Reliability Assessment for an IoT Device. Use Case: Parkinson's Patient Spoon

Marius Misaroș*, Ștefan-Dragoș Cîrstea, Dan-Ioan Goța, Ovidiu-Petru Stan, and Cristian-Liviu Miclea

***Abstract*—Nowadays, the number of connected IoT devices grows to nearly 12.5 billion globally. IoT devices contain sensors, actuators, and mini processors that self-report in real-time, can be used in home automation, medical and healthcare, transportation, manufacturing, agriculture and more. Assessing reliability for this type of devices is problematic due to the computing reliability indicators, failure rate, mean time between failure and the need of a huge amount of information about the device and its components (operating parameters, environment, quality, etc.). This paper presents a method to assess an IoT Parkinson's patient spoon with respect to reliability. With these indicators determined, it is easy to create a more dependable product by experimenting with alternative solutions and scheduling maintenance procedures.**

***Index Terms*—reliability, reliability assessment, Parkinson's disease, failure rate, mean time between failures (MTBF)**

I. Introduction

The term "reliability" is common in the life cycle of a system. Reliability boils down to asking whether you can actually trust your system. It is an umbrella term, one of the key properties of dependability, and it is defined as the probability that a certain system will successfully complete a mission of a particular duration [1]. In other words, the reliability *R* of *t* is the reliability at time *t*. The operating period (operating time) means only the period of actual operation, without considering periods of deliberate interruption. T is a time function, T(t) - t, 0, i.e., it is a continuous random variable.

Since it is a complex function, reliability can be revealed by means of the numerical characteristics that encounter the random variable T as well as the operating time until the first fault is encountered. These characteristics are referred to as mean value, root mean square deviation and running time quantiles.

According to the definition, the mean value of the running time (which is a random variable) in which the system does not show any fault is given by Eq. (1):

$$M(T) = \int_0^\infty tf(t)dt \qquad (1)$$

In the literature, in order to simplify the writing, when there is no likelihood of confusion, the mean value defined by M(t) is simply denoted by the letter m. Thus, in reliability theory, for a given mean value of the random variable t, the notation MTTF is used, which is short for Mean Time to Failure. Therefore, this notation will be used and written as Eq. (2):

$$MTTF = \int_0^\infty tf(t)dt \qquad (2)$$

Therefore, the mean time that the technical system operates without failure, more precisely the mean value of the random variable T, can be expressed more clearly with the help of the reliability function defined by equality as Eq. (3) [2]:

$$MTTF = \int_0^\infty R(t)dt \qquad (3)$$

We have to mention the fact that there are some assumptions behind that mission time t. We need to assume that between each mission any broken components are repaired, and a complete diagnostic is performed so that any redundancy that we're counting on to improve reliability is still there. In other words, we assume that every mission starts with a perfect fault-free system.

In the reliability mathematical equation there is a term, λ, called the failure rate and is expressed in failures per hour. There is an assumption of random independent failures which is generally useful for electronic components and computers, but might not be applied to everything, especially mechanical components. An issue with λ is that a constant failure is a bit of a fiction.

If we look at a graph of a failure rate versus component age, Fig. 1, we can easily observe that the failure rate is constant only during the middle of the component'sd life [3].

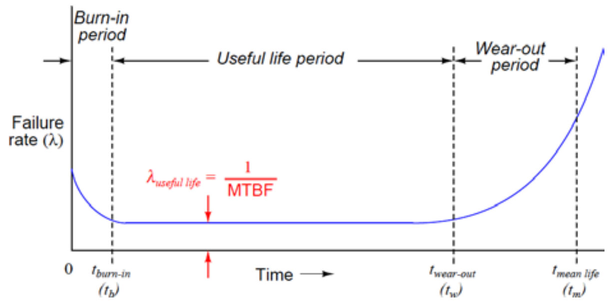

Fig. 1. Reliability curve.

At the beginning, components have a high failure rate due to manufacturing defects that manage to pass tests, but make the component wear out very quickly. This is called the burn-in phase. After the burn-in phase, the useful life period does indeed provide a constant λ value. But we also need to

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worry about the end of the product's life, where the λ value increases since the components begin to wear out due to use and age.

It is important to note that the component age axis is logarithmic, so that burn-in period is relatively short, while the end-of-life period is a very long slow ramp up. Eventually the wear out components must be discarded or replaced, because their λ is no longer the λ that we used for the equation.

