic weapon firing circuit to the electromagnetic weapon. Because there are two factors that increase the power of the electromagnetic weapon: coil winding number(N) and electric current(I). The related magnotomotive force formula(F) is as follows(1):

$$F = N x I \quad (1)$$

The weapon system of EWATR is designed as electromagnetic pulse unlike conventional gunpowder guns. The pressure generated during the firing of gunpowder in conventional gunpowder firing guns is used in the forward propulsion of the projectile core. The firing of gunpowder produces sound, gunpowder smoke and recoil movement, which can cause detection by the enemy in the war environment. The electromagnetic weapon of EWATR, on the other hand, creates a strong electromagnetic field with electric energy and performs the firing of ferromagnetic projectiles with it. No recoil, gunpowder smoke and sound are produced as a result of electromagnetic firing. These are important advantages in the choice of electromagnetic weapon in unmanned combat robot. The energy of the electromagnetic weapon depends on the capacitance of the capacitors(C) and the ignition voltage(V). The calculation of the energy stored(E) in the capacitor is as follows(2):

$$E = \frac{1}{2} C V^2 \quad (2)$$

However, the efficiency of electromagnetic weapons is quite low[17,18]. Therefore, not all stored energy can be used. To increase the power of the elektromagnetic weapon, either the capacity of the capacitors should be increased or the voltage sent to the gun should be increased. The characteristics of the capacitors used in EWATR have 780V operating voltage and 1360uf capacity. Additional capacitors can be connected in series and in parallel, increasing the power and ignition voltage of the electromagnetic weapon. Capacitors feeding the electromagnetic weapon are filled with DC-DC amplifier circuit on the robot. Battery voltage is not sufficient to charge capacitors. Because electromagnetic weapons and capacitors need hundreds of volts, while the battery voltage is only at 12-14.4V levels. When the electromagnetic weapon is used, the battery voltage is directed to the DC-DC amplifier circuit with the power transistor and the capacitors are filled by obtaining high voltage. When firing command is given, thyristor located between the electromagnetic weapon and capacitors provides electrical transmission, and high voltage is transferred to the gun and the projectile is launched.

V. FAST OBJECT LEARNING

The haar cascade classifier can be used to detect other objects as well as face recognition[19-21] Objects such as vehicles, equipment, people and buildings seen in the field can be recorded in the format defined by EWATR when necessary. Facial recognition software in the literature needs a large database previously obtained as a result of long processes in order to be able to identify[22]. Object recognition algorithms in the literature work with a long-term learning process by passing the images of the relevant object through a neural network. However, there is not enough time in the task area for teaching and introducing a new object that is seen for the first time in the field. A rapid object learning algorithm has been created to track and identify the target when the recognition software does not recognize the object. The rapid object learning algorithm learns the object in a much shorter time than the object learning algorithms in the literature. The aim is to provide the target object to learn quickly without being connected to the database and neural network, and then to create the object model to teach the recognition algorithm. When an object that the recognition algorithm cannot identify in the camera image in EWATR, the user marks this object on the camera screen (Fig. 3).

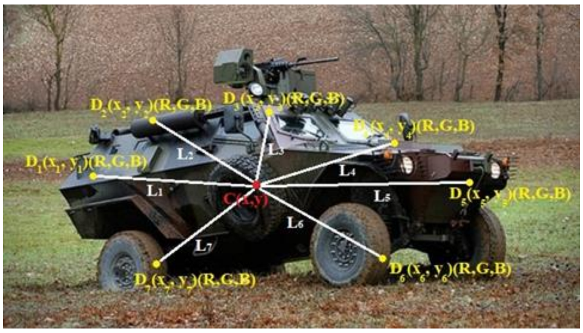

Figure 3. Object learning with fast learning

During the marking, the areas where the object is located are marked (D) by the user and the learning model about the object is created by taking the position, color information (Red, Green, Blue) and size of the object on the screen. The more points marked on the object, the more successful the detection of the object. In the learning model, it is also possible to define objects of different sizes or distances by adding the distance (L) of the points determined on the object and the coordinates of the points (x, y) to the model. Thus, even if the object moves away, object recognition is continued since the distance values of the points will change at the same rate. In the image processing based model, the center of the target (C) is determined and aimed by finding the center of gravity of the object thanks to the coordinates of the points. Objects that have been marked and taught to the algorithm within a few seconds by the user can be identified and monitored without being connected to any network and database (Fig. 4). This method is a good solution when the recognition algorithm does not have time to learn the object.

