Proceedings of

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FOREWORD

The everyday life of the ordinary people is full of automated gadgets, e.g.: intelligent washing machines, dishwashers; remote controlled TV sets, music centres; almost full automated car drive systems; mobile phone controlled AC system of the house etc. These mechatronic devices are designed by the highly qualified mechatronic engineers, technicians. The fundamental task of institutions having technical tendency in higher education, is to provide these highly qualified technicians, engineers, developers to the society.

After the recession of the 1990s, Hungarian industry has started a dynamic growth and by 2000 it has already significantly extended. The determining factor for this increase was a major growth in exports, primarily concerning the products of multinational companies (Opel, Audi, Mercedes). By applying advanced mechatronics technology and in collaboration of domestic suppliers have also been able to expand their production. To maintain this development, highly qualified engineers are required who are familiar with modern design, technological and operational methods and are able to adapt the knowledge into practice. In order to meet these needs, we decided to start the Mechatronics BSc course.

The predecessor of Óbuda University -the Budapest Tech-, firstly introduced bachelor's level "mechatronics engineering" course in September 2005. As an opportunity for full academic education, in September 2009 we started mechatronics engineering on master's level too, however only as a part-time education course.

The English language Mechatronics course, launched in 2011, gives the frame for more intensive participation in international programmes like ERASMUS by admission of foreign teachers and students. It results in an increased mobility of Hungarian students and teachers.

This conference series[1], started in 2012, targeting: to provide opportunity to the students, for Hungarians as well as students from abroad (e.g. Erasmus), to deepen their knowledge in the field of mechatronics sciences, to networking, to improve their professional knowledge, presentational skills and proficiency in English communication.

This is the first time (IMSμ2016), when the students have submitted their papers, not just orally presented their works. The revised manuscripts are collected in this proceeding.

Nagy I.

....
Conference Founding Chair

[1] International Mechatronic Students micro-Conferences

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International Mechatronic Student Micro-Conference

Bánki Donát Faculty of Mechanical &Safety Engineering,

Budapest, 20th of December 2016.

THE MECHATRONIC EDUCATION AT THE BÁNKI FACULTY OF ÓBUDA UNIVERSITY

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Abstract

The predecessor of Óbuda University, -Budapest Tech-, first introduced its bachelor's level "mechatronics engineer" course in September 2005. As an opportunity for full academic education, in September 2009 we started the mechatronics engineering on master's level, too, however only on part-time course. In year 2011 the English Mechatronic Course has been launched on BSc level, and later in 2015 on MSc level. These new conditions motivated the institute constantly renew its mechatronic teaching plan. In this paper the history of formation of "Institute of Mechatronics and Vehicle Engineering" as well as the developing of the Mechatronics Teaching Plans will be introduced.

Keywords: Mechatronic, Teaching Plan, Credits, Ministry of Human Resources MHR,

1. Introduction

Hungarian industry after the recession of the 1990s has started a dynamic growth and around 2000 it has already achieved significant progress. The determining factor for this increase was a major growth in exports, primarily concerning the products of multinational corporations applying mechatronic high-technology, in collaboration with domestic suppliers. To maintain this development knowledgeable engineers are required who are familiar with modern design, technological and operational methods, and are able to adapt them into practice. In order to meet these social needs, Budapest Tech decided to start the Mechatronics BSc course [1].

1.1. The history of formation of the "Institute of Mechatronics and Vehicle Engineering"

Regarding to the development line of the *Mechatronic Institute*, we have to consider the following predecessors. In year 1879 has been established the "*Public Secondary Industrial School of Budapest*", what later operated under the name "*Hungarian Royal Public Higher Industrial School*" (year 1898). As a result of educational reforms following World War II, the school provided training and education as a secondary school of mechanics. At the ceremony of the 75th anniversary of its foundation, the institution adopted the name of **Donát Bánki** [2]**.** In 1969 the institution earned the **College** rank. From 1991**,** the name of the institution was modified to **Donát Bánki Technical College** by broadening the educational profile, ensuring that engineers have a wide range of professional skills and state-of-the art information [2]. By integration of three highly noted colleges of Budapest: Donát Bánki Mechanical, Kálmán Kandó Electrical Technical Colleges and Technical College of Light

Industry was established the **Budapest Tech**, in year 2000. Here, the "**Institute of System and Machine Engineering**" was the predecessor of the "**Institute of Mechatronics and Vehicle Engineering**". In year 2010 the Budapest Tech, based on actual accreditation, earned the "university" level and continued as **Óbuda University**, with 5 faculties, from which the above mentioned institute is acting in ***Donát Bánki Faculty of Mechanical and Safety Engineering***.

1.2. The history of formation of the Mechatronic Course

The mechatronic education began during the period of *Donát Bánki Technical College*, by teaching of subject "***Basics of Mechatronics***", in year 1997. This subject has been taught ever since, only the number of hours and prerequisites have changed.
According to the Bologna Agreement, from September 2005, the two level training (BSc, MSc) has been introduced in the Hungarian system of higher education. At the Óbuda University the BSc "*mechatronics engineer*" **course** was introduced in 2005, in Hungarian, and in year 2009 the MSc, also in Hungarian. Two years later, in the 2011/12 academic year, the English mechatronic course has been started at the Bánki Donát Faculty of Mechanical and Safety Engineering. That time, the actual directive stated the tasks of mechatronic engineers in following way: The mechatronic engineer receiving BSc level education has to be able to create mechatronic equipment as well as their installation, operation, maintenance and control. MSc level engineers can be involved also into researching and development tasks. Nowadays the requirements are stated by the ministry of education also in form directives.

2. The teaching plan developing

The actual Teaching Plan developing in form of directive originates from Ministry of Human Resources (MHR), and contains the general features (as level of qualifications, attitudes, responsibility, etc…) and competencies of the graduates of different professions. These features are commonly named as *"educational and outcome requirements"* of the given profession. One of these professions is "Bachelor/Master Level of Mechatronical Engineering", where the graduates are titled as "Mechatronical Engineer" [3]. Generally, in this directive are stated the followings:

- denomination of the profession (Mechatronical Engineering)
- qualification (Mechatronical Engineer)
- level of qualification (BSc/MSc)
- educational area (technical)
- length of education (BSc-**7** semesters/MSc-**4** semesters)
- number of credits (BSc-**210** credits/MSc-**120** credits)
- aims of education
- competencies to be acquired
- other features, as basic characterization of the given profession

2.1. Basic Characteristics of the Mechatronic Course

The basic characteristics of the mechatronic course is beginning by the features obtained from MHR, where are stated the scientific disciplines/areas of the profession from which the course is built up. These areas (with the recommended min-max credits) are, see **Table 1**.

Table 1. *The basic knowledge areas, with recommended min-max Credits in Mechatronic education*

BSc Level	***MSc Level***
Natural Sciences (40-50 credits)	Natural Sciences (25-35 credits)
Economics and Human Sciences (14-30 credits)	Economics and Human Sciences (10-20 credits)
Basic Mechatronic Knowledge (70-105 credits)	Basic Mechatronic Knowledge (15-35 credits)
Specialized Mechatronic Knowledge (min 40 credits)	Specialized Mechatronic Knowledge (40-60 credits, together with thesis credits)

The first 3 rows of **Table 1**. contains the basic knowledge areas, while the last, 4th is the specialization one. What is this mean? The mechatronic course, depending on the particular institution (university or college), can have several specializations, e.g.: bio-mechatronics, opto-mechatronics, etc…

Óbuda University, over the basic mechatronic knowledge, has 1 specialization on the BSc level (**Industrial Robot Systems**), and 2 on the MSc level (**Vehicle Informatics** and **Mechatronics of Intelligent Robot Systems**).

The basic characterization of the course is continuing by the defining of **requirements** regarding **foreign languages** and defining of **requirements of internships**.

2.2. Characteristics of the Mechatronic Course at the Óbuda University, Donát Bánki Faculty of Mechanical and Safety Engineering

Starting by the directive of MHR, the teaching plan of Hungarian institutions having technical orientation is generally structured into four main knowledge areas: Natural Sciences, Economics and Human Sciences (HR), Basic Professional Knowledge (*in case of mechatronics: Basic Mechatronic Knowledge*) and Specialized Knowledge. Basically it is not differing in case of Óbuda University, for the exact classification, see **Table 1**. For the accurate classification of the areas with the actual assigned credit points, see **Figure 1**., and **Figure 2**.

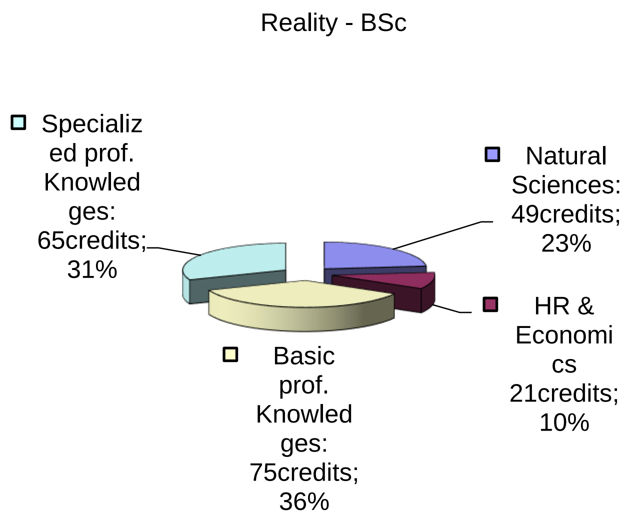

Fig.1. *The main knowledge areas of* ***BSc*** *level with the real assigned credit points*

If the credits are summarized the result (*210*) is in compliance with the credit numbers given in listing (*6th row*) in *Chapter 2* of this paper.

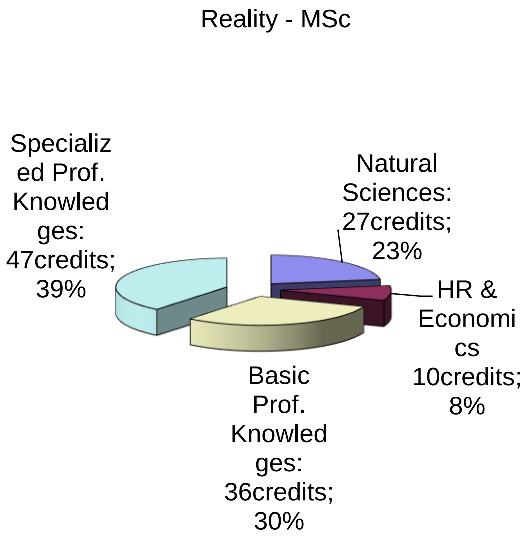

Fig.2. *The main knowledge areas of* ***MSc*** *level with the real assigned credit points*

This credit system is also agreeing with the expected, because after summarizing the result (*120*) is in compliance with the credit numbers given in listing (*6th row*) in *Chapter 2* of this paper.

Properly to the latest definition of Mechatronics "*Is a synergetic integration of physical systems with IT and complex-decision making (in the design, manufacturing and operation of industrial products and processes)*", see **Figure 3**.

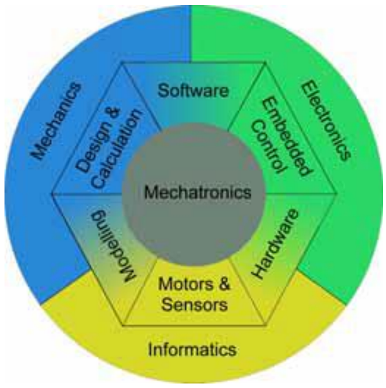

Fig.3. *The Mechatronics is a synergic integration of illustrated knowledge areas*

There are three faculties are participating in the Mechatronic Education at the Óbuda University. There are:

- Donát Bánki Faculty of Mechanical & Safety Engineering
- Kálmán Kandó Faculty of Electrical Engineering
- John von Neumann Faculty of Informatics

In order to achieve better quality of education the professional subjects are reasonable shared between these faculties.

2.3. Developing of the Teaching Plan

Basically at the teaching plan developing we have to consider firstly, the directives of MHR, secondly the special directives of University, which are refining and concretize the previous one. Such regulations are, e.g.:

- number of contact hours/week/subjects (variable)

- number of credits/semester (27-33 credits)
- stating the internships requirements (summer internship 6 weeks, integrated professional internship 14 weeks)
- stating the minimal entry requirements for English/German courses (intermediate language exam)
- stating the credit transfer rules
- defining the compulsory and optional subjects
- etc…

If these rules are kept, this ensures the balanced academic life of students, such as mentors. Moreover, in each developing have to be considered the available HR and laboratory background, too. At the Óbuda University the topics, subjects and the requirements of the mechatronic course are the same in both (Hungarian and English language) education forms, i.e. the curricula are totally identical. The personal background of this course is provided by the long-term expertise of the teaching staff involved into the Integrated Engineering Course programme, which course is running out soon. The subjects comes under the BSc/MSc degrees at given specializations are given in **Tables 2., 3.**

Table 2. *The basic knowledge areas in BSc Level, with appropriate subjects*

BSc Level , specialization – Industrial Robot Systems			
Natural Sciences	***HR & Economics***	***Basic Mechatronic Knowledge***	***Specialized Mechatronic Knowledge***
Mathematics I,II	*Macro-microeconomics*	*Informatics I,II*	*Industrial Robot programming & Simulation*
Eng. physics	*Business Economics I,II*	*Machine design I,II*	*Robotics & production automation*
Intro to Mechatronics	*Quality assurance*	*El. machines & drives*	*Industrial robot kinematics & dynamics*
Mechanics I,II,III	*Legal knowledge*	*CAD systems*	*Mechatronic system diagnostic*
Electrical Eng.	*Basics of Management*	*Material technology*	*Basic operation of mobile robots*
Engineering materials		*System engineering*	*Vehicle mechatronics*
Basics of Material Technology		*Control Engineering*	*CAD designing*
		Programming languages	*IT networks*
		Digital techniques	*Diploma work / project work*
		pneumatics & hydraulics	
		PLC knowledge	

		Manufacturing engineering	
		Electronics	
		Precision mechanics	
		Interfaces	
		OSH safety Eng.	

Table 3. *The basic knowledge areas in MSc Level, with appropriate subjects and specializations*

MSc Level , and specializations: 1, 2				
Natural Sciences	***HR & Economics***	***Basic Mechatronic Knowledge***	***1. Vehicle Informatics***	***2. Mechatronics of Intelligent Robot Systems***
Optimization methods	*Business Economics*	*Embedded systems*	*Vehicle's information systems*	*Intelligent systems*
Eng. physics	*Engineering management*	*Micro-, Nano techniques*	*Vehicle dynamics*	*Multi-agent mobile robot systems*
Selected Chapters of Mechanics		*Engineering optics*	*Vehicle electronics*	*Modern productive technologies*
Electricity		*Modelling & Simulations*	*Transport's information technology*	*Adaptive Control Systems*
Selected parts of Thermo- & Fluid dynamics		*System & Control theory*	*Multi-agent mobile robot systems*	
Material Sciences		*Mechatronic constructions*	*Reliability of the mechatronic systems*	
		Sensors & Signal analysis		
		Intelligent Eng. Systems		
		CAD systems		
		Fuzzy systems		
		Self-organizing systems		

As clearly can be seen in **Tables 2, 3**, the mechatronic education on BSc level has just one specification, while in MSc level there are two specifications.

Further expectation regarding Mechatronic education is referring to balance the theory vs. practice ratio, what will be discussed in chapter *3. Conclusion*.

3. Conclusion/Summary

In the conclusion I would like to compare the credit points given by Ministry Directives versus real credit points earned by real subjects in real teaching plan, and the predetermined practice vs. theory ratio by the real ratio one.
Firstly, lets carefully check the **Tables 2, 3**. The attentive reader will recognize, that subjects in MSc course are based on subjects given in BSc level. It was very important, that the MSc subjects must give more specific, more exact knowledge and certainly widen the scientific viewing angle of students. And finally the evaluations, where on *X* axis are the Basic Knowledge Areas: 1-*Natural Sciences*, 2-*Economics & HR*, 3-*Basic Mechatronic Knowledge* (*as it is given in* **Table 1.**) and on *Y* axis are given the min-max credits recommended by MHR and in the middle (*purple*) the earned real credits after completing the teaching plan, see **Figures 4, 5, 6.**

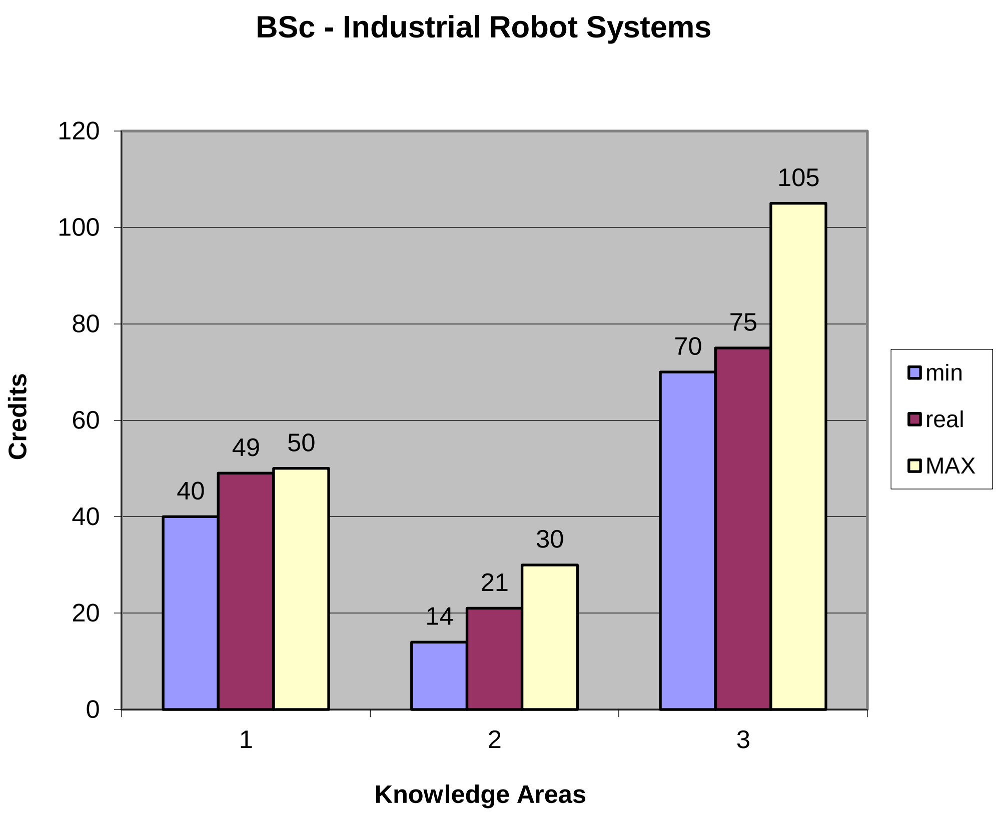

Fig.4. *The BSc level comparison – specialization: Industrial Robot Systems*

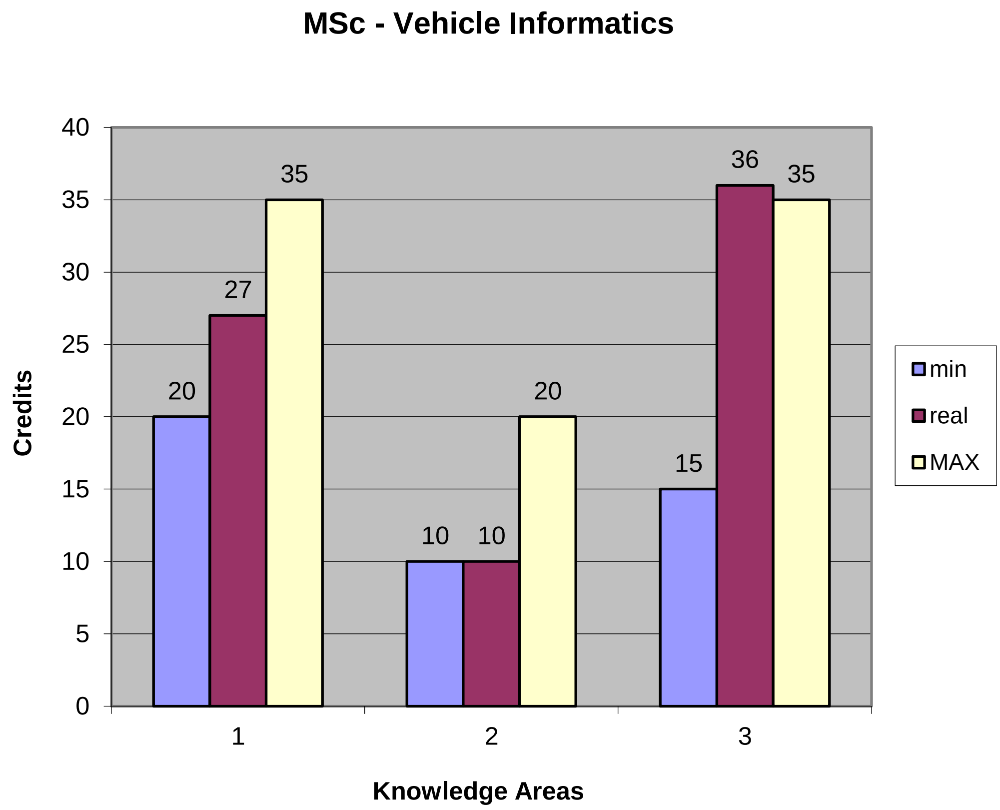

Fig.5. *The MSc level comparison – specialization: Vehicle Informatics*

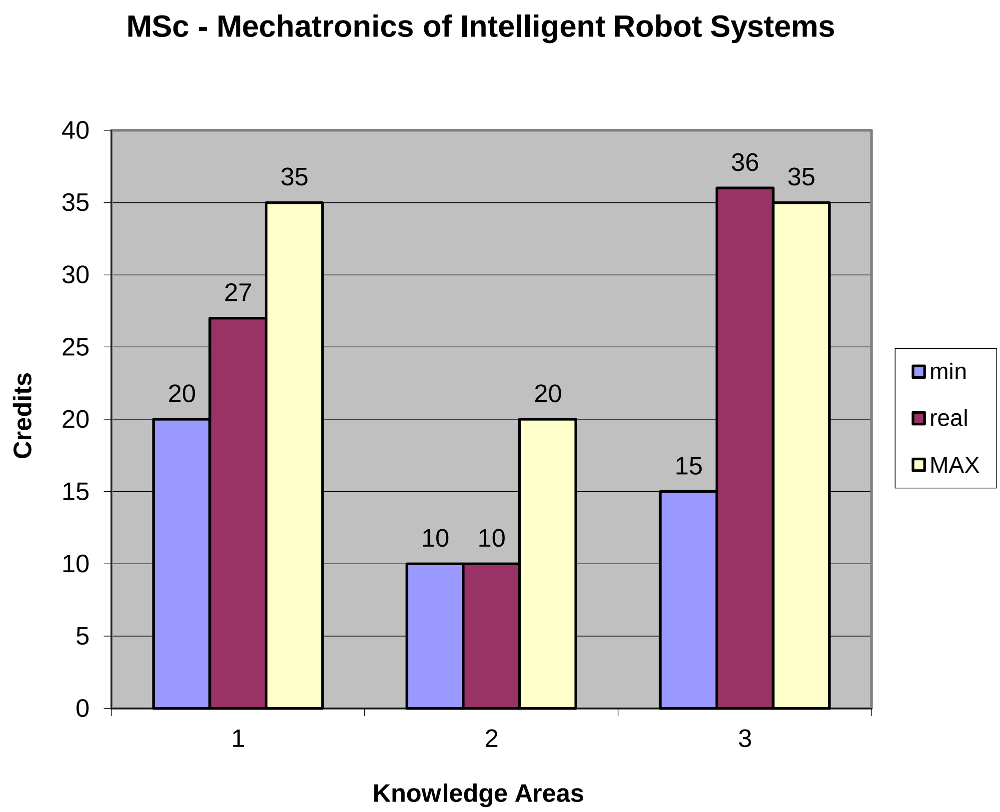

Fig.6. *The MSc level comparison – specialization: Mechatronics of Intelligent Robot Systems*