Consider only the flat part of the curve, there is an equation that gives the reliability of the product in his useful life period. Because we assumed that failures were random and independent, we can use an exponential form to predict reliability (Eq. 4)

$$R(t) = e^{-\lambda t} \tag{4}$$

The implication of this exponential equation is that it is much harder to successfully complete a long mission than a short mission. Intuitively, what this is showing us, is that getting lucky for a bunch of hours in a row, where lucky means no failure, is a lot harder than only getting lucky for one hour.

As one can see, getting good reliability is all about having a really small λ. If you want to improve your λ there's some good news and some bad news. The bad news is that a λ of once per million hours is not unusual for an electronic component and the even worse news is that if you have a life critical system you must do a lot better than one failure per million hours for almost any application.

The reliability of a complex system is calculated for each component of the system so that the whole system is divided into subsystems, which at their root have specific components. The level of reliability of a system impact both the manufacturer and the end-user. From the user's point of view, if the purchased product has low reliability and does not perform, it increases the frequency of failures and requires new investments. When the product has low reliability the manufacturer faces problems with customer trust, increased warranty costs, and brand denigration [4].

The period in which a product or system will run until a failure occurs is called the Mean Time Between Failures (MTBF) which is measured in hours.

$$MTBF = \frac{1}{\lambda} \tag{5}$$

A. Systems Reliability

Complex systems, which are made up of several elements, the reliability of each of which is known, the total reliability of the whole system will depend primarily on each component element and the way in which these elements are interconnected: series, parallel or series combined with parallel.

The system that has the component elements connected in series is a sensitive system because, when one element fails, it will lead to the imminent failure of the whole assembly or system. Thus, the basic condition of the series system is that all its component elements are working at time t. The example of a series system can be seen in Fig. 2, which consists of connecting n elements of a series system.

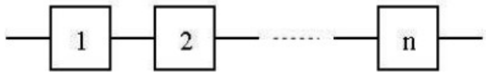


Fig. 2 Series system.

Therefore, the total reliability of a system that has components connected in series and the elements fail independently of each other is equal to the product of the reliability of all the elements that make up the system.

$$R_s(t) = \prod_{i=1}^{n} R_i(t) \tag{6}$$

The system that has the component elements connected in parallel is not as sensitive, so if all the elements in the system fail, only then will the whole system fail. Therefore, for such a system to work it is necessary that at least one element of the whole system works at a certain time t. This type of system can be seen in Fig. 3.

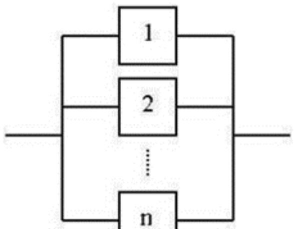


Fig. 3. Parallel system.

Eq. (7) will be used to calculate the reliability of a system with n components connected in parallel.

$$R_s(t) = 1 - \prod_{i=1}^{n} 1 - (R_i(t)) \tag{7}$$

In practice, one encounters systems that are combinations, which have more complicated assemblies. Thus, complicated systems can be divided into subsystems, and each subsystem can contain either series-only or parallel-only assemblies. Thus, this system will be called a series-parallel system [2].

Assessing reliability is a continuous activity that occurs throughout the development process of a device, from design through manufacturing and beyond. The prediction's goal is to offer a quantifiable forecast of the trustworthiness that a certain device may accomplish its mission. Generating a

reliability and performance forecast can yield valuable information. These data may serve as the basis for remedial action to be conducted to address problems compromising reliability. Furthermore, by forecasting reliability, problems such as misinterpretation of specifications, causes of fault, fault propagation, errors, and failures may be overcome.

An IoT device in the field of e-health was chosen as the reference system for reliability assessment. To be more precise, a spoon designed specifically for Parkinson's patients has been designed, implemented, and evaluated for reliability.

The presented paper is structured as follows: in Section II the core concepts regarding the prototype of the IoT device are presented, Section III presents the reliability assessment and, in the end, in Section IV one can read the conclusions.

II. Parkinson's Patient Spoon

Globally, the market for e-Health applications is rapidly growing and the beneficiaries are citizens, patients, doctors, and nurses on a personal level, healthcare managers, for public health institutions and hospitals as well. Frequently, decision-makers (medical experts or professionals) in the services are faced with inaccurate, incomplete, or excessive information. As a result, more and more questions arise in this area about the quality of the eHealth applications, such as those related to data quality, in particular security, confidentiality and dependability [5].

Internet of Things (IoT) e-health devices aim to provide a method by which quality healthcare can be delivered remotely and by which active participation of patients and physicians at all levels of the healthcare system is encouraged to prevent, diagnose and treat diseases. As a result, e-health aims to increase patient quality as well as using technology to decrease multimorbidity [6].