These learned objects can be classified as friends and enemies, and if necessary, autonomously intervene in the objects defined as enemies. EWATR has the ability to automatically track the objects it has learned. In this way, possible threats are automatically tracked and targeted by EWATR's weapon system without the need for user control. Thanks to EWATR's ability to automatically aim at the target, there is not much work left for the user. If there is a threat situation, the user only orders the firing. Some contenders argue that autonomous weapon systems can be unreliable and cause accidents[23]. The ongoing discussions about whether civil and military objects will be targeted by mistake are answered in this study by the mechanisms brought by gradual object recognition processes and high-security communication systems.

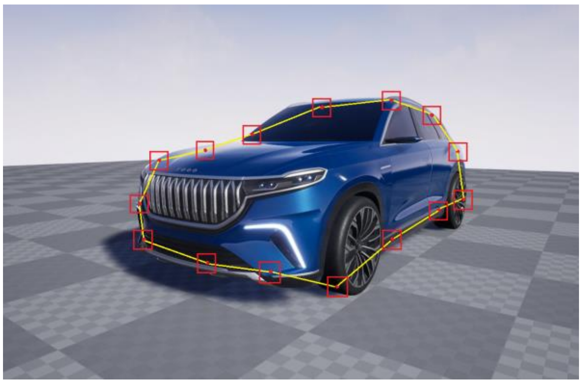

Figure 4. Identification of car with quick object learning model

VI. AUTONOMOUS TARGETING SYSTEM

When the literature is examined, it is seen that many robots used in the field are controlled by the user[24]. Even simple tasks such as rotating the cameras of the robot are performed by the user, especially in applications such as observation and monitoring in the military field[25]. Dealing with such simple tasks, such as turning the camera, may limit the actual task of the user in the task area. To solve this problem, automatic targeting system was implemented in EWATR. Automatic targeting system means directing the robot's camera and weapon system to the target automatically without the need for the user. The camera images taken from the task area are displayed to the user in the computer program of EWATR. The user opens the relevant command in the program according to the type of object to be targeted (human face or object) and allows the object to be selected by the computer program. In the image in the figure, since the target object is at the bottom right of the screen, command is sent to EWATR to turn its electromagnetic weapon in the right-bottom direction. In order to target the object displayed in the frame by EWATR, the coordinates of the target object on the screen are taken. By measuring the distance of the marked object from the center of the screen, the distance between the aiming area on the horizontal and vertical axis is calculated. The aiming area is the center area where the object is correctly targeted. The object entering the aiming area means that EWATR is fully targeted by the weapon system. After calculating the distance of the object to the center aiming area on the screen, the horizontal distance and vertical distance information obtained are sent to EWATR via encrypted and secure connection. EWATR's processor transmits this axis distance information it receives as a signal to two servo motors that direct the weapon system on the horizontal and vertical axis, and the weapon is provided to follow the target autonomously and aim. Weapon orientation model has been developed for tracking the detected object and aiming autonomously by the weapon system. The list of variables to define the weapon orientation model is shown in Table 1. Weapon routing equations are derived as follows:

Variable	Description
AA	Aiming Area
TO	Target Object
Xi	i horizontal value on the x axis
Yi	j horizontal value on the y axis
Xc	Center point on the x axis
Yc	Center point on the y axis
AA(Xi,Yi)	Coordinate of the Aiming Area on the x and y axes
TO(Xi,Yi)	Coordinate of the Target Object on the x and y axes

Table 1. Description of the system variables in the dynamic model

First of all, the center point of the Target Object on the screen must be determined (Fig. 8 and 9). To find the center point, the center point of the distance the Target Object occupies on the horizontal (x) and vertical (y) axis on the screen is calculated (3,4):

$$TO(Xc) = (TO(x_2) - TO(x_1)) \quad (3)$$

$$TO(Yc) = (TO(y_2) - TO(y_1))/2 \quad (4)$$

In order to direct the weapon system to the target object, the location of the target object on the screen must be calculated (5,6). At this stage, the calculation of the distance between the center point of the Targeting Area and the center point of the Target object, that is, the rotation distance of the servo motors that will direct the weapon system to the target:

$$Distance(Dx) = (TO(x_C) - AA(x_C)) \quad (5)$$

$$Distance(Dx) = (TO(x_C) - AA(x_C)) \quad (6)$$

Since the rotation angles of the servo motors are proportional to the gear rotation ratios, an F (factor) constant has been determined. This constant F determines the speed (servo motor speed) of the weapon system towards the target. If the constant F is kept low, the weapon rotates slowly to the target, and if the constant F is kept high, the weapon can aim at the target very quickly and miss the target. Accordingly, when the vertical servo motor angle of weapon is shown and horizontal servo motor angle of weapon (Hm), the routing of the servo motors is done according to the following algorithm model. The method proposed here refers to autonomous aiming at the target object with the weapon system. However, this method can be useful for close-range shots, because in long distance shots, the projectile will deflect slightly down due to gravity. To solve this, the gravitational drop should be taken into account in the method mentioned above and a method to add some angle to the vertical servo motor that guides the gun to the target should be added (5). The firing angle (∝) depends on the projectile rate (V), the distance of the target (D) and the acceleration of gravity (g). When starting from the distance-launching formula:

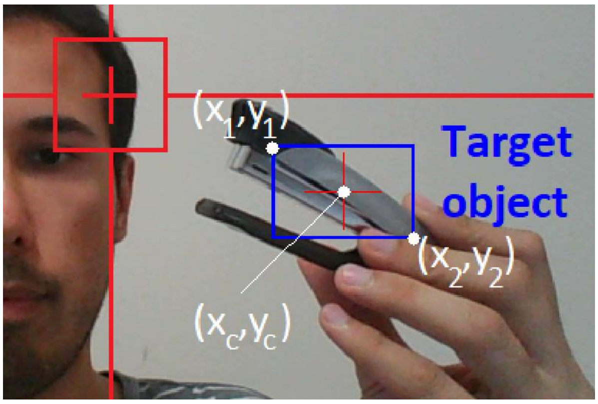

Figure 8. Calculation of the center of the target object

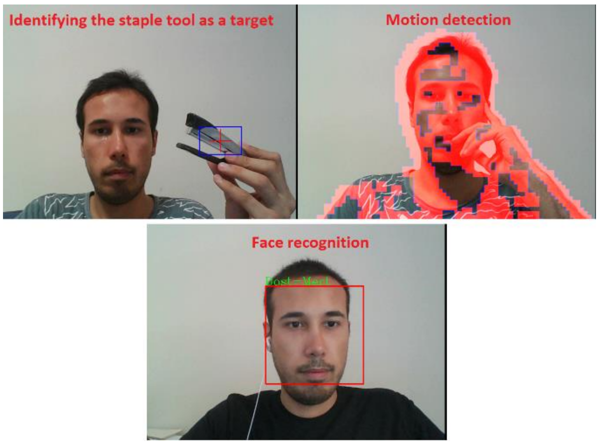

Figure 9. EWATR's softwares

$$D = V.\cos \propto . \frac{2.V.Sin\propto}{g} \quad (7)$$

As a result, just before the gun is fired, the angle value to be given to the vertical servo motor in the gun system is obtained as follows(8):

$$\propto = arcsin \frac{D.g}{2.V^2} \quad (8)$$

After this calculation, the angle value to be given to the vertical servo motor in the weapon system was obtained for long-range shooting. When the obtained angle value is added to the equation (9) in the weapon system (Fig. 10), the new equation of the electromagnetic weapon system, which is directed autonomously to the target, is obtained:

$$Angle(Hm, Vm) = \begin{cases} Vm += Dy.F+\propto & if\ Dy > 0 \\ Vm -= Dy.F+\propto & if\ Dy < 0 \\ Hm += Dx.F & if\ Dx > 0 \\ Hm -= Dx.F & if\ Dx < 0 \end{cases} \quad (9)$$

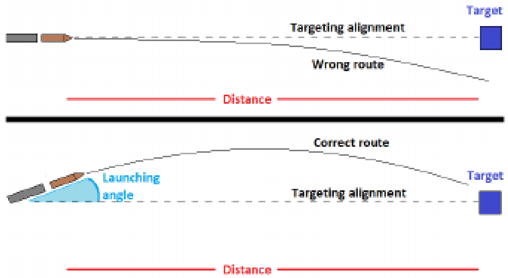

Figure 10. Angled positioning of the weapon for the correct route

VII. CONCLUSIONS

As an alternative to today's conventional gunpowder gun robots, the prototype model of the electromagnetic weaponed EWATR was realized in line with the needs and goals. The prototype model weighs 6kg, is 50cm long, 40cm wide and 40cm high and can fit in a soldier's backpack. This land vehicle with an electric weapon will be more independent and useful than vehicles with traditional gunpowder gun. Because ammunition in conventional gunpowder vehicles is limited. The vehicle, which can charge itself and has an electrically powerful weapon, will be able to fire more rounds. No sound, gunpowder fumes, recoil events seen in gunpowder guns from electromagnetic gun of EWATR were observed during the shots made during the experiments. These are important factors that give the robot a superiority over conventional gunpowder guns. It has become clear that it is feasible to integrate and use the electromagnetic weapon in a land vehicle of this size. It is clear that an electrically powered robot with weapon system, engine equipment and other systems will be quieter, stealthy, and more capable than its rivals.