Regarding recommended (*what was **40% vs. 60%**)* and real *practice vs theory* ratio, see **Figure 7,8.**

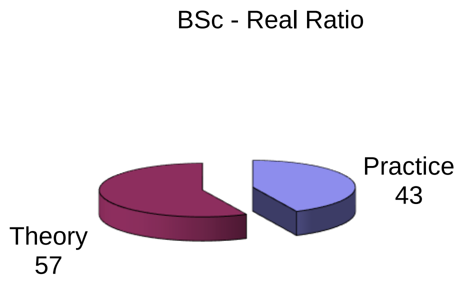

__Fig.7.__ Earned Real Ratio on BSc Level

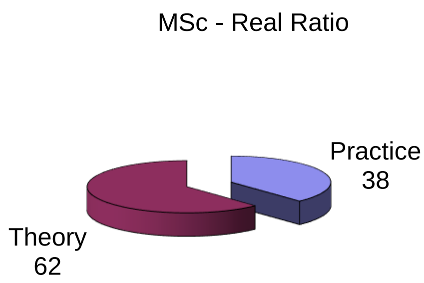

__Fig.8.__ Earned Real Ratio on MSc Level

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International Mechatronic Student Micro-Conference

Bánki Donát Faculty of Mechanical &Safety Engineering,

Budapest, 20th of December 2016.

INVESTIGATING CONFIGURATION SPACE SINGULARITIES OF A KUKA KR5

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Abstract

Automation has become a key segment of the industry. Although automating several tasks within a factory might be capital intensive, in the long term it is actually cost effective. In order to automate these tasks, we need robust and efficient machines. A class of these machines are robots, and within the robots we have manipulators. These manipulators usually mimic the form of a human arm, hand, or fingers. A combination of joints, links, actuation and control of these joints, enables one to achieve full automation of common industrial tasks. Within the Department, we are lucky to have a KUKA KR5 arc welding robot. This robot has a maximum payload of 5kg, is robust and quite efficient. But there's a very serious and dangerous problem with these class of robots. They experience what is known as singularity. At specific configurations when controlling the robot in the world coordinate frame, the velocity of the joints tends to infinity, as the determinant of the jacobian matrix becomes zero. At this instant we lose control of the robot and, its operation is unpredictable and unstable. There are several ways one might tackle the problem. These include; revision of the mathematical theory, enhancing the robot's controller to handle singularities, or enforcing mechanical limits.

Keywords: configuration space, operational/task space, jacobian

1. Introduction

Our research began with first understanding the motion of the robot, and how to represent this motion mathematically. We derived a system of equations representing the robot's dynamics, and kinematics. Observing the rules of a control law and utilizing the system of equations, we developed a LabVIEW VI for designing and simulating the robot's joint controller. We set out to develop a robust and critically damped controller model.

2. Brief Description

<u>The Robot System</u> consists of:

- the ROBOT itself;
- a robot CONTROLLER;

- a CABLE SET;
- a KUKA CONTROL PANEL(KCP) teach pendant;
- SOFTWARE;
- and OPTIONS [SafeRobot(robot moves within configured limits), RoboTeam(cooperation with other robot systems)].

The Robot is designed as a ***6-axis jointed*** arm kinematic system, its ***main components*** are:

- an ARM;
- an IN-LINE WRIST;
- a ROTATING COLUMN;
- the BASE FRAME;
- a LINK ARM;
- and ELECTRICAL INSTALLATIONS.

The base of the robot is the Base Frame, which is bolted to the mounting base. Located at the base frame, is a flexible tube for the electrical installations, as well as a cable junction box.

Within the Rotating Column are the motors for axes 1 and axes 2. The rotational motion of the robot about axis 1, is a result of the column rotating. The column has the link arm mounted on it, and is screwed to the base frame via a gear unit.

The Link Arm consists of the link arm body located between the arm and the rotating column.

Between the in-line wrist and the link arm, is the Arm. The arm carries the motors of the wrist axes (A 4, A 5, A 6), as well as its main axis (A 3). Buffers attached to the link arm mechanically limit the arm's maximum swivel angle.

The end effector is attached on the In-line Wrist's mounting flange. Axes 4, 5, and 6 are located at the in-line wrist.

3. Technical Data

Basic Data about the robot system include:

- it's type → [KR 5 arc];

– it has a total number of [6] axes;

– a pose repeatability of radius [±0.04**mm**];

– [8.4$\mathbf{m^3}$] of working envelope space;

– with a reference point at the [intersection of axes 4 and 5];

– and it's weight is [approx. 127**kg**].

The <u>Connecting Cables</u> include:

– a motor cable → [X20 - X30];

– a control cable → [X21 – X31];

– a SafeRobot control cable → [X21.1 – X41];

– and a ground connector.

The <u>Axis Data</u> include:

– Axis [1] has a range of software limited motion between [±155°], with a rate payload speed of [154°/**s**];

– Axis [2] has a range of software limited motion between [+65° to -180°], with a rate payload speed of [154°/**s**];

– Axis [3] has a range of software limited motion between [+158° to -15°], with a rate payload speed of [228°/**s**];

– Axis [4] has a range of software limited motion between [±350°], with a rate payload speed of [343°/**s**];

– Axis [5] has a range of software limited motion between [±130°], with a rate payload speed of [384°/**s**];

– Axis [6] has a range of software limited motion between [±350°], with a rate payload speed of [721°/**s**].

The <u>Payloads</u> include:

– The rated payload is [5**kg**];

– The horizontal and vertical load center of gravity is at [100**mm**] and [120**mm**], respectively;

– The permissible mass moment of inertia is [0.15$\mathbf{kgm^2}$];

– and the maximum total load is [37**kg**].

4. Kinematics

The Denavit-Hartenberg Parameters for the KUKA KR5 include:

- [joints] → A1, A2, A3, A4, A5, A6;
- Joint angles [θ_j **rad**] → q1, q2, q3, q4, q5, q6;
- Links' offset [d_j **mm**] → 400, 135, 135, 620, 0, 115;
- Links' length [a_j **mm**] → 180, 600, 120, 0, 0, 0;
- Links' twist [α_j **rad**] → π/2, π, -π/2, π/2, -π/2, 0.

The forward kinematics of the end effector is derived from a combination of transformations along several axes, starting from the base to the end effector. The product of the forward kinematics function is a homogenous transformation matrix describing the pose of the end effector, ξ_E.

$$\xi_E = \begin{bmatrix} \boldsymbol{T}_{rotation} & \boldsymbol{T}_{translation} \\ 0 \quad 0 \quad 0 & 1 \end{bmatrix} \tag{1}$$

where,

$\mathbf{T}_{rotation}$ and $\mathbf{T}_{translation}$ are the rotational and translational transformations, respectively.

$\mathbf{T}_{rotation}$ may be described as it is, a homogenous transformation matrix. Although this form of representation requires a relative higher amount of computer memory than other representations. Euler angles are another way $\mathbf{T}_{rotation}$ may be represented but notorious for singularities, the popular 'Gimball lock' is an example of the problems associated with Euler angles. Therefore we shall represent $\mathbf{T}_{rotation}$ as a vector of unit quaternions, which is concise and free of singularities. This enables one to represent ξ_E as a vector.

$$\xi_E = [\boldsymbol{T}_{rotation} \quad \boldsymbol{T}_{translation}] \tag{2}$$

5. Dynamics

The mass and inertia properties of the KUKA KR5's parts, proved difficult to come by. Luckily these properties have been generated using Autodesk Inventor. Arun Dayal Udai, C.G Rajeevlochana, and Subir Kumar Saha presented these properties in their research paper titled, '*Dynamic Simulation of a KUKA KR5 Industrial Robot using MATLAB SimMechanics'*. These properties include:

- [parts] → Link0(L0), Link1(L1), Link2(L2), Link3(L3), Link4(L4), Link5(L5), Link(L6);

– [mass **kg**] → 55.4025, 26.9797, 15.9204, 25.8524, 4.08846, 1.61544, 0.0160103;

– [moment of inertia **kgm²**] → $\mathbf{I}_{L0}$, $\mathbf{I}_{L1}$, $\mathbf{I}_{L2}$, $\mathbf{I}_{L3}$, $\mathbf{I}_{L4}$, $\mathbf{I}_{L5}$, $\mathbf{I}_{L6}$.

$\mathbf{I}_{L0}$ = [0.858811, -0.0111649, -0.0995688;

-0.0111649, 1.52724, -0.00250204;

-0.0995688, -0.00250204, 1.30055]

$\mathbf{I}_{L1}$ = [0.321807, -0.0175473, -0.145272;

-0.0175473, 0.467086, -0.0136195;

-0.145272, -0.0136195, 0.477758]

$\mathbf{I}_{L2}$ = [0.54137, 0.000435555, -0.00455128;

0.000435555, 0.55181, 0.0174856;

-0.00455128, 0.0174856, 0.0436346]

$\mathbf{I}_{L3}$ = [0.775113, -0.00947011, 0.0247925;

-0.00947011, 0.750399, 0.00744338;

0.0247925, 0.00744338, 0.207558]

$\mathbf{I}_{L4}$ = [0.00950111, 0.00163357, -8.41256e-006;

0.00163357, 0.0201731, 2.69102e-006;

-8.41256e-006, 2.69102e-006, 0.0241324]

$\mathbf{I}_{L5}$ = [0.00151607, 0.000409305, 0;

0.000409305, 0.00355535, 0;

0.0, 0.0, 0.00358942]

$\mathbf{I}_{L6}$ = [6.20477e-006, 0.0, 0.0;

0.0, 3.01352e-006, 0.0;

0.0, 0.0, 3.29301e-006]

Deriving the equations of motion in configuration space

The velocity of the center of mass and the angular velocity of the $\mathbf{i}^{th}$ link, $\mathbf{v}_{mi}$ and $\boldsymbol{\omega}_i$, respectively, are obtained by the following,

$$\boldsymbol{v}_{mi} = \boldsymbol{J}_i^v \dot{\boldsymbol{q}}, \quad \boldsymbol{J}_i^v \,\varepsilon\, \Re^{3\times n} \tag{3}$$

$$\boldsymbol{\omega}_i = \boldsymbol{J}_i^\omega \dot{\boldsymbol{q}}, \quad \boldsymbol{J}_i^\omega \,\varepsilon\, \Re^{3\times n} \tag{4}$$

where,

$\dot{\mathbf{q}}$ is the joint velocities,

$\mathbf{J}_i^v$ is the Jacobian matrix relating $\mathbf{v}_{mi}$ to $\dot{\mathbf{q}}$,

$\mathbf{J}_i^\omega$ is the Jacobian matrix relating $\boldsymbol{\omega}_i$ to $\dot{\mathbf{q}}$.

The total energy of the system, T, can be expressed as,

$$T = \frac{1}{2}\dot{\boldsymbol{q}}^T \boldsymbol{A}(\boldsymbol{q})\dot{\boldsymbol{q}} \tag{5}$$

where,

$\mathbf{q}$ is the joint displacements

$\mathbf{A}(\mathbf{q})$ is the robot's kinetic energy matrix, it incorporates the robot's mass properties, and is obtained as follows,

$$\boldsymbol{A}(\boldsymbol{q}) = \sum_{i=1}^{n}(\boldsymbol{J}_i^{vT} m_i \boldsymbol{J}_i^v + \boldsymbol{J}_i^{\omega T}\boldsymbol{I}_i\boldsymbol{J}_i^\omega), \quad \boldsymbol{A}(\boldsymbol{q})\ \varepsilon\ \Re^{n\times n} \tag{6}$$

where,

m_i and $\mathbf{I}_i$ are the mass, and inertia matrix of the $\mathbf{i}^{th}$ link, respectively.

The elements of the Euler-Lagrange equations contributed by the kinetic energy are as follows,

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{\boldsymbol{q}}}\right) = \boldsymbol{A}(\boldsymbol{q})\ddot{\boldsymbol{q}} + \dot{\boldsymbol{A}}(\boldsymbol{q})\dot{\boldsymbol{q}} \tag{7}$$

$$\frac{\partial L}{\partial \boldsymbol{q}} = \frac{\partial T}{\partial \boldsymbol{q}} = \frac{1}{2}\begin{bmatrix} \dot{\boldsymbol{q}}^T \boldsymbol{A}_{q1}\dot{\boldsymbol{q}} \\ \cdots \\ \dot{\boldsymbol{q}}^T \boldsymbol{A}_{qn}\dot{\boldsymbol{q}} \end{bmatrix}, \quad \boldsymbol{A}_{qi} = \frac{\partial \boldsymbol{A}}{\partial q_i} \tag{8}$$

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{\boldsymbol{q}}}\right) - \frac{\partial T}{\partial \boldsymbol{q}} = \boldsymbol{A}(\boldsymbol{q})\ddot{\boldsymbol{q}} + \dot{\boldsymbol{A}}(\boldsymbol{q})\dot{\boldsymbol{q}} - \frac{1}{2}\begin{bmatrix} \dot{\boldsymbol{q}}^T \boldsymbol{A}_{q1}\dot{\boldsymbol{q}} \\ \cdots \\ \dot{\boldsymbol{q}}^T \boldsymbol{A}_{qn}\dot{\boldsymbol{q}} \end{bmatrix} \tag{9}$$

$$\boldsymbol{b}(\boldsymbol{q},\dot{\boldsymbol{q}}) = \dot{\boldsymbol{A}}(\boldsymbol{q})\dot{\boldsymbol{q}} - \frac{1}{2}\begin{bmatrix} \dot{\boldsymbol{q}}^T \boldsymbol{A}_{q1}\dot{\boldsymbol{q}} \\ \cdots \\ \dot{\boldsymbol{q}}^T \boldsymbol{A}_{qn}\dot{\boldsymbol{q}} \end{bmatrix} \tag{10}$$

where,

L is the Lagrangarian,

$\mathbf{b}(\mathbf{q},\dot{\mathbf{q}})$ encompasses the Coriollis and centrifugal terms.

The conservative forces are given as partial derivative of the potential energy, U, stored in the robot's links,

$$\frac{\partial U}{\partial \boldsymbol{q}} = g_i(\boldsymbol{q}) = \boldsymbol{g}^T \boldsymbol{J}_i^v \boldsymbol{m} \tag{11}$$

$$\boldsymbol{m} = \begin{bmatrix} m_i \\ \vdots \\ m_n \end{bmatrix} \tag{12}$$

where,

$g_i(\mathbf{q})$ is the gravity term of the $\mathbf{i}^{th}$ link,

$\mathbf{g}^T$ is the gravitational acceleration column vector.

Nonconservative forces acting on the robot can be incorporated into the Euler-Lagrange equations by determining the work related to these forces. The work done by these forces is the inner product of joint torques, $\boldsymbol{\tau}$, and joint displacements, $\mathbf{q}$. The configuration space dynamics of the robot can be written in this form,

$$\boldsymbol{A}(\boldsymbol{q})\ddot{\boldsymbol{q}} + \boldsymbol{b}(\boldsymbol{q},\dot{\boldsymbol{q}}) + \boldsymbol{g}(\boldsymbol{q}) = \boldsymbol{\tau} \tag{13}$$

Synchronous servo motors are responsible for the motion of the robot's joints. The motors' stator and rotor windings are resistive in nature. It is also important to note that friction exists between the relative motion of the stator and rotor elements. The total mechanical dissipative forces, $\mathfrak{R}_{em}$, acting at each joint may be derived as the following,

$$\left(\frac{d\mathfrak{R}_{em}}{dq}\right)_i = r(\dot{q}_i) = B_i \dot{q}_i \tag{14}$$

where,

B_i is coefficient of friction between the $\mathbf{i}^{th}$ motor's stators and rotors.

The extended Euler-Lagrange equation may be written as,

$$\boldsymbol{A}(\boldsymbol{q})\ddot{\boldsymbol{q}} + \boldsymbol{b}(\boldsymbol{q},\dot{\boldsymbol{q}}) + \boldsymbol{g}(\boldsymbol{q}) + \boldsymbol{r} = \boldsymbol{\tau} \tag{15}$$

N.B. This model does not capture the constraint forces acting on the system!

<u>Deriving the equations of motion in operational space</u>

One might ask the question. What is operational space? Operational space coordinates may represent any set of coordinates defining kinematic mapping between configuration space and operational space. Pay attention to the fact that the model derived in the previous section, does not capture constraint forces acting on the system. Equations derived from modeling in operational space, in combination with those derived previously in configuration space, will produce a concise system of equations that take into account the effect of the constraint forces. The operational space configuration vector, **x**, describing the position and orientation of an arbitrary point on the system, may be derived from the system's kinematics. The system's kinematics equates the operational space configuration vector, as a function of the generalized configuration space coordinates.

$$\boldsymbol{x} = \boldsymbol{\xi}_E = \boldsymbol{f}(\boldsymbol{q}) \in \Re^{1\times m} \tag{16}$$

The operational space velocities are the time derivatives of **x**.

$$\dot{\boldsymbol{x}} = \frac{\partial \boldsymbol{f}(\boldsymbol{q})}{\partial \boldsymbol{q}}\dot{\boldsymbol{q}}, \qquad \boldsymbol{J} = \frac{\partial \boldsymbol{f}(\boldsymbol{q})}{\partial \boldsymbol{q}} \in \Re^{m\times n} \tag{17}$$

where,

J(**q**) is the kinematic Jacobian.

N.B. J(q)'s determinant may become zero and appear to have a singular position, as a result of certain configurations.

The kinetic energy in operational space is expressed as,

$$T = \frac{1}{2}\dot{\boldsymbol{x}}^T\boldsymbol{\Lambda}(\boldsymbol{x})\dot{\boldsymbol{x}}, \quad \boldsymbol{\Lambda}(\boldsymbol{x}) \in \Re^{m\times m} \tag{18}$$

where,

Λ(**x**) is the operational space kinetic energy matrix.

Taking into account the potential energy, U(**x**), and the nonconservative operational space forces, **F**, the Euler-Lagrange equations representing the motion in operation space and identification of particular terms, is expressed as,

$$L = T(\boldsymbol{x}, \dot{\boldsymbol{x}}) - U(\boldsymbol{x}) \tag{19}$$

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\boldsymbol{x}}}\right) - \frac{\partial L}{\partial \boldsymbol{x}} = \boldsymbol{F}, \qquad \boldsymbol{F} \in \Re^{m\times 1} \tag{20}$$

$$\frac{\partial L}{\partial \dot{\boldsymbol{x}}} = \boldsymbol{\Lambda}(\boldsymbol{x})\dot{\boldsymbol{x}} \tag{21}$$

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\boldsymbol{x}}}\right) = \boldsymbol{\Lambda}(\boldsymbol{x})\ddot{\boldsymbol{x}} + \dot{\boldsymbol{\Lambda}}(\boldsymbol{x})\dot{\boldsymbol{x}} \tag{22}$$

$$\frac{\partial L}{\partial \boldsymbol{x}} = \frac{\partial T(\boldsymbol{x}, \dot{\boldsymbol{x}})}{\partial \boldsymbol{q}} - \frac{\partial U(\boldsymbol{x})}{\partial \boldsymbol{x}} = \frac{1}{2}\begin{bmatrix} \dot{\boldsymbol{x}}^T\boldsymbol{\Lambda}_{x1}\dot{\boldsymbol{x}} \\ \cdots \\ \dot{\boldsymbol{x}}^T\boldsymbol{\Lambda}_{xm}\dot{\boldsymbol{x}} \end{bmatrix} - \boldsymbol{p}(\boldsymbol{x}) \tag{23}$$

$$\boldsymbol{\Lambda}_{xi} = \frac{\partial \boldsymbol{\Lambda}(\boldsymbol{x})}{\partial x_i}, \qquad i = 1, 2, \dots, m \tag{24}$$

The operational space dynamics of the robot is derived from the previously expressed terms as,

$$\boldsymbol{\Lambda}(\boldsymbol{x})\ddot{\boldsymbol{x}} + \boldsymbol{\mu}(\boldsymbol{x}, \dot{\boldsymbol{x}}) + \boldsymbol{p}(\boldsymbol{x}) = \boldsymbol{F} \tag{25}$$

$$\boldsymbol{\mu}(\boldsymbol{x}, \dot{\boldsymbol{x}}) = \dot{\boldsymbol{\Lambda}}(\boldsymbol{x})\dot{\boldsymbol{x}} - \frac{1}{2}\begin{bmatrix} \dot{\boldsymbol{x}}^T \boldsymbol{\Lambda}_{x1} \dot{\boldsymbol{x}} \\ \cdots \\ \dot{\boldsymbol{x}}^T \boldsymbol{\Lambda}_{xm} \dot{\boldsymbol{x}} \end{bmatrix} \tag{26}$$

Due to the fact that **F** can be implemented only by applying $\boldsymbol{\tau}$, it is necessary to find the functional relationship between forces in the operational and configuration spaces. Identifying the relationship between coordinates and their derivatives, as well as the invariance between the kinetic and potential energy with a coordinate change.