In this proposed method, we want to address a topical issue, namely Parkinson's disease. We believe that the normal and long-lasting functionality of one product addressing this disease is a very important factor, as the users of this prototype need a product with high reliability to improve theirs and their family members' quality of life. At the same time, reliability in the context of this application plays an extremely important role, because with its help we can observe whether the whole created system performs its intended function under certain conditions of use for a certain period of time [7].

A. *Parkinson Disease*

Parkinson's disease is a disorder of the nervous system and has a direct impact on a person's mobility. Its symptoms can fall into different categories of severity and progress gradually from a mild tremor of the hand extremity to tremor accompanied by locally felt stiffness and mobility difficulties. It is estimated that Parkinson's disease affects older people over the age of 60. It has also been found that male individuals are more likely to develop the disease than the female population [8].

Among the most common warning, signs and symptoms of the disease are tremors, lack of mobility, tense muscles, postural and balance deficiencies, and loss of the ability to perform reflexive movements such as blinking, smiling, or automatic arm movements while walking. In advanced stages of the disease, the symptoms affect the individual at a behavioral level, influence sleep, cause fatigue, impair memory or lead to depression.

Parkinson's disease tremor affects up to 80% of Parkinson's sufferers and can affect the following parts of the body: tongue, jaw, fingers, hands, feet; or it can be reported as an internal tremor in the chest or abdominal area. The tremor itself does not pose a major risk to the patient's condition, but it brings with it discomfort in everyday activities, social activities, or at work. To better understand the tremor specific to Parkinson's syndrome, the following characteristics of tremors are identified and analyzed:

- It is an involuntary, resting tremor, meaning that it is often felt when the muscles are not moving. When movement is performed, the tremor disappears, but it will recur when the affected limb is held in one position for a long period. For example, when the patient wants to eat and holds the eating utensil at mouth level, the tremor may cause the food to spill or scatter. Patients usually experience this type of tremor in one of their hands, or a finger.
- It is a slight tremor, rhythmic in nature, meaning that it occurs continuously. It is thus different from a spasm, twitch, shock, or tic.
- It is a tremor that occurs asymmetrically in one part of the body. It is usually the part where the tremor first occurs that is most affected by it. The tremor may spread during the evolution of the disease to other parts of the body or continue to affect only one area [9].

In summary, the motor symptoms that define Parkinson's disease have a focused onset, as it starts in one limb. This phenomenon is the consequence of a decrease of more than 70% of dopamine concentration in the posterior pupil (a motor region).

The main motor aspects of this disease are akinesia, bradykinesia, rigidity and tremor which can be easily identified in the basal ganglia circuits that control movements. The symptoms of Parkinson's are represented by a group containing both negative and positive symptoms that are found individually or in combinations. For the disease to be correctly diagnosed, at least two symptoms and one obligatory symptom must be present, namely bradykinesia (slower movements, slower initiation of voluntary movements, associated with a progressive decrease in the speed of repetitive movements).

Over the years and thanks to various studies, it has been found that Parkinson's disease is initiated and even maintained by oxidative stress. It involves the displacement of biological and chemical processes at the cellular level and causes excessive oxidation of cells, which ultimately leads to a rapid depletion of lipid compensation mechanisms, which ultimately leads to cell death. Thus, it has been concluded that there are several factors that can contribute to the onset of the disease, such as oxidative stress, UPS, mitochondrial dysfunction, inflammation, and excitotoxicity, which gradually lead to progressive degeneration of dopaminergic neurons.

In the last 50 years, new manifestations of Parkinson's disease have emerged that are not part of the previous natural history of the disease. As a result, neuropsychiatric symptoms such as anxiety, depression, dementia, delirium, delusions, hallucinations, confusion, panic attacks, etc. have appeared. Other symptoms are also associated with Parkinson's disease such as sleep disturbances, low blood pressure, chest pain, vomiting, agues, olfactory disturbances, fatigue, diplopia, etc.

Because of the changes in the manifestations of Parkinson's disease, a more intensive and elaborate study is needed to diagnose the condition as early and as quickly as possible, so that the patient accumulates as few lesions as possible, and the disease does not worsen. Therefore, the evaluation of a patient with Parkinson's disease is done on a continuous basis, from the diagnosis of the disease to the monitoring of the clinical course. The most common symptom leading to the diagnosis of Parkinson's disease is related to the motor component, thus the disease primarily affects: walking, writing, social and professional activities, self-care. Parkinson's disease currently has no known cause, so there is no treatment to eliminate the cause and no treatment to prevent the disease, only a symptomatic treatment to control the disease [10].