A comprehensive object recognition library has been created for preferred recognition algorithms for secure recognition. Autonomous targeting software and face and object recognition software are integrated with each other for the security robot to work in the task area. In this way, target faces and objects identified without the need of the user were automatically aimed by the gun of the robot. In addition, a new rapid recognition model has been proposed to ensure that objects that cannot be identified by the recognition algorithms in the literature are quickly learned in the task area and aiming by EWATR. Learning the objects is realized in a few seconds with the rapid recognition model software. With this model, it is a solution that can help in learning every small and large object and groups of objects. The rapid recognition model is a model that distinguishes objects without the need for any learning network and object database and can be developed for future studies.

Electromagnetic launch gun of suitable size for this size safety robot has been created and integrated on the robot. The electromagnetic launch gun supports firing 10 times per minute, and the EWATR's battery supports firing 40 rounds with an electromagnetic gun. The voltage status of the battery after each ignition is shown in Figure 11.

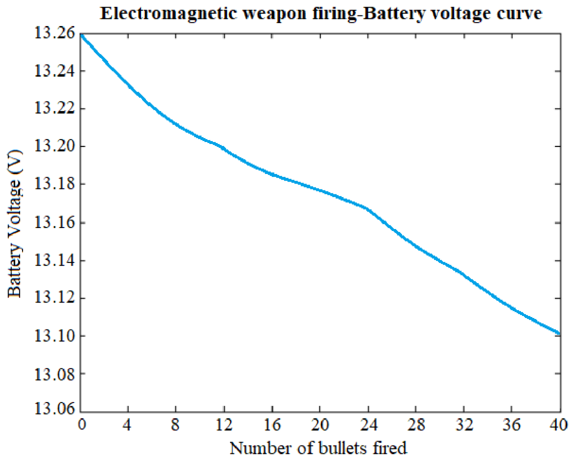

Figure 11. Battery voltage level chart after electromagnetic firing

Battery level, initially at 13.26V, dropped to 13.10V after firing 40 bullets. In the trials, 40 bullets were fired while LifePO4 batteries were at 85.8% charge level. It was observed that the charge level of the batteries was 79.1% after 40 bullets were fired. Therefore, about 7% level was used to fire 40 bullets, which means that more bullets can be fired with these batteries. The number of bullets fired to meet the electrical needs of the other equipment of the robot is limited to 40. It was beneficial to place a solar panel on the robot for the energy needed in the task area as shown in Figure 12 and Figure 13. In this way, the robot, which is away from electrical sources while in the field, can charge its batteries with solar panels on its own. The shells fired with 780V were found to be effective at 40 meters. The problem of the deviation of the bullet fired in electromagnetic weapons from the target is solved by the autonomous targeting model created. With the autonomous targeting system, the electromagnetic weapon was given the required angle right before the firing of the tracked and targeted object, and the target was fired more accurately. The fact that electromagnetic armed robots have a silent and powerful weapon, are managed with smart software and equipped with smart solutions in the field will make them more effective and successful in the task area.

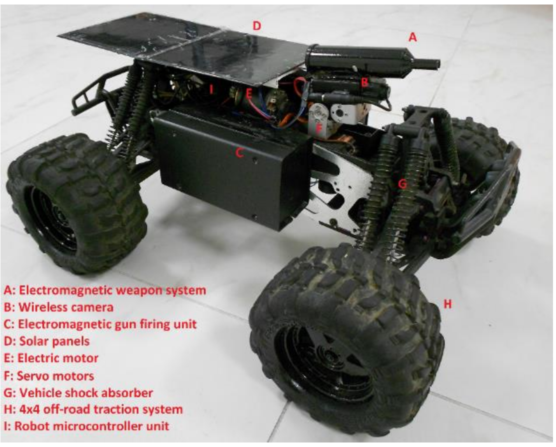

Figure 12. Front view of EWATR

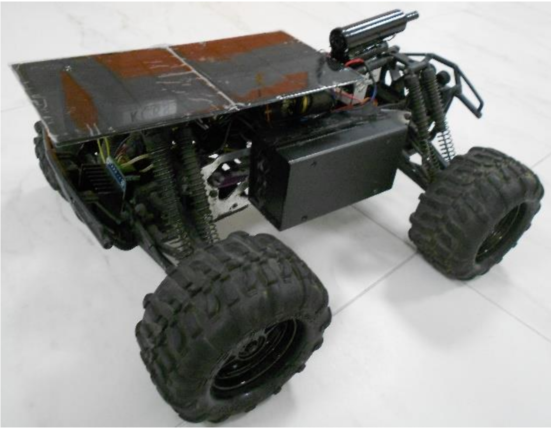
Figure 13. Back view of EWATR

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