Recall that,

$$\dot{\boldsymbol{x}} = \boldsymbol{J}\dot{\boldsymbol{q}} \tag{27}$$

Thus the invariance of kinetic energy yields,

$$\frac{1}{2}\begin{bmatrix} \dot{\boldsymbol{q}}^T \boldsymbol{A}_{q1} \dot{\boldsymbol{q}} \\ \cdots \\ \dot{\boldsymbol{q}}^T \boldsymbol{A}_{qn} \dot{\boldsymbol{q}} \end{bmatrix} = \frac{1}{2}\begin{bmatrix} \dot{\boldsymbol{x}}^T \boldsymbol{\Lambda}_{x1} \dot{\boldsymbol{x}} \\ \cdots \\ \dot{\boldsymbol{x}}^T \boldsymbol{\Lambda}_{xm} \dot{\boldsymbol{x}} \end{bmatrix} = \dot{\boldsymbol{x}} = \frac{1}{2}\begin{bmatrix} (\boldsymbol{J}\dot{\boldsymbol{q}})^T \boldsymbol{\Lambda}_{x1} \boldsymbol{J}\dot{\boldsymbol{q}} \\ \cdots \\ (\boldsymbol{J}\dot{\boldsymbol{q}})^T \boldsymbol{\Lambda}_{xm} \boldsymbol{J}\dot{\boldsymbol{q}} \end{bmatrix} = \frac{1}{2}\begin{bmatrix} \dot{\boldsymbol{q}}^T (\boldsymbol{J}^T \boldsymbol{\Lambda}_{x1} \boldsymbol{J}) \dot{\boldsymbol{q}} \\ \cdots \\ \dot{\boldsymbol{q}}^T (\boldsymbol{J}^T \boldsymbol{\Lambda}_{xm} \boldsymbol{J}) \dot{\boldsymbol{q}} \end{bmatrix} \tag{28}$$

By inserting $\mathbf{J}^T\boldsymbol{\Lambda}\mathbf{J}$ into the dynamical model of the robot in operational space yields,

$$\boldsymbol{J}^T[\boldsymbol{\Lambda}(\boldsymbol{x})\ddot{\boldsymbol{x}} + \boldsymbol{\mu}(\boldsymbol{x}, \dot{\boldsymbol{x}}) + \boldsymbol{p}(\boldsymbol{x})] = \boldsymbol{J}^T\boldsymbol{F} = \boldsymbol{A}(\boldsymbol{q})\ddot{\boldsymbol{q}} + \boldsymbol{b}(\boldsymbol{q}, \dot{\boldsymbol{q}}) + \boldsymbol{g}(\boldsymbol{q}) + \boldsymbol{r} = \boldsymbol{\tau} \tag{29}$$

6. Control

In order to control the robot, its dynamics must be examined, hence the purpose of the previous chapter. A practical and universally accepted control scheme is that of the computed-torque control. Recall that servomotors serve as the robot's actuators, and there are six of them. $\boldsymbol{\tau}$ is proportional to the electromagnetic forces required to drive the motors. Considering the coriolis, centrifugal, gravitational, and frictional forces as torque disturbances in the system, yields the following,

$$\boldsymbol{A}(\boldsymbol{q})\ddot{\boldsymbol{q}} + \boldsymbol{\tau}_d = \boldsymbol{\tau} \tag{30}$$

The shaft displacement of each motor, can be considered as an element of **q**. The plant may be modeled in the following manner,

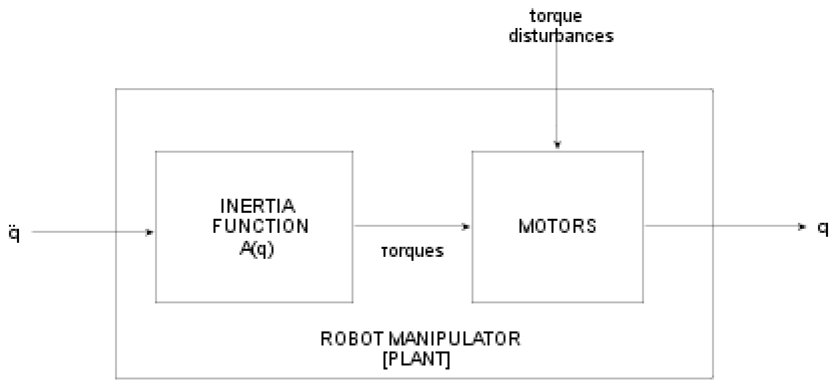

Fig. 1. *Plant Model*

where $\ddot{\mathbf{q}}$ is the system's input, and it's output **q**, is a vector of sensor measurements made by encoders within the motors. A PID controller may be implemented, in order to drive the robot to a desired joint configuration $\mathbf{q}_{\mathbf{des}}$. For optimal control and overall stability of the system, a scheme consisting of several loops enabling velocity and acceleration control is the final product of the control design process in this research.

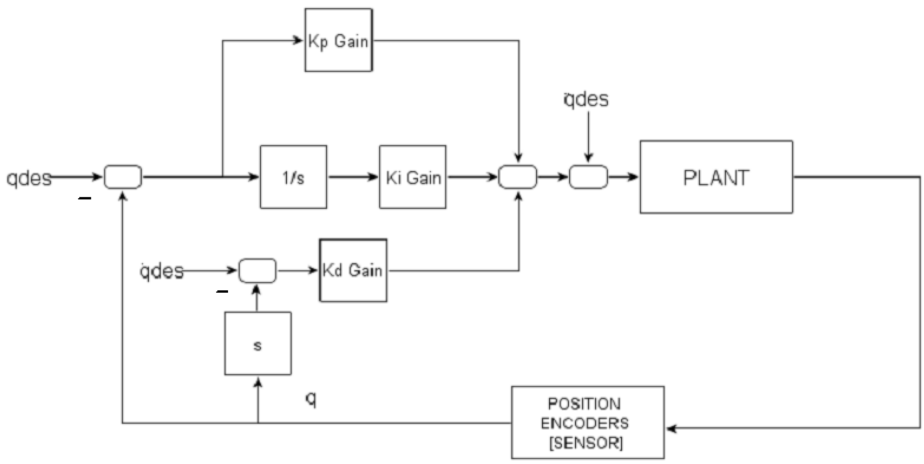

Fig. 2. *Control Design Scheme*

7. LabVIEW Implementation

Implementing the control scheme in LabVIEW using the control design and simulation module, involved several steps. These may be categorized into two parts; control design, and simulation. Control design steps include,

- Construction of the open loop plant model;
- Stability and response analysis of the open loop model;
- Construction of the closed loop model with the PID controller;
- Stability and response analysis of the closed loop model.

Simulating the system involved,

- Initialization of a simulation loop;

– Developing the control scheme within the loop;

– Setting up the simulation parameters;

– Running the simulation and investigating the system's response.

Below is the step response and of the closed loop model between the PID controller, servo-drive, and the plant (robot). The PID gains are tuned by trial and error method.

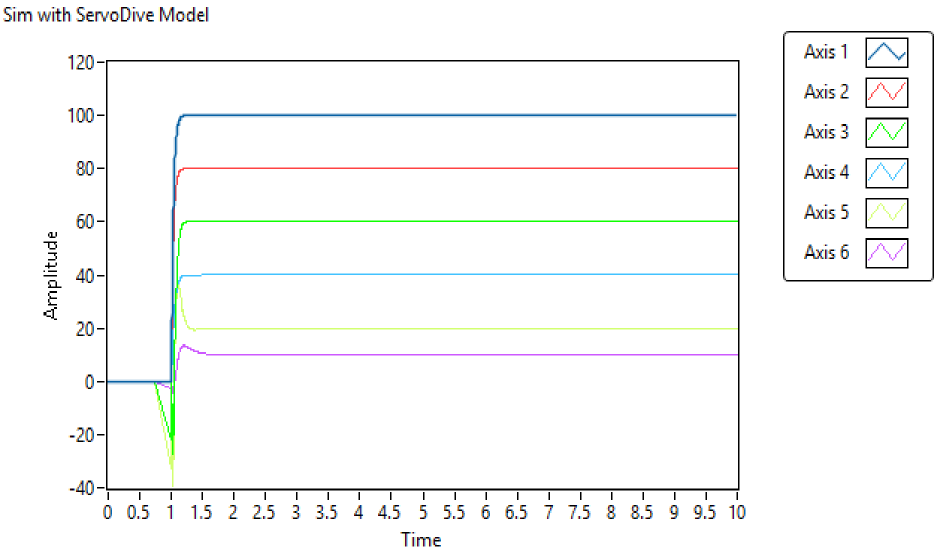

Fig. 3. *Step Response of Simulated Closed Loop*

8. Conclusion

With all indications it is safe to say the designed model is responsive and quite stable. In order to verify our model, we introduced a noise signal, and ran the simulation. The step response remains the same for relatively low levels of noise. We also removed the servo-drive block, and observed the system become extremely unstable (the step response signal does not converge). One might ask, what was the purpose of designing a robot joint controller in LabVIEW? The answer is simple, this is the first part of an ongoing research work at the Electrical and Mechatronics Department of the Engineering Faculty at the University of Debrecen. Robots, including the ones situated in our robot laboratory, experience configuration singularities. It is evident that when the robot is controlled in the joint coordinate frame, singularities are non-existent. Although when commanding the robot in the world coordinate frame, singularities do occur. Now that we have developed a joint controller, future research will involve developing a word coordinate frame controller, enabling us to investigate further and analyze the singularity problem.

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MECHATRONICS IN AERONAUTICS INDUSTRY

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Abstract

We are going to talk about the mechatronics in general. After this we are going to continue with the application of mechatronics (Aircraft manufacturing, General aviation activities, Airline operation, Airport operation, Aviation support industries). Then we are going to resume with the application of mechatronics in the aircraft (aileron and its types: single acting, wingtip, differential). Flaps and Actuator drive unit- types (power drive unit, hydraulic power drive unit, electrical drive unit). Mechanical actuators (Linear, Rotary, Transmission components, brakes and feedback devices). Pilot static system and its parts (fly by wire control system, yaw damper, primary flight control system, under carriage)). After this we are going to speak about the characterization setup of motors, batteries and propeller (measurement of motor RPM, measurement of air flow velocity, aircraft altitude measurement sensor, air Speed). Eventually we are going to finish our presentation with the stealth aircraft and its limitation.

Keywords: Mechatronics, Pilot Static System, Stealth Aircraft, Definition of Mechatronics

1. Definition of Mechatronics

It is a synergetic integration of physical systems with information technology and complex- decision making in the design, manufacturing and operation of industrial products and processes. In other words, it is a combination of control systems, electronics systems mechanical systems and computers.

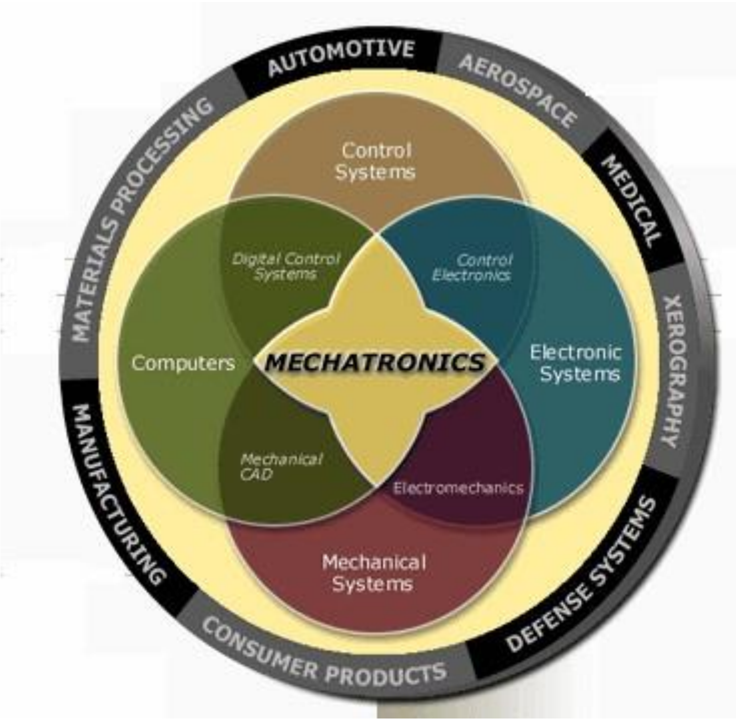

Fig.1. *Definition of Mechatronics [1][2]*

2. Applications of mechatronics in aviation

2.1. Aircraft manufacturing [3]

The demand for air travel drives the need for increased aircraft production. With a predicted production requirement of 35,000 commercial airplanes between 2014 and 2032 it is imperative that manufacturers update their processes to accommodate the predicted demand. Progress of aviation technology will contribute to space craft progress as well. Although processes may not directly transfer to space craft they will still influence design due to the similarities between airplanes and space craft. Advances in manufacturing technology can offer an improvement in overall efficiency by increasing the number of materials available to designers. Other areas where the mechatronic devices can be found:

- General aviation activities
- Airline operation
- Airport operation
- Aviation support industries
- Application of mechatronics in the aircraft

2.2. Aileron [3]

Components of aileron (Horns and aerodynamic counterbalances, trim tabs, spades, mass balance weights). This aileron was mounted by the hinges in a reaction test frames and variety of actuator configurations with adjustable links. Electro dynamic shaker attached with a bonded pad to the outboard closeout rib are used to apply various frequencies and amplitude to the aileron. An accelerometer used to monitor the frequency responses. If the frequencies were comparable the flutter free performance of the composite aileron was predicted. A pair of actuators fixed by the pads to the rear of the ailerons. This is used to load and determine the chord wise bending and torsional rigidity. The movements are measured at nine points on the ailerons, where are measured by two ways. These two ways are the linear transducers and the optical one.

2.3. Flaps and Actuator drive unit [3]

These flaps are constructed with parametric computer model and actuator system. The overall model could move the full range of flap rotation and deflections and it could represent the thermal expansion in both vertical directions and longitudinal. The drive unit rotates in its mounting axis to maintain tangency of the pinion gear and sector gear regardless of any shifts in the location of the flap hinge axis. The existing computer design model is used to determine the real movement at the bearing with the system in a thermally deflected and conform the required movement. This computer model is used to find the sources of interference and eliminates the source. This system is reliable as well as critical for real time determination of components locations in the vehicle. It is very difficult for proper alignment of the parts without this computer model and drive unit.

2.4. Mechanical actuators

This actuator drive unit is designed to create maximum torque and speed if any two electrical or controller failures. Due to weight concern mechanical redundancy is not provided also it will increase effect of complexity and overall reliability. To resolve this, issue the failsafe design were included into the individual components to improve the reliability concerns. When the motor channel fails the rest of the channel would drag along the failed motor.

2.5. Pilot Static system [3]

This pilot static system is mostly used in aircrafts to determine the aircrafts airspeed, Mach number, altitude and altitude trend. This system consists of pilot tube, a static port and pilot static instruments. This unit also measures the external forces acting on the aircraft like temperature, pressure, density and viscosity of the fluid while in operation. Rest of the instruments connected to monitoring computers and data recorders, altitude encoders, cabin pressure controllers and various speed switches. Most of the commercial aircraft disasters have been traced to a failure of the pilot.

- Pilot static instrument (Airspeed indicator, Altimeter, match meter,
- Vertical speed indicator)
- Errors (Blocked pilot tube, Blocked static port, inherent, position, lag).

2.6. Fly by wire control system

This fly by wire control systems is most reliable than manual control of an aircraft. The changes in flight control components are converted to control signal and transmitted to flight control computers by the wires to determine how to move the actuators at each control surface. This flight control computer gives feedback to stabilize the aircraft performance even without pilot knowledge.

- operation
- analog/digital systems
- developments (fly-by-optics, power-by-wire, power-by-wireless, intelligent flight control system).

2.7. Yaw damper- operation

In many air craft usually in jets and turboprops to decrease the damper due to Dutch roll mode this Yaw damper is used. It includes Yaw rate sensors and processor. This overall unit gives signal to an actuator which is connected to the rudder. The purpose of this yaw damper is to give solution for the better ride to passengers. This component is required in aircraft to ensure the stability stays within the certified values.

2.8. Primary flight control system

This mechanically controlled system design is to provide responds to primary flight control system. For flight envelope protection this electronically system is used. This control system is split into two levels, the four actuator controls and three primary flight computers. This gives warnings to pilot.

In internal navigation system includes motion sensors (accelerometers) and rotation sensors (gyroscopes). This setup is continuously calculating the reckoning position, orientation, and velocity of an aircraft and space craft.

- cockpit flight control (mechanical, hydro-mechanical),
- secondary flight controls
- -Inertial navigation system- role and operation

2.9. Under carriage

When takeoff and landing it allows the aircraft to move as a taxi. This structure compile with wheels, floats and landing gear system. The landing gear is hydraulically rotated forward and up during the ground operations until it engages an unlock hook. This landing gear doors having high temperature reusable surface insulation thermal protection systems tiles joined together with their outer surface. parts in picture

3. Characterization setup of motors, batteries and propeller

In Mini and Micro air vehicles the characterization setup module has been using. This set up having motors, batteries and propellers, computer, multifunction I/O card, tachometer, current sensor, air velocity transducer, thermocouple with conditioner and necessary hardware interface. The DC voltage applied to the motor is controlled by LabVIEW based software. This software continuously collects the six channels data, calculates the engineering inputs, as well as keep updating the screen readout and displays the data also save the data into ASCII spreadsheet file. The collected and displayed data includes motor current, voltage, temperature, RPM, air velocity, thrust, calculated instantaneous power and calculated torque.

3.1. Measurement of motor RPM

It is important to measure most efficiently motor, propeller and gear box combination RPM. Motor RPM based on varying the combinations of the propulsion system components. Another important operation is to detect when motor failure occurs. For this detection this system applies two methods to design Tachometer. In first method a wiring harness to connect to the existing real time system, magnets and Hall effect sensor on the gears or motor fan. When the fan starts to rotates, the Hall effect sensor detects the field magnetism which is developed due to rotation and sends a signal to the board that is having capability to count the pulses. In second method an optics module is focused to illuminate the spinner from the side. When light reflects off a white stripe on the spinner is detected by the photo sensor for each revolution.

3.2. Aircraft altitude measurement sensor

For altitude measurement Piezoresistive silicon sensors are mostly used. Due to high accuracy requirement the monolithic silicon pressure sensors are used and it delivers high level analog output signal is proportional to the applied pressure. In case of change in temperature the silicon sensors are compensated due to these are temperature dependent. This altimeter is used as an absolute sensor. The outcome of the sensor is directed to an operational amplifier. The gain and offset of the amplifier circuit is modifying by two trimmers, so that it can be calibrated.

3.3. Air Speed

This differential airspeed pressure sensor output is connected to an operational amplifier. To calibrate the signal gain one of the trimmer is used. The ports of silicon based sensors are static and variable. To determine the outside air pressure sensor pressure controller was used to apply a standalone pressure to the static port. When increase in the pressure difference between two ports it generates the output voltage. The output voltage is the lowest when the pressure is equal also it offset the voltage.

3.4. Stealth aircraft

They are designed to avoid detection using a variety of technologies that reduce reflection/emission of radar, infrared, [1] visible light, radio-frequency (RF) spectrum, and audio, collectively known as stealth technology. Stealth aircraft makes it difficult for conventional radar to detect or track the aircraft effectively, increasing the odds of an aircraft successfully avoiding detection by enemy radar and/or avoiding being successfully targeted by radar guided weapons.

The general design of a stealth aircraft is always aimed at reducing radar and thermal detection. It is the designer's top priority to satisfy the following conditions, which ultimately decide the success of the aircraft:

- Reducing thermal emission from thrust
- Reducing radar detection by altering some general configuration (like introducing the split rudder)
- Reducing radar detection when the aircraft opens its weapons bay
- Reducing infra-red and radar detection during adverse weather conditions

3.5. Instability of design

Early stealth aircraft were designed with a focus on minimal radar cross section (RCS) rather than aerodynamic performance. Highly-stealth aircraft like the F-117 Nighthawk are aerodynamically unstable in all three axes and require constant flight corrections from a fly-by-wire (FBW) flight system to maintain controlled flight

3.6. Aerodynamic limitations

Earlier stealth aircraft (such as the F-117 and B-2) lack afterburners, because the hot exhaust would increase their infrared footprint, and flying faster than the speed of sound would produce an obvious sonic boom, as well as surface heating of the aircraft skin which also increases the infrared footprint.

3.7. Electromagnetic emissions

The high level of computerization and large amount of electronic equipment found inside stealth aircraft are often claimed to make them vulnerable to passive detection. This is highly unlikely and certainly systems such as Tamara and Kolchuga, which are often described as counter-stealth radars, are not designed to detect stray electromagnetic fields of this type. Such systems are designed to detect intentional, higher power emissions such as radar and communication signals. Stealth aircraft are deliberately operated to avoid or reduce such emissions

3.8. Sensitive skin

Stealth aircraft often have skins made with Radar-absorbent materials or RAMs. Some of these contain Carbon black particles, some contain tiny iron spheres. There are many materials used in RAMs, and some are classified, particularly the materials that specific aircraft use.