B. Gimbals Mechanism

A self-balancing mechanism assumes the function of allowing an object to be able to isolate its movements in the support of the mechanism. We attribute this definition to the generic term gimbal [11]. A gimbal is associated with a system of pivoting gimbals corresponding to an initial set number of axes. Thus, we find gimbals designed on two, three [12][13], or even four axes (three standard axes and a fourth redundant axis) [14]. Technological progress facilitates their appearance in almost every field of activity today: in inertial navigation, attributed to ships and submarines, where systems consisting of three gimbals must be placed on navigation equipment (to counteract rotational movements around the axes, more specifically, roll, pitch and yaw movements) [15]; in space rocket propulsion, where rocket motors are generally mounted on a pair of gimbals to allow vectoring in both pitch and yaw motion; in the photography industry, on portable equipment or to fix the lens of small cameras or photographic telescopes.

Mechanisms incorporating the gimbal system have gained remarkable attention in recent years, due to their various potential applications, such as stabilizing observation systems with optical or camera equipment for target detection and tracking and other individual purposes. Many researchers have investigated the dynamics of the parameters corresponding to the gimbal mechanism, namely the pitch-yaw parameters [16].

Our showcase is a three-axis gimbal (consisting of servomotors and an inertial IMU sensor) used in the aviation industry to ensure the smooth running of activities such as: tracking a target, surveillance or photography of airspace, autonomous navigation [11]. This gimbal mechanism has two types of control strategies, derived from traditional and evolutionary algorithms, which provide simple but efficient tuning of the parameters of a PID. The two techniques aim to provide the system with high performance and accurate response while ensuring computational efficiency. The PID controller controls the actuators of the gimbal device that regulates the motion of a camera. The authors of the study [11] used the mathematical model of a three-axis gimbal, defined by the Denavit-Hartenberg method, through which they extracted the rotation matrices around the X, Y, Z axes corresponding to the pitch, yaw, and roll motions respectively in Fig. 4.

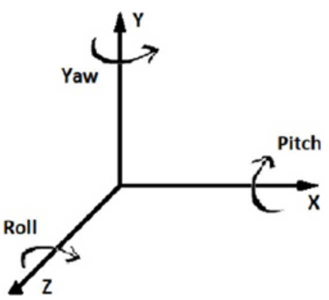


Fig. 4. Types of rotary motion.

The Gimbal mechanism is a stable system that can support an object through 3 different axes. Compared to other mechanical devices that are meant to have a supporting function, which are quite resistant to shocks and vibrations, gimbal mechanisms are complex equipment that are equipped with three or even four motors to be able to control each axis individually and to be able to provide high stability to the handled object, which is of course mounted on the roll, pitch and yaw axes. The most significant part of the gimbal mechanism is that of kinematic analysis, the latter being associated with the consideration of coordinate sideteams for easier determination of the position and orientation of rigid bodies in space, combining their position and transformation of their particular coordinates with classical coordinate systems [16].

In the matrix writing of formula (3) one can observe the mathematically equivalent form of a yaw motion around the vertical axis (Y); In matrix (4), the equivalent form of a roll motion around the longitudinal axis (Z); and in the corresponding matrix (5) one can observe the writing of a pitch motion along the transverse axis (X). Transformation from other coordinate systems into basic coordinate systems e.g., from other systems into the 0-system is the most desired and executed procedure. Thus, the basic rotation matrices for the case where the three-dimensional system is used are as follows:

$$R_1 \begin{pmatrix} \cos\alpha & -\sin\alpha & 0 \\ \sin\alpha & \cos\alpha & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad (8)$$

$$R_2 \begin{pmatrix} 1 & -0 & 0 \\ 1 & \cos\alpha & -\sin\alpha \\ 0 & \sin\alpha & \cos\alpha \end{pmatrix} \quad (9)$$

$$R_3 \begin{pmatrix} \cos\alpha & 0 & \sin\alpha \\ 0 & 1 & 0 \\ -\sin\alpha & 0 & \cos\alpha \end{pmatrix} \quad (10)$$

If multiple rotations are performed, the matrices corresponding to these movements defined above are multiplied together to obtain the final matrix corresponding to the rotation process. Direct kinematics or process-specific kinematics, thus calculated, compute the final position and orientation of the final rotation effect, which is realized according to the articulation variables of the system quadrant. Therefore, although many of the coordinate systems can be connected in an arbitrary way in accordance with the quadratic links, as well as systematically selecting the position and orientation of the systems to increase the efficiency and reduce the computation. Therefore, systems connected by linkages and thus any homogeneous transformation such as transformations from system i to systems of type i-1 can be expressed by means of one product of four basic transformations as follows:

$$H = Rot_{x,a} Trans_{z,d} Rot_{z,\theta} = \begin{pmatrix} C_{\theta i} & -S_{\theta i}C_{\alpha i} & S_{\theta i}S_{\alpha i} & \alpha i C_{\alpha i} \\ S_{\theta i} & C_{\theta i}C_{\alpha i} & C_{\theta i}S_{\alpha i} & \alpha i S_{\theta i} \\ 0 & S_{\alpha i} & C_{\alpha i} & d_i \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad (9)$$

Further where ai, αi, di, θi represent link length, link twist, link offset, and joint angle of the ith interface and the ith joint respectively. However, it should be taken into account that the Ti-1 matrix is a function that has only one variable, consequently, three of the parameters represented above will always be constant and only one of them will be variable. In conclusion, θi is a variable if the ith joint is rotational, and di is a variable if the ith joint is prismatic [16].

C. Parkinsonian Tremor Monitoring Devices

Wearable sensor technology is increasingly used in the early detection of symptoms characteristic of PD (Parkinson's Disease) [17].

Wearable sensors are wearable and mobile accessories that can be worn on the body or incorporated into an individual's clothing. These devices include smart glasses, smartwatches, smart clothing, or footwear fitted with pressure sensors, among others. They contain both pre-defined hardware functionality and software technology with unique functions for collecting space-temporal kinematic parameters, data processing, storage, and transmission. With the rapid development of the Internet of Things and the emergence of machine learning algorithms, wearable technology has been widely used in various fields. Currently, most wearable devices used in the field of PD are gyroscopes, accelerometers, or magnetometers. Through specific software designed to reproduce motor gestures, these devices can perform real-time monitoring of PD symptoms to establish multiple data patterns. This allows clinicians to accurately analyze patients' movement status in real-time [18].

A new algorithm was developed to assess the tremor of PD patients by calculating the percentage of time the tremor is maintained (PTT) between the hourly intervals 09:00 - 18:00 to distinguish between resting and postural tremors. This algorithm not only increased the sensitivity and selectivity of the assessment of tremor occurrence but also analyzed the relationship between tremor and bradykinesia. In addition, the algorithm identified a threshold at which tremor begins to occur. This approach to quantifying tremors will help researchers understand the neural mechanisms of PD and develop new therapies [19].

D. Assistive Devices for Parkinson's Patient

Lift ware is a computerized self-stabilizing handle and features a selection of accessories, including a spoon. The choice of all accessories has been carefully made so that the prototype does not inconvenience the user in performing the feeding activity when using it. At its base is the micro-controller whose main purpose is to process data to combat pitch and roll movements. The MPU-6050 sensor was chosen for data acquisition because it uses the basic principles of the IMU sensor. The responsible output elements in this product are two SG90 servomotors which are connected to the Arduino development board. The servomotors were attached to the project at a 90-degree angle. The choice for this implementation is since a servomotor cannot rotate at a negative angle, so we want to have equal ranges of servo rotation in both directions.

This assembly compensates for hand tremor, allowing people with mild to moderate tremors due to conditions such as essential tremor, Parkinson's disease, or other neurological disorders to eat more easily. The handle uses computer technology to detect the direction of the tremor and move the utensil attachment in the opposite direction.

Another review involving studies in the existing literature led us to study [19], which proposed an approach, using including the Internet of Things (IoT) and machine learning. It started from a prototype like the previous projects, using an inertial measurement unit (IMU), a microcontroller, this time different from Arduino, namely, MSP430 developed by Texas Instruments and two units represented by servomotors. As a control strategy, a PID implementation was chosen, on data filtered by a median filter.

E. Unit of Inertial Measurement

An inertial measurement unit, or IMU for short, is a hardware component consisting of a combination of three gyro sensors and three accelerometers placed orthogonally to each other to form a coordinate system. We refer to this type of IMU as a 6-axis IMU. Depending on the requirements of the systems in which it is used, three magnetometers may also be included, resulting in a 9-axis IMU. Number three indicates that one component is assigned to each of the three axes of motion of a vehicle.

Technically, the term “IMU” refers only to the sensor itself, but IMUs are also often associated with fusion software that combines data from multiple sensor types to provide bearing and direction measurements. Commonly, the term "IMU" can be used to refer to the combination of the sensor and its fusion software; this combination is also referred to as AHRS (Attitude Heading Reference System).