3.9. Infrared (heat)

Some analysts claim Infra-red search and track systems (IRSTs) can be deployed against stealth aircraft, because any aircraft surface heats up due to air friction and with a two channel

IRST is a CO_2 (4.3 μm absorption maxima) detection possible, through difference comparing between the low and high channel.

4. Advancements in computational power

The stealth platforms may have slower advances in materials technology and physical limits so that further advances in stealth become either impossible or unaffordable. This may force future stealth platforms to stand off from their targets and use active countermeasures and long range weaponry to strike targets.

5. Conclusion/Summary

This paper is a survey regarding the mechatronic parts used in aeronautics industry.

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Fully automated payment system with RFID-antennas

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Abstract

RFID (*radio-frequency identification*) describes a technology for transmitter-receiver systems for automatic and non-contact identification and localization of objects with radio waves. An RFID system consists of a transponder, which is located on or in the object and a reading device for reading the identification number. The motivation for this work is to make an approach on how to substitute the widely used barcode system in stores with a fully automated and much faster RFID-antenna system. RFID´s are already commonly used in logistics where the transponders are being scanned with handheld RFID readers. To fully substitute barcodes in stores every item needs to carry a RFID-transponder which contains the serial number. Also a system is required which is able to identify many items in a cart in a very short period of time. In this approach we will use passive non-rewritable UHF RFID tags which are implemented in the packaging. We will show how a fully automated payment system in stores could look like and how it is working.

Keywords: RFID-antennas, barcodes

1. Basic thoughts in advance of modeling the RFID system

1.1. Energy supply of the transponder

There are generally two types of RFID tags: active RFID tags, which contain a battery, and passive RFID tags, which have no battery. For passive RFIDs the high-frequency energy it receives via the antenna serves as a power supply for its chip during the communication process. The passive tags are very cheap (only a few cents) and are therefore used in this approach.

1.2. Amount of information stored on RFID tags

Simple RFID tags contain only a 96-bit or 128-bit serial number. The simple tags are cheaper to manufacture and are more useful for applications where the tag will be disposed of with the product packaging [1].

1.3. Placement of the RFID-transponders on the product

The RFID-transponder replaces the barcode in our system, because of that we need a RFID-tag on every product. The best solution is, when the RFID-tags will be placed on the packaging of the products. The tags can be easily pasted on the packaging or can be included while producing the packaging [2].

1.4. Eliminating influence of antenna orientation

Because the products in the shopping cart are in confusion, we do not exactly know the orientation of the transponder-antenna to the reader-antenna. This is a problem, because antennas have to be aligned exactly. The solution of this problem is a reader-antenna, which sends with a circular polarization. In this case the field force vector rotates right or left and stays vertical to the propagation direction.

1.5. Choosing a certain frequency range

The best frequency scope for our system is UHF (960 MHz) because the electromagnetic field has to run through the products and the shopping cart (UHF has a 3-6m range). Furthermore, we get a faster system with UHF. Due to the fact that metal reflects and absorbs electromagnetic fields it can lead to faults in the data of our system, therefore the shopping cart has to be built from only plastic [2].

1.6. Shielding of the system

Moreover, our system needs an electromagnetic shielding. This is necessary so that the system does not recognize other products of the supermarket, which are not in the shopping cart. There are many options for materials, which absorbs the electromagnetic fields e.g. a faraday cage.

2. Mechanical construction of the system

Figure 1 shows how the system is supposed to look in reality. The RFID-reader as well as the photocells and the LED´s (which are behind the same lens) are integrated in an aluminium housing. The display is located at a stand cash desk and is not shown in the figure below.

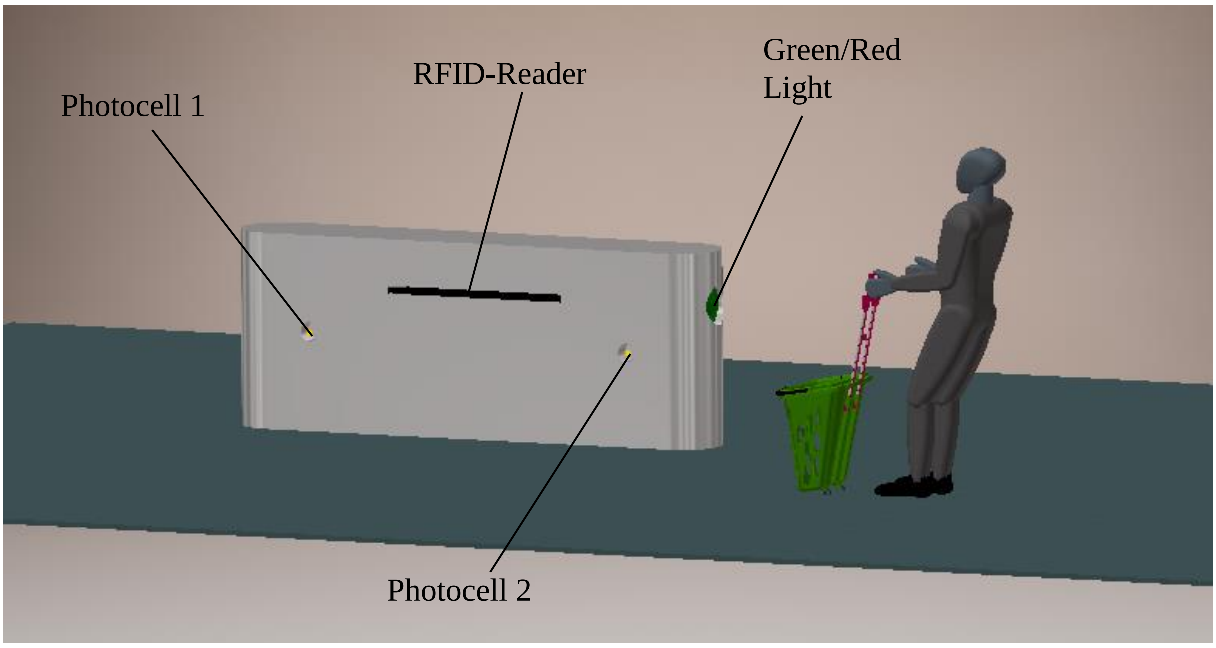

Fig.1. *The mechanical construction [source: own illustration]*

3. Operation of the fully automated payment system

3.1. The mechatronic system

The control system/unit gets the input data from the sensors, over the input interface. The photocell sensors tell the control system whether someone or something is in the portal. When a person goes in with a shopping cart the RFID-system will be activated. It recognizes all the products in the shopping cart, while the person walks through the portal.
If the control system has calculated all the information about the products, the output data will be sent to the actuators.

The products, prices and the calculated sum of the prices will be listed on the display. The green and red lights are only there for visualizing, if you can go into the portal or someone is already in the portal.

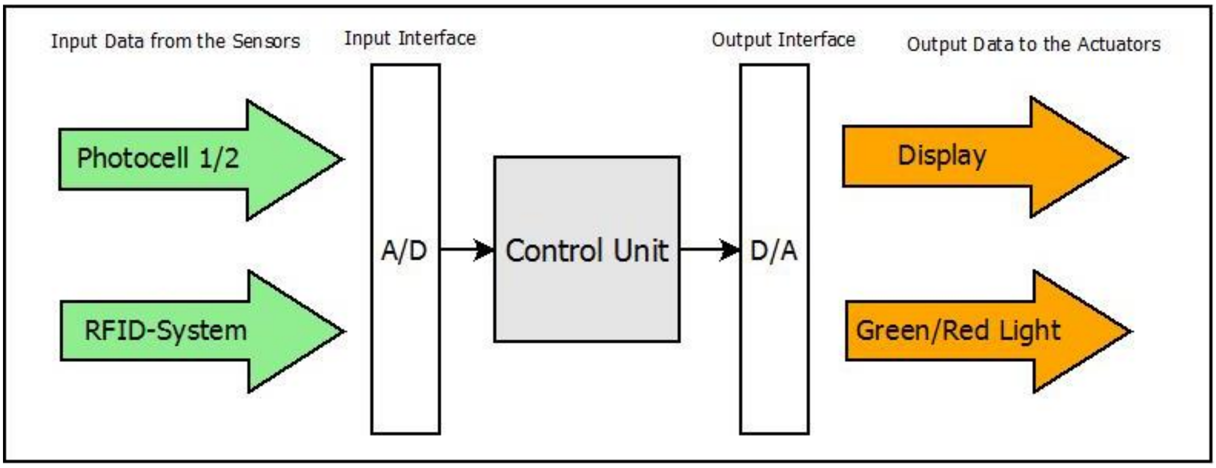

Fig.2. *The mechatronic system [source: own illustration]*

3.2. The realization of the software

Figure 3 shows the structure of the software in a flow chart.

1. At first it is necessary to define and initialize the variables and functions which we need.
2. Afterwards, the program will run in an endless loop ('yellow' while(1))
3. Thirdly, there is called an if-statement. If the first light barrier is activated (1.photocell=1), the program will continue on the yes-path. If the light barrier is not activated (1.photocell=0) the program code will be over jumped. On the no-path the green light is activated (greenL=1) and the red one is putted off (redL=0). Then the program repeats from the endless loop.
   → This if-statement realizes that the system waits until someone goes into the portal
4. On the yes-path the green light is putted off and the red one is activated, to signalize someone is in the payment system and the next customer has to wait. Then the RFID-reader is started. It recognizes the transponders and sends the data to the control system. With the function readData() the program reads and stores all the reference numbers of the products in the memory.
5. The green while loop (while(data=1)) runs so long until there is no more reference number of a product in the storage (data=0). In the first round of the loop the program takes the first reference number. Then it looks in the data bank under this reference number for the necessary information of this product (price, name, weight, ..) and send the information to the display (writeDataScreen()). In the next round of the while loop the program takes the second reference number and so on, until there is no more number in the storage (data=0).
6. When all product information are sent to the display, the RFID-reader will be stopped.
7. On the next if-statement the program waits until the person leaves the payment system. This happen about the second light barrier. The program only continues when the second light barrier will be activated (2.photocell=1).

When the person has leaved the payment system, the green light is activated and the red one is putted off. Finally, the system waits for the next customer.

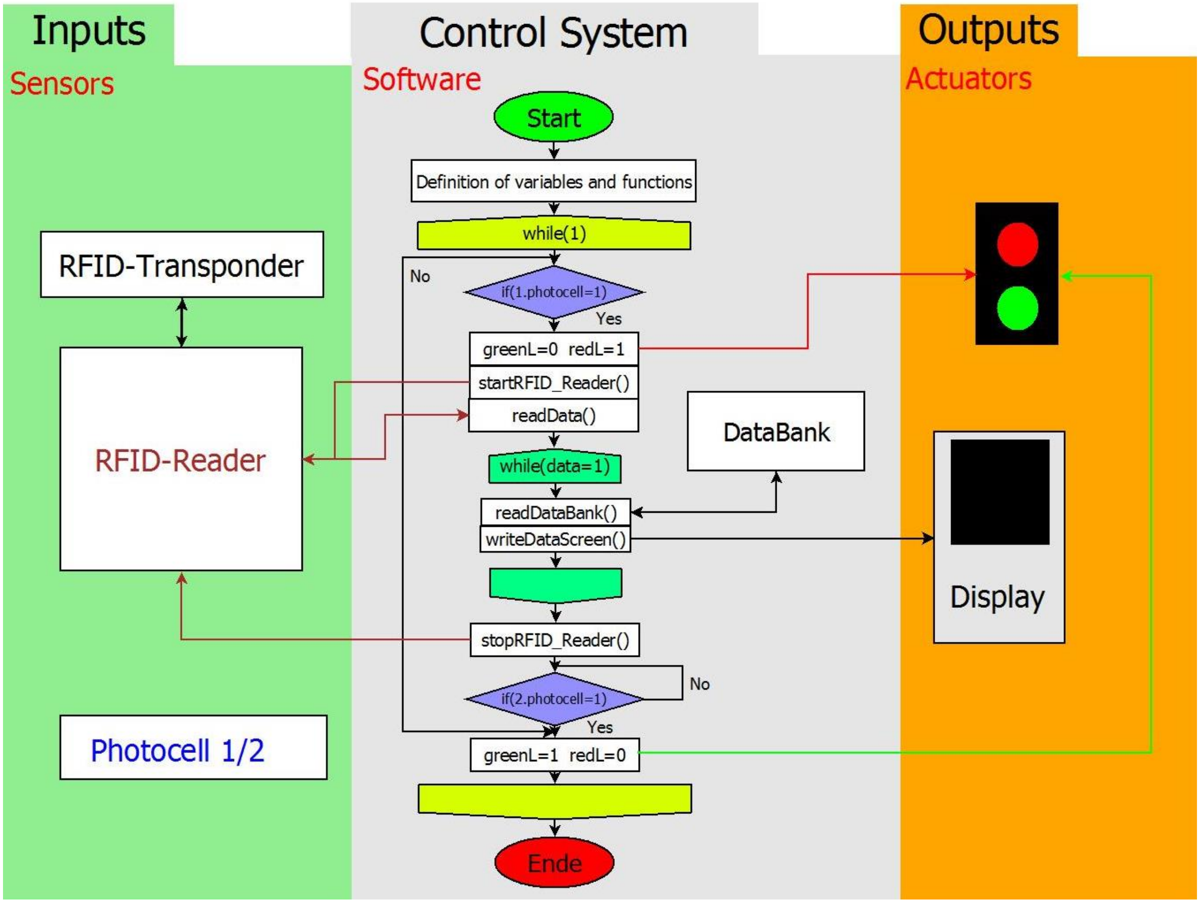

***Fig.3.** The flow chart of the system [source: own illustration]*

4. Conclusion

RFID Tags have the potential to fully replace bar codes in stores. They can be read from large distances and don't need to be in sight of the scanner. Also they can store huger amounts of data, e.g. the store, where the product is going to be offered. In fact it is even possible to give every single product and every shop its own unique serial number. However they are still quite expensive in manufacturing and an easy way to implement them into food wrappings has yet to be found. To fully replace bar codes these disadvantages have to be removed through further research. Also the RFID method will have to compete with other methods like the recently introduced system in Amazon Go stores. This system uses a smartphone app, cameras, face tracking and intelligent algorithms to keep track of what customers add to their shopping cart.[3]

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The Potential Role of Thermoelectronic Devices in Automotive Industry

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Abstract

About 30% of the energy produced by fuels being used for automotive industry is actually generating movement, letting the rest of it to get lost as dissipation in friction and heat. Based on that statement and on the fact that the technologies are nowadays exponentially increasing, the possibility of creating new systems that can recover and convert most of this heat energy into useful electrical energy for hybrid automotive systems is discussed. The basic understanding on the current approaches to manufacture these materials are briefly described and so, the proposals for encouraging research in this field of work are given. Also, since some general context may be required, statics that justify the importance of the research on thermoelectrics, as well as some fundamental concepts are provided.

Index Terms

Thermoelectric Materials, Automotive Applications, Mechatronics in Environmental Sustainability.

I. Introduction

Energy generation and consumption has remained a constant topic of interest for most of the nations throughout the last decades. It is true that major improvements have been achieved within many fields of technology which has lead us to new research fields; development of green or echo friendly materials and technologies is one of the increasingly trending matters of study nowadays. Their importance and relevance is directly proportional to the fact that energy is present in every important process and many times it's being wasted as a side effect of them. Talking about waste energy, almost immediately implies heat. Heat is the most common way of waste energy and it occurs not only in engineering or industrial processes, but to a household level as well; cars are the most clear and accesible example for it. Approximately 40% of the fuel energy is wasted in exhaust gas, 30% is dissipated in the engine coolant, 5% is lost as radiation and friction, and only 25% is used for vehicle mobility and accessories. [1]
With the previous statement, it could be inferred that from out of the nearly 3042.5 thousand barrels of gasoline consumed in Europe per day [2], only 760.6 are effectively producing motion, which turns out to be a concerning number. From that, it is clear that the applications for heat recovery systems is needed and therefore, the connections between heat and electricity shall be exploited. The Seebeck effect turns into the fundamental for creating these systems.
The field of thermoelectrics require not only of ideas on applications but firstly the research and development of highly efficient thermoelectric materials. This has been done for the last

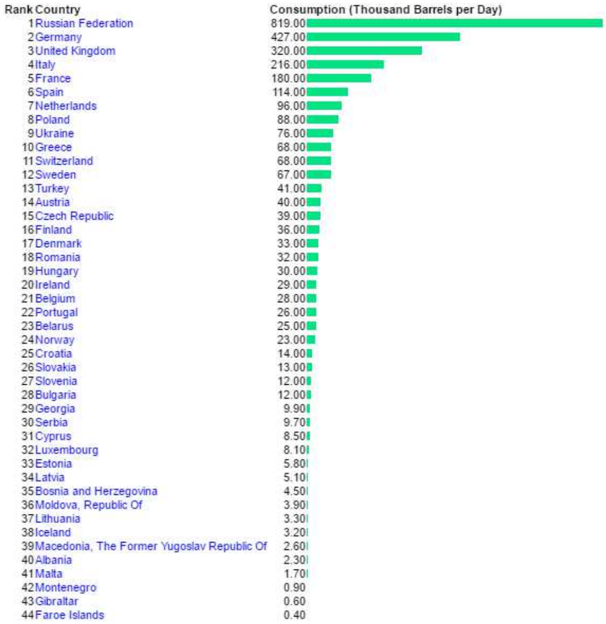

Figure 1. Gasoline consumption in Europe, sorted by country (2012). [2]

decades with some progress but it is until more recently with the arrival of nano-structured technologies that major progress is seeing the light.

II. Theoretical Framework

For proper and full understanding of the topics discussed along this paper, it is expected from the reader to have some fundamental knowledge on heat transfer, semiconductor materials and general electronics. For the matter, this section will review some of the concepts that must be clear before going further with the main topic.

- *Electrical Conductivity:* The electrical conductivity is referred as the quantity that is reciprocal to the electrical resistivity ρ. Then it's known that the units for electrical conductivity are *siemens per meter* or $\frac{S}{\Omega}$. This property is possible because of the so called free flow of electrons accross the material. This is given due to the material's composition. [3]
- *Thermal Conductivity:* Can be defined as the rate of heat transfer through a unit thickness of the material per unit temperature difference. Then, the thermal conductivity of a material is a measure of the ability of the material to conduct heat.[4]. The thermal conductivity can be interpreted as a physical property having 2 components, being the K_e and the K_l the electronic and lattice thermal conductivities, respectively. The first one being directly correlated to electrical conductivity and the second one completely independent from it.
- *Semiconductor Material:* Semiconductor materials can be both, pure and compound; they posses variable electrical conductivities (conductances) depending on certain external temperature conditions applied on the material and due to the energy behaviour between the valence and conduction bands within the atomic configuration of the material.
  The following is the characteristic energy of the gap between bands given for semiconductor materials:

$$np = N_V N_C \boldsymbol{e}^{-(E_C - E_V)/kT} = N_V N_C \boldsymbol{e}^{-E_g/kT} \tag{1}$$

This is true both for pure and compound semiconductor materials. For giving examples of common pure semiconductor (also known as Intrinsic Semiconductors) materials, we have Germanium (*Ge*) and Silicon (*Si*); on the other hand we can mention Gallium Arsenide (*GaAs*) ,Indium Antimonide (*InSb*) and Cadmium Selenide (*CdSe*) as examples of different types of compound semiconductor materials. (Their difference is driven by the number of valence electrons). [5]

- *Seebeck Effect:* Thermoelectric devices can convert thermal energy from a temperature gradient into electrical energy. This phenomenon was discovered in 1821 and is called the Seebeck Effect. [6]
- *ZT:* This is the so called adimensional figure of merit and is what determines the efficiency of a thermoelectric material. It's definition is as follows: [7]

$$ZT = \frac{S^2 T}{K\rho} = \frac{S^2 T}{(K_e + K_l)\rho} \tag{2}$$

Where $S = SeebeckCoefficient$, $K = K_e + K_l = ThermalConductivity$, $\rho = ElectricalConductivity$ and $T = AbsoluteTemperature$.

- *Phonon:* A Phonon is the quanta for the discrete amounts of vibrational energy that a solid system can receive. The Phonon Mean Free Path rffers to the space that phonons have to move freely through the crystaline structure of a given material. This is an important concept for the development of thermoelectric high efficient materials. [8]

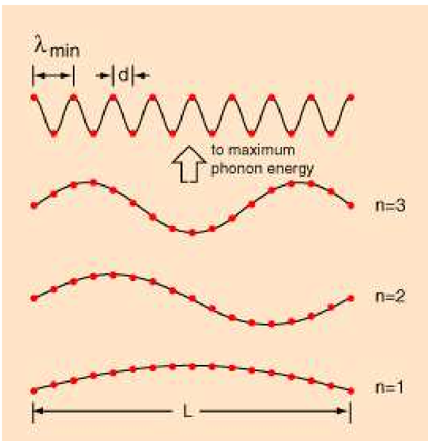

Figure 2. Ilustration of a Phonon. [8]

III. Background

The future of the environmental technologies relies on the development of new materials that can gather the required characteristics for them to be able to recover as much energy as possible from common energy losing processes.

Thermoelectric devices can be one of many efficient solutions for energy recovery, since it's known that mostly every process generates a considerable amount of energy loss in the form of heat; when talking about processes it is not only a reference to industry but to every motion related system, since motion depends on energy and therefore has a narrow relationship with heat. For this issue, automotive potential applications are discussed, even though there are several other areas for which thermoelectric materials become a matter of interest.