When installed on a device, the IMU can capture data about the motion of the device, measuring and reporting the specific acceleration and angular velocity of a body, in some cases even the magnetic field.

Specific IMU applications include a variety of industries and domains, so IMU sensors find application in GPS systems, user gesture tracking systems, drone industry, robotic vacuum cleaners, or other IoT devices. IMUs are also found in antenna or satellite positioning tasks and manned and unmanned aircraft handling.

Are micro-electromechanical systems that are made using microfabrication technologies. These devices can range in size from less than a micron to a few millimeters and can vary in complexity from very simple mechanical motion systems to highly sophisticated systems with integrated electronics [20].

F. Overview of the IoT Device Implemented

One problem encountered in the design of self-balancing systems is the locking of the system when a physical phenomenon occurs that leads to the alignment of two of the three axes and thus results in the loss of a degree of freedom in the rotational motion. The gimbal locking phenomenon imposes a constraint on gimbal mechanisms and requires proper expert analysis [14]. As a result, the current scientific framework proposes numerous methods by which its occurrence can be avoided.

To place the theoretical foundations introduced in the previous paragraphs in a motivational context that also implies the importance of the project, the idea of this paper arose from a thorough study of Parkinson's syndrome, the concepts that constitute e-health and self-health systems. Thus, with the help of tremor compensation devices, people affected by Parkinson's syndrome can more easily perform some tasks that occur in everyday life. With a stabilizing spoon, a patient can eat independently and does not need assistance from another person. The motivation is to make a positive impact in the community: all over the world, food is eaten with a spoon in the first place, and because of this disease, people affected by it cannot keep the spoon stable enough to have a smooth experience in the task of eating a meal. The most effective way to solve this difficulty is to create a device that counteracts the movement of the hand to allow only minimal vibrations to manifest.

The implementation method chosen for use in this work involves the creation of a prototype, with a high degree of efficiency and which excludes an expensive budget related to the variants available on the market, which are not within the reach of all social categories of patients. The latter are key arguments in defining an implementation plan that includes the use of a list of components.

The following specific components were used to design this system to help people suffering from Parkinson's disease: Arduino UNO, Arduino Nano, MPU-6050 Sensor, SG90 Servomotor, XL6009 Voltage and a Lowering Module.

The code was written to read the angles along the x, y and z axes from the accelerometer sensor and the gyroscope sensor, which provide data according to the equivalent rotation matrices (8), (9), (10) on pitch, roll and yaw movement. The data from the two sensors were merged to render the real-time changes in pitch of the IMU sensor. Fig. 5 shows the real-time characteristic movements provided as input data from the IMU MPU6050 sensor, aiming to highlight the characteristic movements represented by different colors as follows: pitch-blue, roll-red, yaw-green.

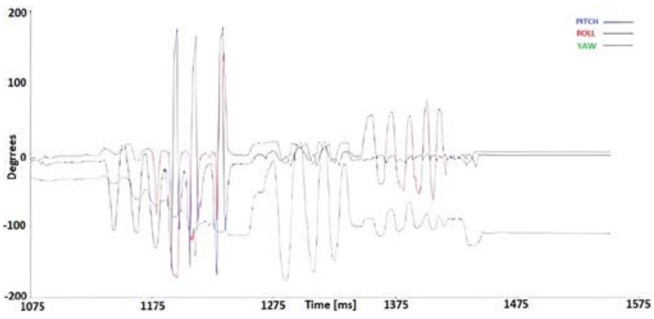


Fig. 5. Characteristic pitch, yaw, and roll movements.

The application we want to realize aims to combat pitch and roll movements, so it is necessary to use a two-axis gimbal system, represented by two SG90 servo motors and in Fig. 6 is presented the functional diagram of the IoT device. The software for this project was programmed in the Arduino IDE environment. The program is divided into four parts: Angle reading and data collection (green), Kalman filter application (yellow), PID controller application (red) and servo motor control (blue).

Fig. 6. Functional diagram of the application.

III. Reliability Assessment

A. PTC Windchill Quality Solutions

PTC Windchill Quality Solutions is a software program that can calculate the reliability of a product or system. This software can simplify a system by dividing it into several sub-systems which makes the interpretation of the whole system much easier. Once these subsystems are visible and completed by the user with the necessary elements there is the opportunity to do the calculation individually on each division of the system to calculate each independent part of it independently.

Also, within this property, we have the possibility to visualize the reliability of each component once each element is completed according to the datasheet.

Another important aspect that is favored by this software is that after the whole assembly there is the possibility to visualize the reliability of the system and subsystems in the form of graphs [21].

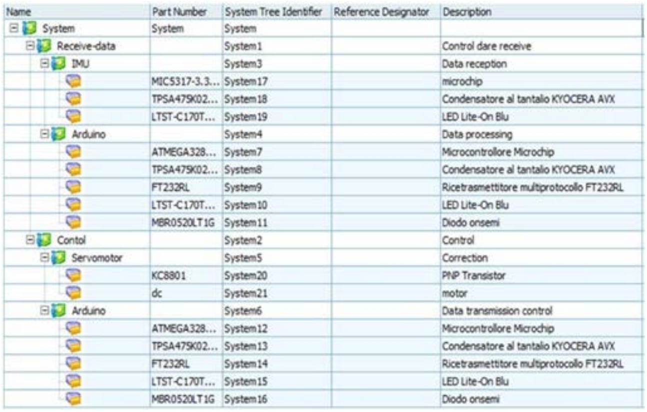
B. Reliability Indicators Computation

To calculate the reliability of this control system, it is necessary to divide it into subsystems and assign the necessary data to calculate each part of the whole. The first step is to divide the whole system into two essential subsystems, namely the acquisition subsystem and the second control subsystem.

- The first subsystem of data acquisition for object position identification is called "Receive-data" and has in its composition the IMU sensor which is composed of 3 main components and the Arduino board which is composed of 6 components that influence its reliability.
- The second subsystem is responsible for the behavior of the prototype and is called "Control". It has in its composition 2 elements, namely Arduino, which is responsible for data processing, and Servomotors, that

must perform the movement of the prototype accordingly.

All these components described above can be seen in Fig. 7. Each of the two subsystems has a common part, namely Arduino. Using this development board, all the necessary data processing can be easily done, which makes the interaction inefficient communication with the environment.



Name	Part Number	System Tree Identifier	Reference Designator	Description
System	System	System		
Receive-data		System1		Control dare receive
IMU		System3		Data reception
	MIC5317-3.3...	System17		microchip
	TPSA475K02...	System18		Condensatore al tantalio KYOCERA AVX
	LTST-C170T...	System19		LED Lite-On Blu
Arduino		System4		Data processing
	ATMEGA328...	System7		Microcontrollore Microchip
	TPSA475K02...	System8		Condensatore al tantalio KYOCERA AVX
	FT232RL	System9		Ricetrasmettitore multiprotocollo FT232RL
	LTST-C170T...	System10		LED Lite-On Blu
	MBR0520LT1G	System11		Diodo onsemi
Contol		System2		Control
Servomotor		System5		Correction
	KC8801	System20		PNP Transistor
	dc	System21		motor
Arduino		System6		Data transmission control
	ATMEGA328...	System12		Microcontrollore Microchip
	TPSA475K02...	System13		Condensatore al tantalio KYOCERA AVX
	FT232RL	System14		Ricetrasmettitore multiprotocollo FT232RL
	LTST-C170T...	System15		LED Lite-On Blu
	MBR0520LT1G	System16		Diodo onsemi

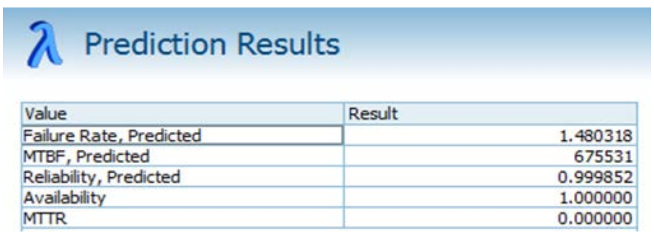
Fig.7. System structure.

Once the structure of the whole system has been properly defined, the next step is to assign specifications to each component of the assembly, according to the datasheet provided by the manufacturer. The summary of the data is shown in Table I. This data is entered manually and accurately into the calculation table so that any minor mistake in entering this data can lead to a major change in the result.

TABLE I: SPECIFICATION DATA

PartNumber	Identifier	Operating voltage	Rated voltage	Max Temp Rating	Min Temp Rating
ATMEGA328P-AU	System1	2.7	5	85	-40
TPSA475K020R1800	System2	2.5	20	128	-55
FT232RL	System3	3.3	5	85	-40
LTST-C170TBKT	System4	2.8	5	100	-30
MBR0520LT1G	System5	0.38	20	125	-65
ATMEGA328P-AU	System6	2.7	5	85	-40
TPSA475K020R1800	System7	2.5	20	128	-55
FT232RL	System8	3.3	5	85	-40
LTST-C170TBKT	System9	2.8	5	100	-30
MBR0520LT1G	System10	0.38	20	125	-65
MBR0520LT1G	System11	2.5	6	125	-40
MIC5317-3.3YM5-TR	System12	2.5	20	125	-55
LTST-C170TBKT	System13	2.8	5	100	-30
KC8801	System14	3.4	7	75	-20
DC	System15	4.8	6	60	-30

Once all the required fields according to the whole system under study have been carefully filled in, as shown in Fig. 7, the next step is the calculation by means of the software used for data synthesis purposes for the compounds entered. The calculation automatically generates values for Failure rate, Mean time between failures, Reliability, Availability. All these results listed above can be viewed in Fig. 8.