For proper energy recovery, highly efficient thermoelectric materials are required; this means, the creation of cost effective, pollution-free materials that gather the next properties:

1. Heavily-doped semiconductors
2. Energy Bandgap $< 1eV$
3. Low thermal conductivity

For accomplishing the previous, there are 2 current approaches for the creation of these materials. The first one involves the alloying of bulk materials which is the most cost friendly option but the results aren't the best by this method since efficiency ZT from these materials isn't high enough for the planned applications. The second method is through the creation of nano-structured based composite materials, which consist of a bulk matrix and some nano-structured alloying material. The nano structures are often nano-wires, this is a 1 Dimensional embedded structure.[7]

The nano approach gets the best results for efficient materials because of the size of the magnitudes it deals with. The idea is interstitially inserting contaminant atoms (creating a nano-structure) in the crystalline network of the bulk material. These specifically located dopant atoms interfere in the phonon mean free path but at the same time leave enough space for the electrons to move freely. This is translated in simple words as a material that will be a good electrical conductor and will show a decreased thermal (lattice) conductivity, which are both requirements for having an efficient thermoelectric material. In Figure 3, a table with some properties from these materials is displayed.

Material systems	Carrier type	ZT	κ_L [W m^{-1} K^{-1}]	T	Synthetic method*	Ref.
PbTe-based nanocomposites						
$AgPb_{18}SbTe_{20}$	n	2.2	–	800 K	NP	[16]
$Ag_{0.5}Pb_6Sn_2Sb_{0.2}Te_{10}$	p	1.45	0.43	630 K	NP	[90]
$Ag_{0.53}Pb_{18}Sb_{1.2}Te_{20}$	n	1.7	–	700 K	NP	[91]
$K_{0.95}Pb_{20}Sb_{1.2}Te_{22}$	n	1.6	0.4	750 K	NP	[92]
$Na_{0.95}Pb_{20}SbTe_{22}$	p	1.7	0.74	700 K	NP	[17]
PbTe–PbS8%	n	1.4	–	750 K	NP	[93]
PbTe–Pb–Sb	n	1.4	0.6	700 K	NP	[94]
PbTe–Si	n	0.9	–	675 K	NP	[95]
$Pb_{9.6}Sb_{0.2}Te_3Se_7$	n	1.2	0.4	650 K	NP	[97]
$(Pb_{0.95}Sn_{0.05}Te)_{0.92}(PbS)_{0.08}$	n	1.50	0.4	642 K	NP	[23]
2%SrTe-containing PbTe	P	1.7	0.45	800 K	NP	[100]
$NaPb_{18}BiTe_{20}$	p	1.3	–	670 K	NP	[103]
$Ag_{0.8}Pb_{22.5}SbTe_{20}$	n	1.5	0.89	700 K	MA+SPS	[106]
SiGe-based nanocomposites						
$Si_{80}Ge_{20}$	p	0.95	–	1073 K	HEBM+HP	[107]
$Si_{80}Ge_{20}P_2$	n	1.3		1173 K	HEBM+HP	[25]
New thermoelectric materials						
$In_4Se_{3-\delta}$	n	1.48	–	705 K	Bridgeman method	[26]
$In_4Se_{3-x}Cl_{0.03}$	n	1.53	–	698 K	Bridgeman method	[109]
β-$Cu_{2-x}Se$	p	1.5	0.4	1000 K	MAG+SPS	[28]
β-Zn_4Sb_3	p	1.35	–	673 K	Bridgeman method	[22]

Figure 3. Properties of Advanced Thermoelectric Materials [7]

The current situation of the previously described materials is unfortunately not the best, since they are complex to produce and therefore they are not still available at a massive production scale that could suit the needs of the potential applications in major industries such as automotive.

Moving onto what has actually been done for applications in automotive industry, more precisely in aerospace, the improvements are still theoretical just like in the case of household automotive (domestic cars); though, Boeing has established a list of actual considerations to take into account for the design or proper thermoelectric energy recovery systems as follows: [9]

1) Efficiency of the thermoelectric materials used should be increased by the time that the production costs get shrunk as much as possible.
2) The expected cold and hot sources should be ambient air and cool fan stream flow and hot air flow and hot surfaces, respectively.
3) These systems should provided electrical power from waste heat and must avoid the use of moving parts.
4) Should operate all over the aircraft flight envelope and shall be independent systems from the operation of the engines themselves.
5) Should also face a series of non-trivial challenges, that may include (but not be limited to) vibration and shock, noise, compatibility of materials, maintenance and reliability.

As for what concerns to the domestic automotive industry, no further development has been made so far due to the ingrowing interest on the development of electric cars; even though these offer just a partial solution to the environmental concerns because of their dependence on the burning of a primary fuel to generate the electricity to later on charge and operate the cars.

IV. Proposals

For the matters of this paper and taking into the account the previously shown information, the team has considered a generalized list of points to describe the proposals made for the further successful applications of thermoelectric devices in automotive industry:

1. To spread the word about the importance of the recovery of heat-loss energy.
2. To encourage private industries and governments to propel the research on these selected topics.
3. To develop hypothetical systems of heat energy recovery that are based on the integration of hybrid automotive systems (fuel and electrical impulsed). This point is strictly important, given the fact that the energetic sector of industry is still dependant on oil and considering a possible future swift into the use of biofuels; for these systems, the electrical energy is planned to be supplied in big part by the thermoelectric devices coupled with solar panels and kinetic recovery systems (already existing).
4. To develop new cooling systems and control units that can help with the integration of the energy recovery and conversion modules so the integration on the existing hybrid systems is fully compatible at a low level.

These generalized steps can be explained forward upon presentation.

V. Conclusion

The world is constantly evolving and changing the way that technologies impact on most areas of daily life. This also means that the way people transports is taking big steps forward a more sustainable future. Thermoelectric materials should, therefore, be more deeply analysed upon the creation of new technologies that can help with the process of manufacturing so that their costs are reduced as their efficiency is inversely increased.

The research on materials is a must and the key to open the doors to a whole new world of possibilities, but also is the design of hybrid system, since these represent the mediation point in between the current mobile technologies and the potential future to where development is aiming at.

This papers purpose is to encourage the industries, governments and scientific community to take one step ahead into this promising horizon of green technologies through the hard work in research and creation of materials that possess the correct properties for making of sustainability a reality affordable for humanity.

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A NEW DIVISION OF VISION: THE INTRODUCTION OF DIGITAL EYESIGHT

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Abstract

Mechatronic engineers are always seeking for new developments in the field of technology as to facilitate the usage of mainly everyday products, hence making our lives easier as well. There exist branches of this profession trying to find solutions for an even “nobler” aim; helping the handicapped by raising their potentials to the level of their more fortunate companions thus giving them the opportunity to enjoy life as easily as everyone else does. All over the world, research teams organized to develop mechatronic systems that are able to fix partly one’s sight. The work processes have just started, though by the correct utilization of the detailed knowledge on eyes and the whole nervous system that the humanity collected through the centuries, by now we can observe huge progress in the field of the research. How can these results stimulate other medical researches? What are the main concepts of these mechatronic devices and how do they work? How far can we push our human limits regarding the compactivity and resolution abilities of these devices? I will examine these questions in my conference paper based on two selected visual prosthesis of different methods.

Keywords: visual prosthesis, retina, nervous system, implant

1. Overview of the sight

1.1. The structure of the eyeball

1.1.1. Basics of eye

Here I list our basic knowledge of the eye:

- the organ of vision, element of the sensory system;
- dual system;
- is in connection with the brain through the optic nerve.

1.1.2. Structure of the eyeball

As to understand how seeing works we have to recall our high school biology studies. Let’s examine the parts of the eyeball involved in vision!

- Cornea: The eye’s outer lens. It gives the eye its major focusing ability;
- Pupil: A hole in the center of the iris that allows light to enter the eye and reach the retina;
- Lens: A clear disc in the eye located behind the iris that helps focus light or an image on the retina.
- Retina: A thin layer of cells at the back of the eyeball that convert light into nerve impulses that travel to the brain. Parts of the retina are the macula and the photoreceptors (rods and cones).

– Optic nerve: A bundle of more than one million nerve fibers that carry visual messages from the retina to the brain. [1]

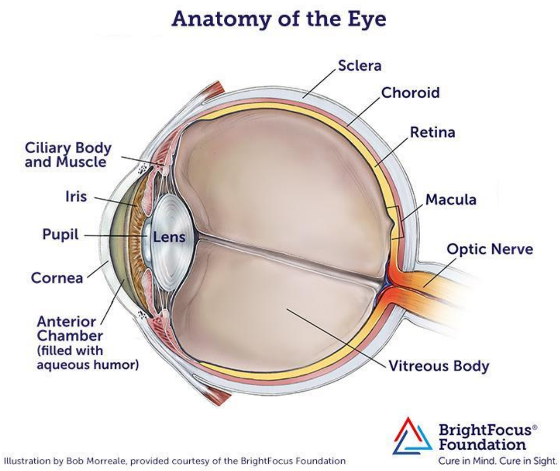

Fig.1. *Parts of the eyeball [2]*

Light enters the eye via the cornea; the amount of light that enters is controlled by the iris, which expands or contracts the pupil in response to the brightness of the scene. The lens then focuses the light into a patterned image on the retina. Cells in the retina called "rods" and "cones" (photoreceptors) convert the light into electrical impulses, which are sent to the brain via the optic nerve. The brain then interprets the impulses and creates what we "see". [3]

2.1. The issue of eye diseases

2.1.1. The global problem

Eye disease is mainly a problem of the poor, with a wide gap between developed and developing countries. It's more than just an individual problem, it is a societal one also which can affect economic productivity and access to education. Almost one in every 200 people on Earth – around 39 million of us – can't see and another 246 million have low vision with moderate or severe limits. However 80% of the cases are preventable or treatable. These terrifying datas urge the development of new cures. [4]

2.1.2. Why the eye?

It is relatively easy to experiment new cures on the eye. We can get access to it safely and with ease, thus we can test methods on it which ones by success can be applied later on other parts of the body. We can also identify easily if there is a problem during the therapy; whether the examined person sees or not. Assuming that the eye is a dual organ, if we apply an experiment on one eye we can compare its effects with the other "non-used" eye. One more important factor is that the eye tolerates pathogens which could cause infections in other parts of the body. [4]

2.1.3. Treatment methods

Nowadays research groups are developing cures for eye diseases in three different styles; two of them strictly uses biological methods (gene and stem cell therapy) and the third one uses mechatronic systems. In the upcoming parts of my paper I am going to deal with the latter one only, by representing two working systems of two research groups. The first one is the so-called "**Argus Retinal Prosthesis**" from a research group in California, and the second one is the **"Alpha IMS Subretinal Implant"** from Germany**.**

2. The Visual Prosthesis

2.1. Overview

The visual prosthesis is an experimental visual device intended to restore functional vision in those suffering from partial or total blindness. It was a Portuguese doctor, Joao Lobo Antunes who firstly implanted a bionic eye in a person born blind. The basis of these devices is the Cochlear implant, a surgically implanted electronic neural prosthesis that provides a sense of sound to a person who is profoundly deaf in both ears. Just like the Cochlear implant, the operation of the visual prosthesis is also based on the concept of using electrical current to provide the required sense in one’s brain. [5] [6]

2.2. Argus Retinal Prosthesis

2.2.1. History

Second Sight Medical Products Inc. was founded in Sylmar, California in 1998 with the goal of creating a retinal prosthesis to provide sight to subjects blinded from outer retinal degenerations, such as retinitis pigmentosa. Second Sight currently employs over 85 employees and has a European office in Lausanne, Switzerland.

The first clinical trial of Argus I began in 2002 involving 6 subjects in total. With the experience gained from the Argus I trial, and further technological developments, a second generation device was created – the Argus II in 2006, containing 60 electrodes while the first edition only contained 16. In total 30 subjects participated in the studies of Argus II, which was approved for commercial use in Europe in 2011, and in 2013 in the United States. The market price of the system is around 100000 USD. [5] [7]

2.2.2. The structure of Argus II

Argus II consists of two main parts; the implant and the external equipment. The implant is a retinal prosthesis surgically implanted in and on the eyeball including an antenna, an electronics case and an electrode array. The external equipment includes the glasses with built-in camera and antenna, a cable and the VPU (Video Processing Unit). [8]

2.2.3. How it works?

The Argus is intended to provide the electrical stimulation of the retina to induce visual perception in blind individuals and is for use in patients with severe retinitis pigmentosa, a disease similar to macula degeneration, when the photoreceptors in the eye are dying.

Firstly, a built-in miniature video camera in the patient’s glasses captures a scene. Then the video is sent to a small patient-worn computer (the Video Processing Unit - VPU) where it is processed and transformed into instructions that are sent back to the glasses via a cable. These instructions are transmitted wirelessly to an antenna in the retinal implant and from there the signals are sent to the electrode array which emits small pulses of electricity. These pulses bypass the damaged photoreceptors and stimulate the retina’s remaining cells which transmit the visual information along the optic nerve to the brain, creating the perception of patterns of light. Patients learn to interpret these visual patterns with their retinal implant. [9]

2.2.4. The key features of Argus II

Argus II has an upgradable external hardware and software to benefit from future innovations. It also has a minimal time from implantation to first system use at home. The VPU has adjustable settings, such as edge or contrast enhancement. The system also comes with a 20 degrees maximum possible field of view. [10]

2.2.5. Statistics

During the trial tests of Argus II, about 23% of the subjects had improvements in their ability to see. 96% of the subjects were better able to identify a white square on a computer scene and 57% were more able to determine the direction in which a white bar moved across a black computer scene. [7]

Fig.2. *The structure of Argus II. [8]*

2.3. Alpha IMS Subretinal Implant

2.3.1. History

A Southern German team led by the University Eye Hospital in Tübingen, was formed in 1995 by Eberhart Zrenner to develop a subretinal prosthesis. As the result of their research work the Alpha IMS was born. [5]

2.3.2. The structure of Alpha IMS

Just like Argus, Alpha IMS has also two main parts; the implant and the external equipment. However there is a huge difference: the Alpha IMS microchip receives the image not from the external camera, but via eye, making it the only retinal implant so far, where the image receiver array moves exactly with the eye (This has practical implications, as natural eye movements can be used to find and fixate a target). The implant part is a subretinal prosthesis surgically implanted in the eyeball including a microphotodiode array (MPDA), a chip with 1500 pixel-generating elements. The external equipment includes a cable and the power supply with the transmitter/receiver. [11] [12]

2.3.3. How it works?

Subretinal prothesis has the microchip which senses light and generates stimulation signals simultaneously at many pixel locations, using the microphotodiode array (MPDA). The subretinal prothesis seeks to replace the function of degenerated photoreceptors directly by translating the light of the image falling onto the retina point by point into small currents that are proportional to the light stimulus. It is the only approach where the photodiode–amplifier–electrode set is contained within a single pixel of the MPDA such that each electrode provides an electrical stimulus to the remaining neurons nearby, thereby reflecting the visual signal that would normally be received via the corresponding, degenerated photoreceptor. [12]

2.3.4. Statistics

In a recent test of Alpha IMS, 23% of the 26 patients could track the path of a moving object, while 46% gained enough vision to use it in their daily activities. [13]

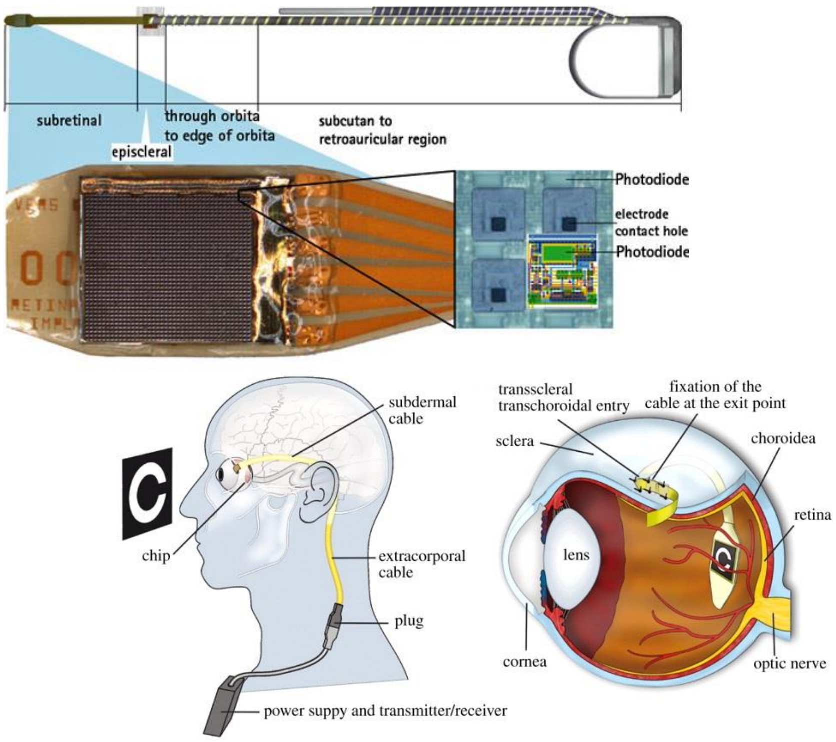

Fig.3. *The structure of Alpha IMS. [14] [15]*

3. Conclusion

Even if there is tense competition between Argus and Alpha implants, we can declare that whichever finds bigger crowd, the other one will also be considered as an alternative in the treatment of eyesight recovery. All we can do is waiting for the outcome of the race and seeking for the new developments.

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TEAMWORK ORGANIZATION IN HUMAN / MULTI-ROBOT INTERACTION

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Abstract

Human - robot interaction design falls at the confluence of several research areas including autonomous systems, human factors, intelligent user interfaces and task analysis. Communication between robots and people significantly increased over last years. The main reason is a huge progress in artificial intelligence. Human - robot interaction is based on the study of functionality and usability of performing some tasks that involve humans. In this paper we will discuss team organization conditions based on [1]. The aim of this paper is to make literature overview and define which teamwork organization is better due to the reducing of workload and increasing performance.

Keywords – Teamwork, MRS, Human - robot interaction, Team organization

1. Introduction

Enhanced autonomy makes it possible for one operator to control multiple robots. It releases an operator from manually controlling each robot and makes it possible to do tasks requiring monitoring, coordination, and complex decision-making [2]. Human - robot interaction is used when the completion of the task is too risky for people. Moreover, even when a single robot can achieve the given task, group of robots is used in order to achieve better performance and increase overall of the system.

Although there are a lot of advantages of using MrCs (Multi-robot Control systems), system can fail. Many teams never reach their full potential. In order to avoid system fails we have to create outstanding taxonomy. Factors that can lead to system fails are the following: poor combination of individual efforts, a breakdown in internal team processes, and improper use of available information. In addition, when people collaborate with autonomous systems, system complexity inevitably increases, and automation can change the way people coordinate with each other [3]. It follows that in multi-robot systems one of the central issues is the study of how groups work in order to avoid fail of the system. A paradigmatic example of joint activity is teamwork, in which a group of autonomous agents choose to work together, both in advancement of their own individual goals and the good of the system as a whole [4].

2. Teamwork organization

Controlling multiple autonomous robots is a complex process. The main elements of teamwork are leadership, mutual performing, backup behaviour and team orientation. The main point of this paper is a team taxonomy.

It is important to make a distinction between team performance and team effectiveness [7]. Team performance accounts for the outcomes of the team's actions regardless of how the team may have accomplished the task [7]. Conversely, team effectiveness takes a more holistic perspective in considering not only whether the team performed but also how the team interacted to achieve the team outcome [7]. This is an important differentiation because many factors external to the team may contribute to the success (or failure) of the team, and therefore in some cases team performance measures may be deficient in understanding the team [7].

2.1 Work organization between robots

We can assume that there are 2 types of work organization between robots: Distributed and Centralized.

Centralized system has an agent (leader) that is in charge of organizing the work of the other agents; the leader is involved in the decision process for the whole team, while the other members can act only according to the directions of the leader [8].

A Distributed system is composed of agents, which are completely autonomous in the decision process with respect to each other; in this class of systems a leader does not exist [8].

The classification of centralized systems can be further refined depending on the way the leadership of the group is played [8]. Specifically, Strong centralization is used to characterize a system in which decisions are taken by the same pre-defined leader agent during the entire mission duration, while in a weakly centralized system more than one agent is allowed to take the role of the leader during the mission [8].

In this paper we talk only about distributed or decentralized work of robots.

2.2 Team structure

Team structure is an important factor that affects to the team effectiveness for the search and rescue setting. Team structure can be described as the work assignment and communication architecture. Work assignment is the "manner in which the task components are distributed among team members" [5]. Team structured is closely related to communication, coordination and team performance.

For a team of operators working together with multiple homogeneous unmanned vehicles, two possible ways to organize the vehicles are as Sectors or as a Shared Pool [6]. In the Sector condition, each operator controls a part of all the vehicles. In the Shared Pool condition, operators share the control of all the robots and service them as needed.

Sector assignment can reduce the number of robots the operator must monitor and control [2]. However, the Shared Pool condition offers a more flexible scheduling advantage of load balancing since any operator in the team can service any robot as needed [2]. Although there was no significant difference on performance, teams that shared the control of all robots were found to have slightly lower workload [1]. In the Shared pool condition second operator may detect problems that were missed by the first operator. It also leads to excessive observation advantage.

In the pool condition members communicate more than in sector and share the workload between the operators and perform more teamwork behaviours. It was investigated that teams with shared control are more willing to work with team members on future projects.

Team members also employed certain team strategies to cope with the increased coordination cost. In the experiment, it was observed that some operators in Pool teams would preplan on which robots to control via verbal communication, even if the plan changed during the task execution [1]. In addition, reduced individual level of effort is easier in Pool teams than in Sector teams. With reduced individual level of effort, the advantage of Pool teams is diminished [1]. Teams that have developed shared mental model have more accurate expectations for the needs of the team and the teammates during periods of stress [7].

3. Conclusion

The effectiveness of the team increases during the process as team members learn how to work with each other and become increasingly proficient in their task work. Operators are suggested to start with simple tasks where they can learn their tasks, roles, performance, progress and the then undertake more complex tasks. It’s better to plan some strategies before the process starts.