Prediction Results

Value	Result
Failure Rate, Predicted	1.480318
MTBF, Predicted	675531
Reliability, Predicted	0.999852
Availability	1.000000
MTTR	0.000000

Fig. 8. Calculated values.

For the best performance of the product, we need to make sure that it can perform all its tasks in real time, so we decided to calculate the reliability of the product as a function of temperature. Temperature can lead to premature damage of components, by overheating them having a negative impact on the performance of the entire system. Also, if the product is operated at a very low temperature its components cannot operate at extreme conditions, thus may lead to irreversible damage to the product. An overview of the temperature ranges in which the prototype operates under optimal conditions can be seen in Table I.

It can be seen in Fig. 9 that once the threshold of 50 degrees is exceeded the failure rate has an increasingly substantial increase.

Once Prediction Results are calculated and we can access them we could calculate a suite of reports. These reports help us to observe the behavior of the system in certain situations and its ability to evolve according to requirements.

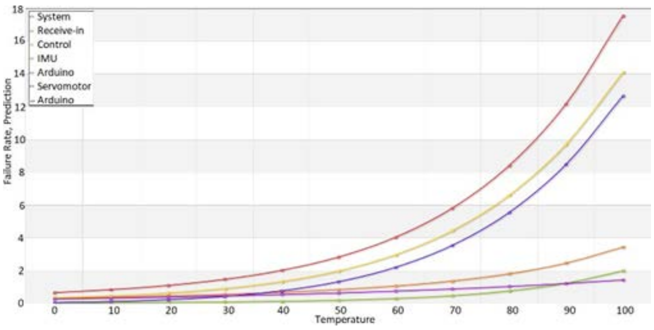


Fig. 9. Failure rate vs Temperature.

To be able to visualize the top 5 failure rates components, the diagram in Fig. 10 is generated showing these components according to their failure rate, indicating on each of them the exact rate in figures.

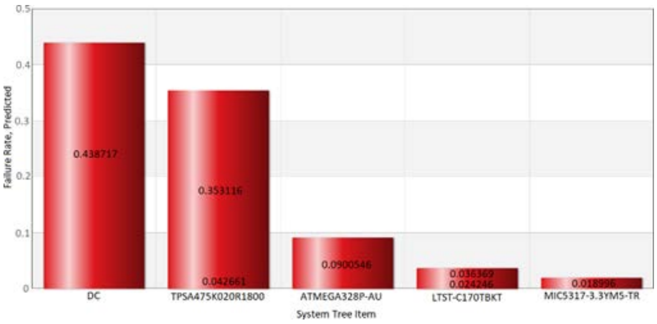


Fig. 10. Top 5 Failure rate components.

IV. CONCLUSIONS

Gimbal systems are a major point of interest in 21st-century industries with various areas of use. Their implementation in the eHealth industry brings increased benefits in healthcare, especially when it comes to the motor difficulties faced by Parkinson's patients.

This project tested the implementation of gimbal mechanism principles in the creation of an eHealth support device for Parkinson's patients. The spoon works effectively in combating pitch and roll movements generated by tremors. The PID control provides high system stability but is challenged by the low hardware specifications of the components.

This research may help any maker of IoT devices, from design to prototype. The standard features of reliability and its indicators are obtained in this manner. Warranty terms and conditions, as well as repair and replacement conditions, may be decided, all of which are critical pieces of information for any manufacturer.

The reliability of an IoT device prototype has been investigated, with the influence of the environment on its components demonstrated. These projections are critical for planning preventative maintenance actions. All the findings show that the designed IoT device has a solid design, that all of the parts work correctly, and that unexpected failures are improbable.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Misaros Marius made the assistive device for the Parkinson's patient. Stefan-Dragos Cîrstea carried out the research. Dan-Ioan Goța wrote the article. Ovidiu-Petru Stan calculated the reliability of the system. Cristian-Liviu Miclea analysed the data. All authors had approved the final version.

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