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Estimation of minimum output power threshold for energy harvesting module: An inspection of battery and charging parameters of cell phones

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Abstract

Scavenging and Harvesting power to low powered devices becomes a huge requirement around the globe. When it comes to a cell phone battery life span the problem still exists which is making significant drawback in an increasingly and highly adaptive technological production. Throughout the innovations in every field the battery technology is on the back foot and could not be able to synchronize with the supply and demand of cell phone’s usage requirement. We need a module that will charge a cell phone when we are off the grid. Research domains are accelerated to figure out the solutions from readily available sources and energy harvesters are being introduced to charge a cell phone, but they were not able to establish the pavement and yet gives an insight to continue the tradition which includes design, compatibility measures, and the most significant is differentiation of cell phone specifications. This research work is based on the findings of heterogeneousness of cell phone battery and charging parameters like battery capacity, battery type, charging current and output power. By applying certain formulation on 100 cell phone models from various manufacturers a data sheet is prepared that would help researchers to make estimations for the output power requirement for cell phones’ under optimal conditions when creating any Energy harvesting module.

Keywords: Energy Harvesting, Radio Frequency, Ambient Energy sources, Renewable Energy,Piezoelectric,Battery.

1. Introduction

There is a cry for ‘battery is about to die’, every time and everywhere. This situation is getting worse in the world where the technological rate of improvement is increasing constantly, but unfortunately it’s not true for cell phone batteries [21] [26]. There is a demand for higher battery capacity that will be topped up by charging only once and will leave cell phone running for several days. However, increasing the size of battery violates the design standards and such bulky model cannot be appreciated by users [21]. Alternatively, Power banks were also introduced to the stated problem, but it remained the same problem to charge them again and again as we do it for cell phones; No way out. We call ourselves the wireless beings, but that’s not true when we look at our usage of technology oriented products in which we are still wired. However, The answer to this problem is only one i.e Energy Harvesting. We need a module which is able to perpetually charge our cell phones with available ambient energy sources. These sources are readily available in our surroundings [05],[27]. Harvesting is a process which is derived from the energy sources, specially Solar Energy, Wind, RF, Human power, Heat energy [1-5]. These remarkable contributions are not only specific to extract the energy from the surroundings, but also they worked in a multidisciplinary approach which includes design, programming, and sensor applications. Despite of availability of different Energy Harvesting Modules that are taking power from readily available energy sources to charge a cell phone [2-5, 7, 8, 20], still they are not much reliable and efficient to charge a cell phone on the go. This paper is organized as follows; The importance of Energy Harvesting is discussed in Section II, Section III is about the review of available energy harvesting devices. The methodology is defined in Section IV followed by the results in section V and conclusion in Section VI.

2. Energy Harvesting Power

The world is facing huge energy crises as we are left with limited fossil fuels. It is predicted that the world will run out of fuel by 2052. This alarming situation is clearly described in Fig.1. Scientists and researchers are trying to find out ways to make this world greener. Energy harvesting is the possible answer for this problem and to achieve this we need ambient energy sources which are surrounded by us every time [21, 27]. Energy harvesting also known as energy scavenging or power harvesting is the process of transforming ambient energy sources into electrical energy. The transformed energy is stored for later use [5]. More precisely energy harvesting is used to convert wasted energy to the usable energy. Ambient energy is said to be the energy that is purely natural, non electrical energy and has self regeneration or it is renewable [2, 11]. Recent trends in the energy harvesting field are moving towards the creation of an Energy Harvesting (EH) module that will constantly charge up the cell phone by harvesting power from ambient energy sources. However, the major issue in the creation of such an EH module is the heterogeneousness of battery and charging parameters of different cell phone devices. Before designing an EH module we must know the battery and charging parameters of different cell phones, as the first and vital step towards the creation of an EH module. Therefore, when developing such prototype regardless of any approach, we must know that how much minimum output power is required to charge a cell phone.

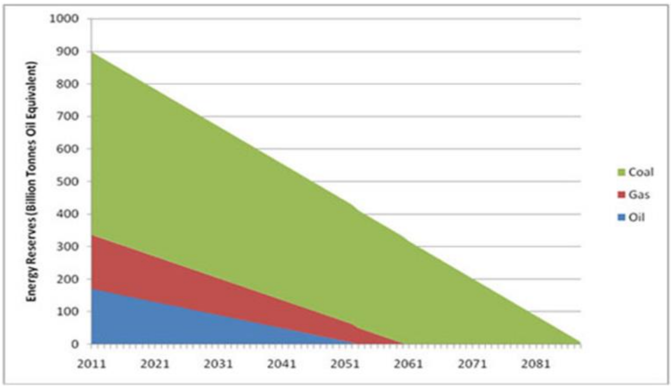


Fig.1. *Energy Reserves*

3. Energy Modules

3.1. Solar Energy Modules

This source is considered as the most powerful of all, as it is available in vast amount to charge the electronic devices. But this is limited to particular time from dawn to dusk, however, still produces excessive energy.There are a number of solar harvesting modules available and lots of research has been done as Qutaiba has proposed a mobile phone charging system in which the base is harvesting circuit that is connected to solar panels having V-I characteristics of the 4.0-100 from “solar world” which captures the power from panels and provides a way towards the target system, a DC-DC converter circuit is connected as shown in Fig. 2, in order to provide a constant voltage required by the system. The proposed work also uses a “Texas Instruments” TPS63000 low power buck booster converter that will support the methodology [3].This module can charge the cell phone and provides the output power that ranges from 100mW to 200mW.

Researchers continually strive to find out the strategies for extraction of power by different control techniques to improve maximum power tracking. For this purpose, a method is employed that suggests the low cost photovoltaic energy harvesting circuit to charge the portable device which uses efficient analog MPPT converter circuit to recognize the constant voltage MPPT rule. This system is able to operate constantly on solar panel’s MPP in order to grant maximum amount of power, this circuit is capable to operate at efficiencies between 80%-90%, within the circuit there is a battery protection component which will charge the rechargeable batteries directly [4]. Another approach is taken under consideration in which a model is designed for charging purpose by using optical wireless power transfer, which comprises of an optical antenna built in on a solar cell. The plasmonic effect has been increased and is efficient enough to wirelessly transfer the power without disregarding human safety regulations, along with solar cell and optical antenna there is a DC-DC conversion circuit, this source is limited to a particular room area where it can charge the electronic devices like cell phones, laptops, etc. Author claim that this approach will increase the output of the solar cell 40 times as compared to the conventional solar cell system [11]. Lots of MPPT techniques are being analysed to find the optimal one which can be used as efficient for energy modules to provide enough power to charge a cell phone. PV cells are the major source to depict the performance. In order to maximize the power extracted from solar panels, a prototype is designed in which the Maximum Power Point Tracking (MPPT) is utilized to collect maximum power from a PV cell and providing power for the charging batteries. It has stop and go strategy [5]. There is also an upgraded version of MPPT method used for charging of batteries by using solar panels which suggest the Maximum Power Transfer Tracking (MPTT) method for charging a cell phone and supports USB compatible charging standard along with dynamic programming based online algorithm for battery independent charger. A supercapacitor based energy buffer is implemented for MPTT in USB solar charger [12]. Many parameters like Solar cell material, location, weather and surroundings has a significant impact on the output performance of power efficient system [5].

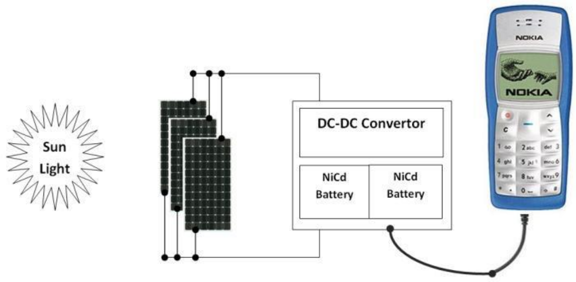


Fig.2. *Solar USB Charger*

3.2. Wind Energy Modules

Wind energy is the second most ubiquitous energy source in the world, and in future it is the rapidly growing renewable source [46]. Researchers have tested many ideas in order to extract the powerful wind energy and to convert it for low powered devices. The research conducted at Virginia tech has created a small scale wind turbine that will charge the low power electronic devices and remote sensor networks. The technique that has been used in small scale structure is based on electromagnetic- motor- based turbines and air-foil-based blades in which interfaces have been developed to cope with charging of cell phones and iPods. This prototype works on discontinuous and low speed wind mode, hence it can successfully charge a cell phone [20]. But here the design is an obstacle because we cannot carry such module with us everywhere that is so bulky. Wind energy could be harvested for cell phone charging, but different techniques are required to gather it effectively.

3.3. Radio Frequency Harvesting Modules

Radio frequency is an important source of energy as we are surrounded all the time by these radio frequency signals which are transmitted by the TV signals, cell phone, radio frequency towers and satellite communication system [1-2, 27]. This radiation can be captured by applying some retrieving techniques which are presented by researchers all over the world. A radio frequency energy harvesting model is proposed in which radio frequency can be extracted by using power generating circuits consisting of an antenna that converts into the DC voltage. In this model, there is printed dipole antenna having the size of a microchip and a power circuitry which extracts the power from GSM900 and GSM1800 and other frequencies such as Wireless LAN (WLAN), in order to increase the power, an array of antennas have been organised. The author affirms that during heavy traffic of frequencies the extracted power can charge a cell phone itself [1]. The power extracted from radio frequency is in smaller amounts, though there are many techniques to extract the power from radio frequency when considering the circuit design [28], whereas, researchers proposed a device, which includes two things; the rectifying circuit and matching circuit, a 2.13 GHz rectenna have been manufactured with a microstrip patch antenna of required size and polarization, the rectifying circuit will improve RF-DC efficiency the whole procedure can charge a single Li-ion battery [14].

It is important to design an energy efficient rectifying circuit and a voltage multiplying circuit to amplify incoming signals [25]. To capture the wireless energy by an antenna and to transmit it to the Energy harvesting circuitry, a system was suggested in which a charge pump is used that converts AC to DC and raises the amplitude, a voltage quadruple circuit that produces a DC output equals to the four times the peak voltage value (4Vp) [22].

3.4. Mechanical Energy Harvesting Modules

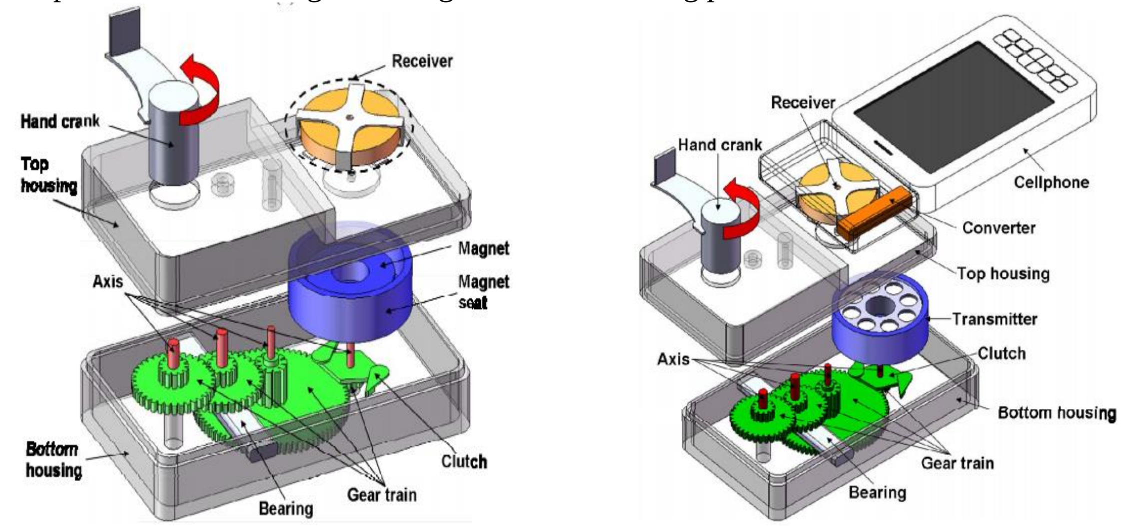
Establishing a paradigm for effectively and efficiently taking out the human power has been under consideration in recent years [09]. Transformation of mechanical energy into electrical energy can be done by using a piezoelectric effect and this effect can be captured by using the piezoelectric material. The mechanical force can be converted from vibration, pressure or force, due to this property piezoelectric became a popular source for energy scavenging [27]. Nowadays piezoelectric materials are used in different varieties for actuating, sensing and harvesting like Lead Zirconate Titanate (PZT) and polycrystalline ceramic, they need to store the generated charge piezoelectric in a circuit. The benefit of using piezoelectric is that it used to directly generate the voltage and does not require any other voltage generator [5].

Many researchers have made significant contributions in order to make piezoelectric transducers and piezoelectric generators, for using a piezoelectric material. An efficient circuit is used which can rectify the generated charge and will charge the portable device, for this purpose Karthik et al proposed a piezoelectric energy harvesting model in which a transducer PSI-5A4E is used and this material is placed below the keypad of cell phone device. A longitudinal effect has been focused and lots of piezoelectric crystals are used below the keypad, hence author claims that the design is appropriate and will charge a cell phone device [1]. Another important consideration is done on the human shoe in which Livingston and Hemlatha put forward a model which consists of 4 piezoelectric sensors that are inserted in the footwear sole for extraction of mechanical strain during the walking and jumping or jogging. This applied pressure is then converted into electrical energy, this electrical energy could reach for 30W but due to other material interferences, this energy could be limited to 100mW, therefore a required power is generated to charge any electrical gadget like cell phones and iPods [19]. Hillyard et al proposed the design and methodology of a piezoelectric shoe which consists of six piezoelectric bending strips that are inserted in the sole of the footwear. This design will convert the mechanical energy that is extracted by the potential energy through the bending piezoelectric strips and therefore will transform into the electrical energy. This generated energy is delivered to an external device that will actually charge a cell phone, it has a USB output that can directly charge an iPhone 5s [18]. Advancements for the extraction of periodic mechanical vibrations have been done and for this purpose important elements are under considerations like AC-DC converter circuit or energy harvester circuits, whereas Huq and Williamson compared 3 different AC-DC energy harvester circuits to observe the different load parameters when Li-ion battery is connected with them. These circuits consider the load voltage, current and in what amount the power is delivered, this research demonstrated the effect of voltage and current by applying 3 different AC-DC energy harvesting circuits [13]. Implementing piezoelectric could be tremendous discovery and may work as an important contribution in the future, special take care is still required for a number of attributes like frequency matching, material, resonant devices and conversion principles.

3.4.1. Human Powered Harvesting Modules

This type of energy has a significant amount of research interest, as it can potentially provide the solution for powering modern low power sensor systems and increase the mobility and independence of user. The investigation shows that several dozens of watts (W) are produced by heel strike, pushing, pinching, squeezing, cranking and shaking [06]. The researchers Linqiang et al advances a system for a manual cell phone charger which is based

on a Hand-Crank generator to provide a charging process, whenever a person is off-grid or away from any AC power source. This generator converts the mechanical energy produced by human kinetic energy into the electrical energy then generated energy will be transferred to the voltage regulator which maintains the voltage according to the cell phone requirement hence enough power is generated to charge a cell phone [07]. Another approach named as Human Powered Wireless Charger (HPWC) has been proposed, it harvests the human power said to be the kinetic energy. This charger transforms it to electrical energy and the produced energy is delivered wirelessly to charge a cell phone. This system uses the technique named as Wireless Electric Energy Transmission (WEET) that transmit the electrical signals from one point to another without using any wires or medium.Transmission is done by an inductive device, however the mechanism follows the technique which generates kinetic energy by hand rotary motion. The extracted power is transformed to the magnetic transmission and therefore wirelessly transfer the electrical power to charge electronic appliances like, cell phone, laptops etc [09]. The advanced version of the above stated technique proposed by the same researchers, worked on further enhancements on the previous prototype and named it as Human Powered Contactless Charger for Cell Phone (HCCC). In this prototype as shown in the Fig.3., there is a human power harvester (HPH) and a receiving unit (RU) including four gears and a hand crank, clutch transmits power with the frequency of 2.5Hz hand shank and charge a cell phone of 1020mAh battery capacity efficiently [10].
Researchers also contributed prototypes for those who are off-grid like rural Africans. A prototype named as Nokia DC-14 Bicycle charger kit proposed by Wyche and Murphy in which human power is harvested by sitting over the bicycle and applying the leg energy that will transmit this energy to the motor named as dynamo that is directly connected to a Nokia cell phone and will charge it through the harnessed leg power [17].



(a) (b)

Fig.3. *(a) The Structure of HPWC; (b) The Structure of HCCC*

3.5. Thermal/Heat Energy Harvesting Modules

Thermal energy harvesting is a process in which heat energy is captured and is transformed as electric energy that is produced by the temperature difference [5, 6]. Dinesh et al have proposed the thermal energy charger that includes a Peltier module or also knows as thermo-electric, it works on Seebeck effect. Whereas the Peltier effect applies a technique that whenever there is a temperature difference between the ends of the thermocouple then potential difference is generated, this system is implemented on the back of the cell phone device as shown in the Fig.4., where two different sides of cell phones cause temperature difference and generates an electric current to charge the cell phone [15].

Fig.4. *Interpretation for charging on back plate*

3.6. Hybrid Energy Harvesting Modules

Combining multiple energy sources and harvesting them in a single platform has been receiving a considerable amount of interest. For harvesting number of energy sources, research is shifted in every direction to find optimal solutions as much as possible; one aspect that has been investigated is through combining more than one energy harvesting techniques to get better results. A prototype given by Wei and Ramasamy in which a model implements two approaches that are mechanical energy harvesting and piezoelectric energy harvesting systems by using human shoe that will be applied by human power. The mechanical energy harvesting system will harvest the kinetic energy of walking of a person and at the same instant the piezoelectric harvesting system will harvest the pressure that comes from the human weight and the produced power is converted in an electrical system. In this system a human walking pattern has been considered as an input and a generator which combines both systems along with their power management circuits, whereas the electrical power can charge the cell phone device [8]. A project prepared by Thermally in which three renewable energy sources are taken which are sunlight, wind and heat energy; for the extraction of sunlight a solar panel has been used, for wind energy a DC brushless fan and to capture the heat energy a Peltier module is used. These three components are combined in one circuitry to work together in order to charge cell phone successfully [16].

4. Methodology

4.1. Heterogeneousness a major problem

For making an Energy Harvesting Module, we must know that what should be the minimum output power requirement for charging a cell phone. Regardless of what approach we adopt for creating an Energy Harvesting Module, the first and most important step is to determine the battery and charging parameters of cell phone devices. Almost all cell phones are manufactured with different specifications. It varies from manufacturer to manufacturer and still the cell phones of the same companies are designed differently, whether it is the charging socket, the battery capacity or battery type.

4.2. Prerequisite for calculation

The required data are being collected from official websites of cell phone manufacturers and 100 cell phone models are selected for this process. According to our research objective following 4 main specs are demonstrated; Battery Capacity (mAh), Battery Life during Stand By (h), Battery life during Talk time (h) and Battery Potential (V).
The cell phone manufacturers are under consideration for the collected data are stated below: Apple [37], Blackberry[38], Huawei[39], HTC[40], Samsung[41], SonyEricsson[42], QMobile[43], LG[44], Motorolla[45], Nokia[46].

In order to calculate the output power (mW) during Stand By and output power (mW) during a talk time; certain formulation is applied.
For calculation of Current (I):

$$\boldsymbol{I = \frac{Q_{battery}}{t}} \tag{1}$$

Reference of the equation (1) Where I is charging current, $Q_{battery}$ is battery capacity and t denotes battery life.

For calculation of Power (P):

$$\boldsymbol{P = V \times I} \tag{2}$$

Reference of the equation (2) Where P denotes Power, V is battery potential and I is charging current.

An example has been taken under consideration of a cell phone model of Apple iPhone 5s along with the required input variables for the desired output.

To calculate required power during standby under optimal conditions we have the following specifications:

- Battery voltage = 3.7 V
- $Q_{battery}$ = 1570 mAh
- $t_{standby}$ = 250 h
- $t_{talk\ time}$ = 10 h

To calculate the power (P) value during standby, first we must need to know that how much current (I) is required for charging purpose. These calculations are assumed to be ideal as we are not including the state of charge (SOC) for current (I) level of a battery cell.

Table 1. *Output Power (P) during standby*

Calculation of Current (I) during Talk Time	Calculation of Power (P) during Talk Time
$I = \frac{1570}{10} = 157\ mA$	$P = 3.7 \times 157 = 580.9\ mW$

Table 2. *Output Power (P) during talk time*

Calculation of Current (I) during Stand by	Calculation of Power (P) during Stand by
$I = \frac{1570}{250} = 6.28\ mA$	$P = 3.7 \times\ 6.28 = 23.236\ mW$

For remaining models the same process is applied and the sampling rate is on 100 models, their calculated data sheet is given at the end of the paper followed by the references. The values in Table 1 and Table 2 shows the charging current needed for charging purpose and output power from any harvesting module required during standby and talk time.

5. Results and discussion

These calculated values as demonstrated from Fig.5 to Fig.14 are used as a point of reference as they only provide estimation and general overview for the different cell phones' power requirement. We have to be careful when we intend to utilize the energy harvesting sources because efficiency varies from one source to another source. Schuss et al established such a calculation to define a charging time for the battery of PV charge and says that current requirement may vary within different manufacturers and this condition depends on the State of Charge (SOC) of every smartphone's battery. For instance, If the SOC is 80 %; the current is lower than when the SOC is at 30%. Therefore, it is not easy to describe the minimum amount of current [24]. For each harvesting module the value for current could be variable and we need to analyse them during charging time depending upon the efficiency of each harvester. The Fig.5 to Fig.14 demonstrates the calculated output power during standby and talk time, which specifies the battery capacity and its power approach.

6. Conclusion

This research work has provided a document based on a thorough review and analysis on the calculated results for which the data consists of 100 cell phone models from different manufacturers. By applying certain formulation to get the required power level of selected cell phone models during standby and talk time. The analysis is done in terms of battery capacity, battery life during standby and talk time and required potential which are considered as key aspects of this research work. This process is considered here as a first and basic step for the creation of any platform independent energy harvesting module and has produced a document that will be beneficial and may be used as a point of reference for future research.

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S.No	Model	Battery Type	Battery Capacity	Unit	Battery Stand By	Unit	Battery Talk Time	Unit	Current for S.B	Unit	Current for T.T	Unit	Voltage	Unit	Power Req: during S.B	Unit	Power Req: duting T.T	Unit
1	iPhone 6	Li ion	1810	mAh	250	h	14	h	7.24	mA	129.285714	mA	3.7	V	26.788	mW	478.357143	mW
2	iPhone5s	Li ion	1570	mAh	250	h	10	h	6.28	mA	157.00	mA	3.7	V	23.24	mW	580.90	mW
3	iPhone5c	Li ion	1507	mAh	250	h	8	h	6.03	mA	188.38	mA	3.7	V	22.30	mW	696.99	mW
4	iPhone5	Li ion	1440	mAh	225	h	8	h	6.40	mA	180.00	mA	3.7	V	23.68	mW	666.00	mW
5	iPhone4s	Li ion	1430	mAh	200	h	8	h	7.15	mA	178.75	mA	3.7	V	26.46	mW	661.38	mW
6	iPhone4c	Li ion	1420	mAh	250	h	10	h	5.68	mA	142.00	mA	3.7	V	21.02	mW	525.40	mW
7	iPhone4	Li ion	1420	mAh	300	h	7	h	4.73	mA	202.86	mA	3.7	V	17.51	mW	750.57	mW
8	iPhone3gs	Li ion	1220	mAh	300	h	5	h	4.07	mA	244.00	mA	3.7	V	15.05	mW	902.80	mW
9	iPhone3g	Li ion	1150	mAh	300	h	10	h	3.83	mA	115.00	mA	3.7	V	14.18	mW	425.50	mW
10	iPhone	Li ion	1400	mAh	250	h	8	h	5.60	mA	175.00	mA	3.7	V	20.72	mW	647.50	mW

Fig.5. *Apple Spreadsheet*

S.No	Model	Battery Type	Battery Capacity	Unit	Battery Stand By	Unit	Battery Talk Time	Unit	Current for S.B	Unit	Current for T.T	Unit	Voltage	Unit	Power Req: during S.B	Unit	Power Req: duting T.T	Unit
1	Z30	Li ion	2880	mAh	384	h	18	h	7.50	mA	160.00	mA	3.7	V	27.75	mW	592.00	mW
2	Q10	Li ion	2100	mAh	360	h	13.5	h	5.83	mA	155.56	mA	3.7	V	21.58	mW	575.56	mW
3	Bold 9790	Li ion	1230	mAh	408	h	5.2	h	3.01	mA	236.54	mA	3.7	V	11.15	mW	875.19	mW
4	Pearl 8110	Li ion	900	mAh	360	h	4.1	h	2.50	mA	219.51	mA	3.7	V	9.25	mW	812.20	mW
5	Bold 9000	Li ion	1500	mAh	312	h	5	h	4.81	mA	300.00	mA	3.7	V	17.79	mW	1110.00	mW
6	9720	Li ion	1450	mAh	432	h	7	h	3.36	mA	207.14	mA	3.7	V	12.42	mW	766.43	mW
7	Q5	Li ion	2180	mAh	336	h	12.5	h	6.49	mA	174.40	mA	3.7	V	24.01	mW	645.28	mW
8	Curve 8520	Li ion	1150	mAh	408	h	4.5	h	2.82	mA	255.56	mA	3.7	V	10.43	mW	945.56	mW
9	Pearl Flip 8320	Li ion	900	mAh	216	h	3.5	h	4.17	mA	257.14	mA	3.7	v	15.42	mw	951.43	mW
10	Storm 9530	Li ion	1400	mAh	360	h	5.5	h	3.89	mA	254.55	mA	3.7	V	14.39	mW	941.82	mW

Fig.6. *Blackberry Spreadsheet*

S.No	Model	Battery Type	Battery Capacity	Unit	Battery Stand By	Unit	Battery Talk Time	Unit	Current for S.B	Unit	Current for T.T	Unit	Voltage	Unit	Power Req: during S.B	Unit	Power Req: during T.T	Unit
1	Ascend Y511	Li ion	1730	mAh	300	h	13	h	5.77	mA	133.08	mA	3.7	V	21.34	mW	492.38	mW
2	Ascend W2	Li ion	1700	mAh	380	h	11	h	4.47	mA	154.55	mA	3.7	V	16.55	mW	571.82	mW
3	Vitria	Li ion	1750	mAh	380	h	11	h	4.61	mA	159.09	mA	3.7	V	17.04	mW	588.64	mW
4	Prism 2	Li ion	1750	mAh	240	h	7	h	7.29	mA	250.00	mA	3.7	V	26.98	mW	925.00	mW
5	Ascend W1	Li ion	1950	mAh	460	h	11.16	h	4.24	mA	174.73	mA	3.7	V	15.68	mW	646.51	mW
6	Verge	Li ion	1150	mAh	350	h	5.5	h	3.29	mA	209.09	mA	3.7	V	12.16	mW	773.64	mW
7	Ascend Y	Li ion	1400	mAh	300	h	7	h	4.67	mA	200.00	mA	3.7	V	17.27	mW	740.00	mW
8	Summit	Li ion	1400	mAh	216	h	7	h	6.48	mA	200.00	mA	3.7	V	23.98	mW	740.00	mW
9	Pillar	Li ion	900	mAh	240	h	4.5	h	3.75	mA	200.00	mA	3.7	v	13.88	mw	740.00	mW
10	Ideos X1	Li ion	1200	mAh	336	h	4	h	3.57	mA	300.00	mA	3.7	V	13.21	mW	1110.00	mW

Fig.7. *Huawei Spreadsheet*

S.No	Model	Battery Type	Battery Capacity	Unit	Battery Stand By	Unit	Battery Talk Time	Unit	Current for S.B	Unit	Current for T.T	Unit	Voltage	Unit	Power Req: during S.B	Unit	Power Req: duting T.T	Unit
1	HTC One Max	Li ion	3300	mAh	585	h	25	h	5.64	mA	132.00	mA	3.7	V	20.87	mW	488.40	mW
2	HTC Butterfly	Li ion	3200	mAh	659	h	25	h	4.86	mA	128.00	mA	3.7	V	17.97	mW	473.60	mW
3	Windows Phone 8X	Li ion	1800	mAh	290	h	11.3	h	6.21	mA	159.29	mA	3.7	V	22.97	mW	589.38	mW
4	HTC One X+	Li ion	2100	mAh	360	h	12.75	h	5.83	mA	164.71	mA	3.7	V	21.58	mW	609.41	mW
5	HTC One SC	Li ion	1650	mAh	317	h	10.5	h	5.21	mA	157.14	mA	3.7	V	19.26	mW	581.43	mW
6	Desire HD	Li ion	1230	mAh	420	h	5.5	h	2.93	mA	223.64	mA	3.7	V	10.84	mW	827.45	mW
7	Hero	Li ion	1350	mAh	440	h	8	h	3.07	mA	168.75	mA	3.7	V	11.35	mW	624.38	mW
8	P3300	Li ion	1250	mAh	200	h	4	h	6.25	mA	312.50	mA	3.7	V	23.13	mW	1156.25	mW
9	Max 4G	Li ion	1500	mAh	350	h	7	h	4.29	mA	214.29	mA	3.7	V	15.86	mW	792.86	mW
10	Salsa	Li ion	1520	mAh	530	h	7.5	h	2.87	mA	202.67	mA	3.7	V	10.61	mW	749.87	mW

Fig.8. *HTC Spreadsheet*

S.No	Model	Battery Type	Battery Capacity	Unit	Battery Stand By	Unit	Battery Talk Time	Unit	Current for S.B	Unit	Current for T.T	Unit	Voltage	Unit	Power Req: during S.B	Unit	Power Req: duting T.T	Unit
1	Galaxy Note 3	Li ion	3200	mAh	490	h	20	h	6.53	mA	160.00	mA	3.7	V	24.16	mW	592.00	mW
2	Galaxy Mega 6.3	Li ion	3200	mAh	420	h	17	h	7.62	mA	188.24	mA	3.7	V	28.19	mW	696.47	mW
3	Galaxy S4 Mini	Li ion	1900	mAh	300	h	12	h	6.33	mA	158.33	mA	3.7	V	23.43	mW	585.83	mW
4	Galaxy S3	Li ion	2100	mAh	750	h	10.833	h	2.80	mA	193.85	mA	3.7	V	10.36	mW	717.25	mW
5	Galaxy Y	Li ion	1200	mAh	540	h	6	h	2.22	mA	200.00	mA	3.7	V	8.22	mW	740.00	mW
6	Galaxy Young	Li ion	1300	mAh	250	h	6.6	h	5.20	mA	196.97	mA	3.7	V	19.24	mW	728.79	mW
7	Champ Duos	Li ion	1000	mAh	490	h	14.833	h	2.04	mA	67.42	mA	3.7	V	7.55	mW	249.44	mW
8	Don	Li ion	800	mAh	720	h	7	h	1.11	mA	114.29	mA	3.7	V	4.11	mW	422.86	mW
9	Galaxy Ace Duos	Li ion	1300	mAh	410	h	6.5	h	3.17	mA	200.00	mA	3.7	V	11.73	mW	740.00	mW
10	Galaxy Star Pro	Li ion	1500	mAh	370	h	15	h	4.05	mA	100.00	mA	3.7	V	15.00	mW	370.00	mW

Fig.9. *Samsung Spreadsheet*

S.No	Model	Battery Type	Battery Capacity	Unit	Battery Stand By	Unit	Battery Talk Time	Unit	Current for S.B	Unit	Current for T.T	Unit	Voltage	Unit	Power Req: during S.B	Unit	Power Req: duting T.T	Unit
1	Live	Li ion	1200	mAh	400	h	6.7	h	3.00	mA	179.10	mA	3.7	V	11.10	mW	662.69	mW
2	Neo	Li ion	1500	mAh	400	h	7	h	3.75	mA	214.29	mA	3.7	V	13.88	mW	792.86	mW
3	Arc S	Li ion	1500	mAh	460	h	7.3	h	3.26	mA	205.48	mA	3.7	V	12.07	mW	760.27	mW
4	Mix Walkman	Li ion	1000	mAh	465	h	9.7	h	2.15	mA	103.09	mA	3.7	V	7.96	mW	381.44	mW
5	Xperia Mini Pro	Li ion	1200	mAh	340	h	5.5	h	3.53	mA	218.18	mA	3.7	V	13.06	mW	807.27	mW
6	Bravia S004	Li ion	930	mAh	260	h	3.5	h	3.58	mA	265.71	mA	3.7	V	13.23	mW	983.14	mW
7	P800	Li ion	1000	mAh	400	h	13	h	2.50	mA	76.92	mA	3.7	V	9.25	mW	284.62	mW
8	K750i	Li ion	900	mAh	400	h	9	h	2.25	mA	100.00	mA	3.7	V	8.33	mW	370.00	mW
9	W715	Li ion	950	mAh	350	h	13	h	2.71	mA	73.08	mA	3.7	v	10.04	mw	270.38	mW
10	W80	Li ion	930	mAh	300	h	13	h	3.10	mA	71.54	mA	3.7	V	11.47	mW	264.69	mW

Fig.10. *Sony Ericsson Spreadsheet*

S.No	Model	Battery Type	Battery Capacity	Unit	Battery Stand By	Unit	Battery Talk Time	Unit	Current for S.B	Unit	Current for T.T	Unit	Voltage	Unit	Power Req: during S.B	Unit	Power Req: duting T.T	Unit
1	Z4 Quadcore	Li ion	2020	mAh	300	h	10	h	6.73	mA	202.00	mA	3.7	V	24.91	mW	747.40	mW
2	Z4 Mini	Li ion	3000	mAh	260	h	8	h	11.54	mA	375.00	mA	3.7	V	42.69	mW	1387.50	mW
3	Noir V4	Li ion	2600	mAh	300	h	19	h	8.67	mA	136.84	mA	3.7	V	32.07	mW	506.32	mW
4	Noir A700	Li ion	2100	mAh	450	h	7	h	4.67	mA	300.00	mA	3.7	V	17.27	mW	1110.00	mW
5	Noir A15 3D	Li ion	2000	mAh	225	h	3.5	h	8.89	mA	571.43	mA	3.7	V	32.89	mW	2114.29	mW
6	Noir A20	Li ion	2000	mAh	400	h	5	h	5.00	mA	400.00	mA	3.7	V	18.50	mW	1480.00	mW
7	Noir A35	Li ion	1500	mAh	175	h	4.5	h	8.57	mA	333.33	mA	3.7	V	31.71	mW	1233.33	mW
8	E950	Li ion	1000	mAh	168	h	8	h	5.95	mA	125.00	mA	3.7	V	22.02	mW	462.50	mW
9	E995	Li ion	1400	mAh	432	h	9.7	h	3.24	mA	144.33	mA	3.7	v	11.99	mw	534.02	mW
10	E900	Li ion	950	mAh	215	h	8.8	h	4.42	mA	107.95	mA	3.7	V	16.35	mW	399.43	mW

Fig.11. *QMobile Spreadsheet*

S.No	Model	Battery Type	Battery Capacity	Unit	Battery Stand By	Unit	Battery Talk Time	Unit	Current for S.B	Unit	Current for T.T	Unit	Voltage	Unit	Power Req: during S.B	Unit	Power Req: duting T.T	Unit
1	Nexus	Li ion	2300	mAh	300	h	17	h	7.67	mA	135.29	mA	3.7	V	28.37	mW	500.59	mW
2	Optimus F7	Li ion	2540	mAh	300	h	13	h	8.47	mA	195.38	mA	3.7	V	31.33	mW	722.92	mW
3	Motion4G	Li ion	1400	mAh	290	h	5.5	h	4.83	mA	254.55	mA	3.7	V	17.86	mW	941.82	mW
4	Quantum	Li ion	1500	mAh	350	h	6	h	4.29	mA	250.00	mA	3.7	V	15.86	mW	925.00	mW
5	Xpression	Li ion	1000	mAh	240	h	3.4	h	4.17	mA	294.12	mA	3.7	V	15.42	mW	1088.24	mW
6	KG 800	Li ion	800	mAh	200	h	6	h	4.00	mA	133.33	mA	3.7	V	14.80	mW	493.33	mW
7	Revere	Li ion	800	mAh	200	h	7	h	4.00	mA	114.29	mA	3.7	V	14.80	mW	422.86	mW
8	Spectrum 2	Li ion	2150	mAh	473	h	10.4	h	4.55	mA	206.73	mA	3.7	V	16.82	mW	764.90	mW
9	Prada 3.0	Li ion	1540	mAh	330	h	5	h	4.67	mA	308.00	mA	3.7	v	17.27	mw	1139.60	mW
10	Optimus Slider	Li ion	1500	mAh	288	h	3.8	h	5.21	mA	394.74	mA	3.7	V	19.27	mW	1460.53	mW

Fig.12. *LG Spreadsheet*

S.No	Model	Battery Type	Battery Capacity	Unit	Battery Stand By	Unit	Battery Talk Time	Unit	Current for S.B	Unit	Current for T.T	Unit	Voltage	Unit	Power Req: during S.B	Unit	Power Req: duting T.T	Unit
1	Droid	Li ion	2130	mAh	312	h	28	h	6.83	mA	76.07	mA	3.7	V	25.26	mW	281.46	mW
2	Moto X	Li ion	2200	mAh	499	h	12	h	4.41	mA	183.33	mA	3.7	V	16.31	mW	678.33	mW
3	Droid Razer	Li ion	3300	mAh	372	h	12	h	8.87	mA	275.00	mA	3.7	V	32.82	mW	1017.50	mW
4	Defy Pro	Li ion	1700	mAh	324	h	12	h	5.25	mA	141.67	mA	3.7	V	19.41	mW	524.17	mW
5	Fire	Li ion	1400	mAh	260	h	5.5	h	5.38	mA	254.55	mA	3.7	V	19.92	mW	941.82	mW
6	Motofone F3	Li ion	800	mAh	300	h	4.5	h	2.67	mA	177.78	mA	3.7	V	9.87	mW	657.78	mW
7	V70	Li ion	430	mAh	145	h	3.6	h	2.97	mA	119.44	mA	3.7	V	10.97	mW	441.94	mW
8	Titanium	Li ion	1820	mAh	235	h	6.75	h	7.74	mA	269.63	mA	3.7	V	28.66	mW	997.63	mW
9	i786	Li ion	1130	mAh	499	h	12	h	2.26	mA	94.17	mA	3.7	v	8.38	mw	348.42	mW
10	Bravo	Li ion	1540	mAh	238	h	6.8	h	6.47	mA	226.47	mA	3.7	V	23.94	mW	837.94	mW

Fig.13. *Motorolla Spreadsheet*

S.No	Model	Battery Type	Battery Capacity	Unit	Battery Stand By	Unit	Battery Talk Time	Unit	Current for S.B	Unit	Current for T.T	Unit	Voltage	Unit	Power Req: during S.B	Unit	Power Req: duting T.T	Unit
1	Lumia 625	Li ion	2000	mAh	552	h	15.2	h	3.62	mA	131.58	mA	1	V	3.62	mW	131.58	mW
2	Lumia 925	Li ion	2000	mAh	432	h	12.8	h	4.63	mA	156.25	mA	2	V	9.26	mW	312.50	mW
3	Asha501	Li ion	1200	mAh	300	h	12	h	4.00	mA	100.00	mA	3	V	12.00	mW	300.00	mW
4	Asha301	Li ion	1100	mAh	750	h	10.833	h	1.47	mA	101.54	mA	4	V	5.87	mW	406.17	mW
5	Lumia 520	Li ion	1430	mAh	540	h	6	h	2.65	mA	238.33	mA	5	V	13.24	mW	1191.67	mW
6	1280	Li ion	800	mAh	250	h	6.6	h	3.20	mA	121.21	mA	6	V	19.20	mW	727.27	mW
7	110	Li ion	1020	mAh	490	h	14.833	h	2.08	mA	68.77	mA	7	V	14.57	mW	481.36	mW
8	103	Li ion	800	mAh	720	h	7	h	1.11	mA	114.29	mA	8	V	8.89	mW	914.29	mW
9	Asha205	Li ion	1020	mAh	370	h	15	h	2.76	mA	68.00	mA	9	V	24.81	mW	612.00	mW
10	6700Slide	Li ion	850	mAh	370	h	15	h	2.30	mA	56.67	mA	9	V	20.68	mW	510.00	mW

Fig.14. *Nokia Spreadsheet*

UNDERGROUND MINING WITH REMOTE CONTROLLED ROBOTS, USING WIRELESS NETWORK

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Abstract

This paper presents a basic idea of modern wireless communication usage in unreachable workspaces such as mines, and includes an extensive overview about the problems with current underground wireless network technology. Since most of the unexhausted mines are either inaccessible or simply too risky for humans to work in, /e.g., due to poisonous gases/ we have to think about alternative solutions. One way of solving this would be to control various robots from a safe place. For more precise controlling the now trending Virtual Reality /VR/ technology is the best pick. Also it touches the idea of Wireless Underground Sensor Networks /WUSN/, as the first step in the process of development.

***Keywords*:** Wireless communication, underground communication, hybrid networks

1. Introduction

Wireless technology is one of the world's lead research at the moment, since in almost every area of work, you need to communicate information. And in more and more cases the option of wired information transmission is becoming either physically impossible or extremely impractical. Just consider nano-bots in medical field, or think about space technology. So we can safely say that this field of information transferring is key in today's world, and researchers are looking for new and better ways every day of the year.

We got far from the telegraph -invented by Joseph Henry & Samuel F.B. Morse in 1832 – to now days most commonly used satellites and Wi-Fi s. [2]

2. Alternate Wireless Data transfer Methods

2.1. Bluetooth

One of the first and most known outdated methods of wireless communication is the Bluetooth technology. The advantages are the low cost, and low power requirement. However it is not a surprise that we don't use them, since the range and data transferring capacity is fairly low. Usually Bluetooth operates in the unlicensed 2.4 GHz to 2.4835 GHz Industrial, Scientific and Medical (ISM) frequency band, which is also used by many other technology such as IEEE 802.11 b/g WLAN standard. Also the communication between the devices uses 79 different radio channels by hoping frequencies at 1 MHz interval giving a high degree of interference immunity.

The approximated data transferring rate is less than 1 Mb/s. The range varies between 1-200m. Despite the disadvantages, we still use it for low data communications, e.g.: Bluetooth headphones, car communication systems, wireless speakers. [3]

2.1. Li-Fi

Light Fidelity or Li-Fi is a Visible Light Communications (VLC) [5] system running wireless communications travelling at very high speeds. It uses common household LED (light emitting diodes) lightbulbs to enable data transfer, boasting speeds of up to 224 gigabits per second. This more secure and faster way of communication may just be a failure, but according to Apple it certainly has some potential.

Li-Fi / Wi-Fi comparison

Parameter	Li-Fi	Wi-Fi
Speed	***	***
Range	*	**
Data density	***	*
Security	***	**
Reliability	**	**
Power available	***	*
Transmit/receive power	***	**
Ecological impact	*	**
Device-to-device connectivity	***	***
Obstacle interference	***	*
Bill of materials	***	**
Market maturity	*	***

* low ** medium *** high

Fig.1. *Li-Fi vs. WiFi Comparison*

2. Wireless Underground Sensor Networks

In the field of underground communication, the lead area of research is the sensor networks. Since they are used in many different cases such as; Environmental monitoring, Location determination of objects, Border patrol & Security. The current technology for underground sensing consists of deploying a buried sensor and wiring it to a data-logger on the surface which stores sensor readings for later retrieval. Data-loggers may be equipped with a device for wired or single-hop wireless back-haul to a centralized sink, but often data is manually retrieved by physically visiting the data-logger [1].

Fig.2. *Wireless Underground Sensors and Data Acquisition Devices*

The leading problem with WUSN-s and high density data transmission underground is the exact same as in most areas of modern remote technology; the power source. In case of WUSN-s the sensors themselves have to be isolated, so they need to have a self-contained power source. However for using wireless methods, we need to have a fairly big energy input. It raises the question if we have the needed energy container, but the sad answer is a short no.

3. Wireless Underground Sensor Network Research Challenges

The underground wireless channel is the second main factor that make realizing WUSNs a challenge. Although digital communication in the underground appears to be unexplored, EM wave propagation through soil and rock has been studied extensively for ground-penetrating radar. Although EM wave propagation has been studied, a comprehensive channel model for the underground does not yet exist. A group of researchers have identified five main factors, however, which impact communication with EM waves in the underground:

- Extreme path loss,
- Reflection/refraction,
- Multi-path fading,
- Reduced propagation velocity,
- Noise

4. The VR requirements

The requirements of a stabile VR connection with the control feedback and the full surrounding sharing is approximated around 20-40Mbps.[4] Also we would need at least a Quad-core 2.7 GHz CPU and a Wi-Fi /or other alternative/ transmitter, and of course at minimum 5 pieces of 72° angle cameras. It is important to mention that this is just the necessary configuration for the VR connection from the mining side of the equation.

5. Conclusion

All in all, this vision of the usage of wireless communication in underground mining is yet to come true. We have to find a powerful enough energy-container, an efficient and fast way of transmitting data through solid materials without any losses and last but not least the mining robots for the job to be done.

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"OCTOBOT" THE ROBOT THAT CAN MOVE WITHOUT BATTERY

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Abstract

Octobot is the a sort of robots that is made of soft and rubbery parts. Octobot is the first with this feature. Because Robots are generally made of hard-featured parts and this hard-featured parts don't let to robots move flexible. Octobot can move flexible because of this soft and rubbery parts. Octobot has one more different property that is to not need to batteries. Octobot can move without batteries. This feature is very useful feature about energy. Octobot has 8 arms that are pneumaticly driven by steady streams of oxygen gas. This gas is given off by liquid hydrogen peroxide fuel after it chemically reacts with platinum catalysts. The robot is 6 gram and that is contrrolled using tiy 3D-printed networks of plumping. Microfluidic Circuitry that can shuffle fluids around pipes have begun developing by scienist in recent years are used for control the robots. The Octobot's microfluidic controller is filled with the liquid hydrogen peroxide fuel. As the fuel gives off oxygen, pressure from the gas builds up in the controller and eventually causes some valves to open and others to close, inflating chambers in half the robot's arms and forcing them to move.

Keywords: Robot, Microfluid, Soft, Pneumatic

1.Introduction

A rubbery little "octobot" is the first robot made completely from soft parts, according to a new study. The tiny, squishy guy also doesn't need batteries or wires of any kind, and runs on a liquid fuel.

The octopus-like robot is made of silicone rubber, and measures about 2.5 inches (6.5 centimeters) wide and long. The researchers say soft robots can adapt more easily to some environments than rigid machines, and this research could lead to autonomous robots that can sense their surroundings and interact with people.

Conventional robots are typically made from rigid parts, which makes them vulnerable to harm from bumps, scrapes, twists and falls. These hard parts can also hinder them from being able to squirm past obstacles. Increasingly, scientists are building robots made of soft, elastic plastic and rubber, designs inspired by octopuses, starfish and worms. These soft robots are generally more resistant to damage, and can wriggle past many of the obstacles that impair hard robots.

However, soft robots were previously limited by rigid batteries or wires needed to power the bots. Now, "we are very excited to present a completely soft, untethered robot," said study co-lead author Michael Wehner, a research associate in materials science and mechanical engineering at Harvard University. "As the field of soft robotics continues to rapidly expand, we feel that our work will allow the field to rapidly move forward in a whole new direction."

The octobot has eight arms (hence the name) that are pneumatically driven by steady streams of oxygen gas. This gas is given off by liquid hydrogen peroxide fuel after it chemically reacts with platinum catalysts.

The 0.2-ounce (6 grams) robot is controlled using tiny 3D-printed networks of plumbing. Whereas conventional microelectronic circuits shuffle electrons around wires, scientists in recent years have begun developing microfluidic circuitry that can shuffle fluids around pipes. These devices can theoretically perform any operation a regular electronic microchip can, previous research suggested.

The octobot's microfluidic controller is filled with the liquid hydrogen peroxide fuel. As the fuel gives off oxygen, pressure from the gas builds up in the controller and eventually causes some valves to open and others to close, inflating chambers in half the robot's arms and forcing them to move. Pressurized gas then builds up once more, triggering valve openings and closures that make the other robot's arms move.

So far, the octobot can only wave its arms. The scientists are now working on developing completely soft machines that are more complex and can propel themselves, and perhaps swim, Wehner said. "Integrated sensors would also allow reaction to the bot's environment"

There is no on-off switch for this current version of the octobot — it activates once it gets filled with fuel, Wehner said. Future bots with more complex controllers and sensors could be envisioned with on-off switches, he noted.

The octobot can currently run for about 4 to 8 minutes. The researchers said they can probably improve the bot's run-time using more sophisticated designs that better control how the fuel is used.

"We foresee soft robots expanding the role of robots in human-populated environments — human-robot interaction," Wehner said.

In addition, "a separate but very interesting potential application for this type of robot is in high-risk, dangerous areas such as search and rescue," Wehner said. "The total material cost for the octobot is just over $2, and fuel costs approximately 5 cents per fill. One could envision a scenario in which 100 bots are deployed to investigate a scene, anticipating that 80 would be destroyed."

2- Microfluidic Circuitry

A computer made using water and magnets can move droplets around inside itself like clockwork, researchers say. The device demonstrates a new way to merge computer calculations with the manipulation of matter, scientists added.

Whereas conventional microelectronics shuffle electrons around wires, in recent years, scientists have begun developing so-called microfluidic devices that shuffle liquids around

pipes. These devices can theoretically perform any operation a conventional electronic microchip can.
Although microfluidic devices are dramatically slower than conventional electronics, the goal is not to compete with electronic computers on traditional computing tasks such as word processing. Rather, the aim is to develop a completely new class of computers to precisely control matter.

"The fundamental limits of computation, such as how fast you can go or how small devices can be, are based in how information has to be represented in physical entities," study co-author Manu Prakash, a biophysicist at Stanford University, told Live Science. "We flipped that idea on its head — why can't we use computations to manipulate physical entities?"

Current applications for microfluidic chips include serving as miniaturized chemistry and biology laboratories. Instead of performing experiments with dozens of test tubes, each droplet in a lab-on-a-chip can serve as a microscopic test tube, enabling scientists to conduct thousands of experiments simultaneously, but requiring a fraction of the time, space, materials, cost and effort of a conventional laboratory.

But one major drawback of microfluidic devices is that the droplets of liquid are usually controlled one at a time. Although Prakash and his colleagues previously demonstrated a way to control many droplets on a microfluidic chip simultaneously, until now, the actions of such droplets were not synchronized with each other. That makes these systems prone to errors that prevented the devices from taking on more complex operations.

Now Prakash and his colleagues have developed a way for droplets on microfluidic devices to act simultaneously, in a synchronized manner. The key was using a rotating magnetic field, like a clock.
The core of the new microfluidic chip, which is about half the size of a postage stamp, consists of tiny, soft, magnetic nickel-iron-alloy bars arranged into mazelike patterns. On top of this array of bars is a layer of silicone oil sandwiched between two layers of Teflon. The bars, oil and Teflon layers are in turn placed between two glass slides.

The researchers then carefully injected water droplets into the oil; these droplets were infused with tiny magnetic particles only nanometers, or billionths of a meter, wide. Next, the researchers turned on a rotating magnetic field.

Each time the magnetic field reversed, the bars flipped, drawing the magnetized droplets along specific directions, the researchers said. Each rotation of the magnetic field was very much like a cycle on a clock — for instance, a second hand making a full circle on a clock face. The rotating magnetic field ensured that every droplet ratcheted precisely one step forward with each cycle, moving in perfect synchrony.
A camera recorded the movements and interactions of all the droplets. The presence of a droplet in any given space represents a one in computer data, while the absence of a drop represents a zero; interactions among the droplets are analogous to computations, the researchers said. The layout of the bars on these new microfluidic chips is analogous to the layout of circuits on microchips, controlling interactions among the droplets.

So far, the droplets in this device are as little as 100 microns wide, the same size as the average width of a human hair. The researchers noted their models suggest the devices could ultimately control droplets just 10 microns large. "Making the droplets smaller will allow the chip to carry out more operations," Prakash said.

The researchers now plan to make a design tool for these droplet circuits available to the public, so that anyone can make them.

"We're very interested in engaging anybody and everybody who wants to play, to enable everyone to design new circuits based on building blocks we describe in this paper, or [to] discover new blocks," Prakash said in a statement.

Prakash and his colleagues Georgios Katsikis and James Cybulski, both of Stanford University, detailed their findings June 8 in the journal Nature Physics.

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TECHNOLOGICAL ADVANCEMENTS IN STROKE HAND REHABILITATION DEVICES: A REVIEW

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Abstract

Stroke is the third most common cause of death and permanent disability among older adults [1]. Stroke victims often lose proper function of at least one hand and fingers, experiencing delays in gripping and releasing ability. Impairment of hand function and mobility is the most common problem that surfaces after developing neurological disorders such as stroke [2], Muscular dystrophy [3] and incomplete spinal cord injury [4]. That was the biggest reason for researcher from all over the work working to develop wearable exoskeleton devices. During the last few years, interest has been growing, exoskeleton devices for rehabilitation technology. In this paper, we are going to review the recent developments for rehabilitation devices based on different technology , like using EMG , Virtual Reality (VR).

Keywords: Stroke, Wearable Devices, Rehabilitation, Exoskeletons, Therapy.

1. Introduction

The Hand is the multi-fingered extremity at the end of the arm. It is one means by which humans have changed the world by creating gigantic buildings and machines, Hands are capable of a wide variety of functions, including gross and fine motor movements. Gross motor movements allow us to pick up large objects or perform heavy labour. Fine motor movements enable us to perform delicate tasks. , natural motor capability is crucial for Activities of Daily Living (ADL) [5]. Losing the hand function is one of the biggest problem worldwide; The statistics suggests 15 million people suffer from stroke worldwide each year. Out of these, 5 million die and another 5 million are permanently disabled. In Europe average approximately 650,000 stroke deaths each year [31]. Cerebral vascular accidents, or strokes, remain the leading cause of adult disability and nearly 80% of stroke survivors suffer hemiparesis of the upper arm [6]. Immediately upon stabilization of the condition, usually the patients are transferred to a rehabilitation institute where they receive complex rehabilitation (physiotherapy, ergo therapy, speech therapy, psychotherapy). Usually the patients are treated for an average of 7 days. While many clinical trials have been conducted to study the efficacy of various robot-assisted rehabilitation devices [7]. Recent development in neuroimaging techniques allows an in-depth investigation of brain motor recovery mechanisms. This is critical to better understanding the effectiveness of different rehabilitation techniques in treatment of neurological disorders [8]. To recover the stroke hand is a fundamental research, in what ways they can revert the hand functioning as it was before. Doctors, neurologists and researchers are trying hard to find ways, therapists need kind of instruments for this rehabilitation process, but with the help of robotic technology and artificial intelligence the process becomes much more reliable and effective. Technology in general has advanced over the years. But because of the complex structure and intricateness of human hands, it imposes a greater difficulty on the development of a hand robotics devices. Based on several researches in hand rehabilitation technique systems, these requirements can be focused on: low mass and inertia, comfort of wearing, extensive range of motion, complexity [9].

2. Functional Electrical Stimulation (FES) technology for hand Rehabilitation

Functional electrical stimulation (FES) is an effective technique for the hand rehabilitation functions such as grasping and releasing [10]. It is a technique that causes a muscle to contract through the use of an electrical current. This might sound strange, but in fact, the body naturally uses electrical currents to make muscles move. Normally, when a part of the body needs to move, the brain sends electrical signals through the nervous system. The nerves, acts like electrical wires, after a stroke, some of these electrical signals do not function as well as they should. FES allows muscles that have been paralysed or partially paralysed by stroke to move again [11]. Electrical stimulation can be applied in a variety of ways to the hemiparesis upper extremity following a stroke. In particular, electromyography (EMG) - triggered electrical muscle stimulation improves the motor function of the hemiparesis arm and hand [12]. Functional electrical stimulation has been applied to provide control of the movements or the functions by generating electrical stimuli to the nerves or muscles [10]. Technology-assisted training of arm-hand skills with functional electrical stimulation (FES) is an attractive treatment option, because it can potentially deliver intensive periods of treatment with comparatively little demand on resources [13]. Some of the most commonly used techniques are demonstrated based on Functional electrical stimulation (FES).

2.1. EMG - controlled FES

The functional rehabilitation uses an EMG controlled stimulator with a pair of surface electrodes records both EMG & delivers electrical stimulation [14]. The main drawback of EMG-triggered neuromuscular electrical stimulation system is that it cannot control electrical stimulation in proportion to voluntary EMG after onset of preprogrammed electrical stimulation [10].

A novel EMG-controlled FES system (Integrated Volitional Control Electrical Stimulator (IVES): OG GIKEN, Okayama, Japan) is a portable, 2-channel neuromuscular stimulator which works to promote wrist, finger extension or shoulder flexion movement during coordinate movement, but will not work when target muscles have no muscle contraction. This device induces greater muscle contraction by electrical stimulation in proportion to the voluntary integrated EMG signal picked up. The system comprises 2 instruments: a setting and input system and a stimulator as shown in Fig. 1

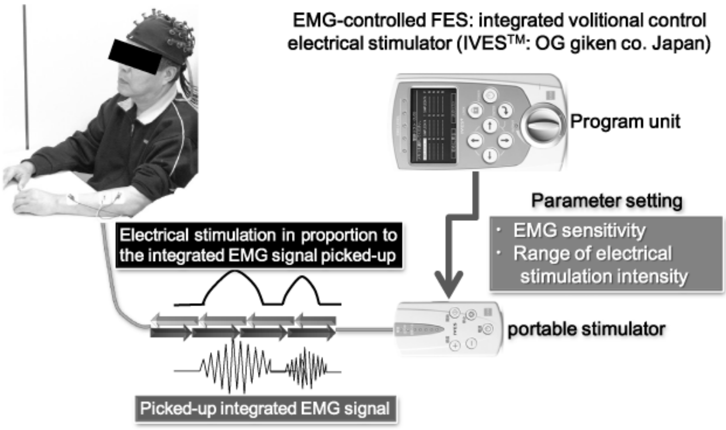

Fig.1. *EMG-controlled FES instrumentation*

A surface electrode picks up the EMG signal and stimulates the target muscle in proportion to the integrated signal. The EMG signal sensitivity is obtained and the electrical stimulation range is set. This device induces greater muscle contraction, because electrical stimulation is proportional to the EMG signal. The EMG-controlled FES unit is an auto-driven system without an on-off switch; therefore, no more operation was required after it had been initially set [12].

2.2. Hybrid EMG - controlled FES

Hybrid robotic systems represent a novel research field, where functional electrical stimulation (FES) is combined with a robotic device for rehabilitation of motor impairment [15]. Antagonist muscle spasticity often disturbs agonist muscle activity; therefore, it is important to reduce finger and wrist flexor spasticity to improve hemiparesis hand function. FES is believed to inhibit antagonist muscle activity [16]. But sometimes the effect is insufficient to control antagonist spasticity. Nerve or motor point block with phenol, in combination with FES is useful for improving hemiparesis hand function. It is used clinically to improve the balance of activity at a joint, to improve motor control, or to increase tolerance to splinting and passive stretching [12]. The rationale for using both modalities is to reduce the neurogenic component of finger flexor spasticity by means of a motor point block with the FES as adjunct therapy to improve the hand function. EMG-controlled FES and motor point block for antagonist muscles have been applied as a hybrid FES therapy in an outpatient rehabilitation clinic for patients with stroke [17].

2.3. A home based rehabilitation program using FES

To assess the effects of daily power-assisted functional electrical stimulation (FES) home program therapy in chronic stroke, a total of 20 consecutively enrolled stroke patients with spastic upper-extremity impairments > 1 year after stroke were recruited for non-blinded randomized controlled trial. Subjects were assigned to control FES groups and followed for 5 months. The FES group used a power-assisted FES device to induce greater muscle contraction by electrical stimulation in proportion to the integrated electromyography (EMG) signal picked up on surface electrodes [18].

2.4. Contralaterally Controlled Functional Electrical Stimulation (CCFES)

Contralaterally controlled functional electrical stimulation (CCFES) is an innovative method of delivering neuromuscular electrical stimulation for rehabilitation of paretic limbs after stroke. It is being studied to evaluate its efficacy in improving recovery of arm and hand function and ankle dorsiflexion in chronic and subacute stroke patients. The initial studies provide preliminary evidence supporting the efficacy of CCFES [19]. CCFES is a new treatment aimed at improving recovery of volitional hand function in patients with hemiplegic stroke [20]. CCFES stimulates the paretic finger and thumb extensors with intensity in proportional to the degree of volitional opening of the contralateral unimpaired hand. The unimpaired hand wears an instrumented glove that detects the degree of hand opening [20]. The device enables patients with hemiplegia to open their paretic hand and practice using it in functional tasks (Figure 2). Surface electrodes were positioned on the forearm and hand. The muscles targeted for activation of functional. Hand opening was the extensor digitorum communism and extensor policies longs. No more than 3 independent monopolar channels (using a common anode) of stimulation were used. The stimulator was programmed to modulate the pulse duration from each stimulation channel from minimum to maximum in proportion to the amount of opening of an instrumented glove worn on the non-paretic hand. The glove consisted of an assembly of 3 bend sensors in cloth sheaths attached to the dorsal side of the index, middle, and ring fingers. Proportional impedance changes in the sensors modulated an analog voltage input to the stimulator [12]. CCFES produced larger improvements than cyclic neuromuscular electrical stimulation on upper extremity impairment and activity limitation in patient's ≤ 6 months post stroke in every clinical measure [21].

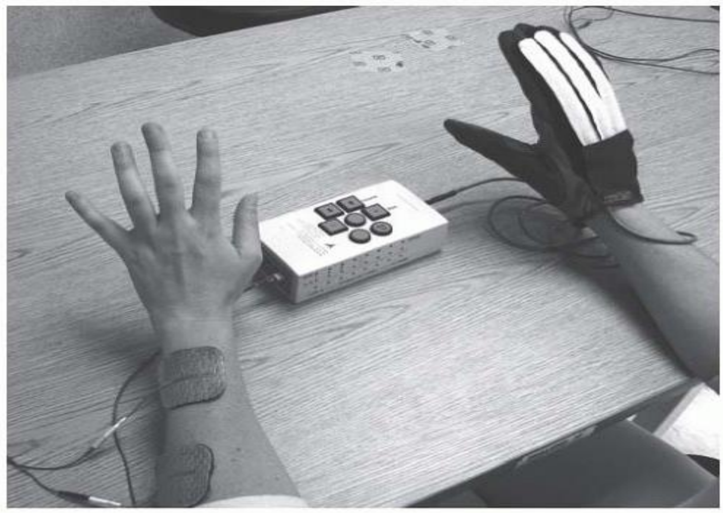

Fig.2. *Contralaterally controlled functional electrical stimulation*

2.5. Functional Electrical Stimulation Devices

There are number of devices based on FES technology are available. Standard electrical stimulation programs can be used to enhance upper and lower extremity muscle re-education and functional use of the arm, hand or leg. The stimulation can be delivered by either a stationary or portable FES electrode unit, or through an external neuro-prosthetic device. BIONESS L300 [32], WALK AIDE [33] and BIONESS H200 WILELESS HANDREHIBLILTATIONSYSTM [34]. Still, many considerations are required to develop efficient devices capable of adapting the human ergonomics using various FES techniques

3. Bilateral Technology for Hand Exoskeleton

3.1. EMG based robotic hand exoskeleton for bilateral

This device is capable to control the objects by the prosthetic hand, the force is harmonized by the EMG signals which is provided by the active hand. The prototype is classified by the neural network and surface EMG to capture the grasp of an object as it is clearly indicated in Fig.3. The author follows the BRAVO project[32], which is intended for stroke rehabilitation trainings for patients. The system consists of an EMG processing module along with BRAVO hand exoskeleton device, which is used as an assistance for holding the object, for better collaboration; two senors FSR(Force Sensing Resistor) are used. In order to hold the object, sensorized objects were arranged with Force Sensing Resistor and Eight FSR 402 were mounted on the circular area along with a resistance of 2.2 KOhm, this setup produced the force of up to 12N. The grasping is measured from 3 forearm muscles; adductor pollicis brevis (APB), flexor digitorum longus (FDL) and extensor digitorum longus (EDL) by electrodes. Due to non linear and multidimensional issues produced by EMG based muscle activity and muscular force, a multilayer perceptron network (NN) is configured. For bilateral process, The neural network is trained by the output signal of the sensorised object from HAND 1, which is actually measuring the EMG signals, the validation process calculates the error exerted by the impaired hand wearing the orthosis compared with the unimpaired hand, The Neural network utilises the supervised learning algorithm. The mean of four FSR sesorized objects signals are supposed to be the trained NN signals. Therefore the grasping force produced by the trained NN by the unimpaired hand can be approximated and syncronised with the paretic hand for holding the object. By applying a transfer function of the BRAVO system on the generated force, which is then sent to the actuators to initiate the holding function.

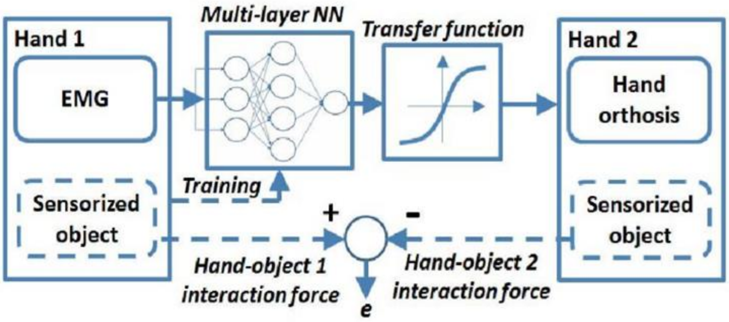

Fig.3. *Global data flow of the system. Dotted lines indicate either training or evaluation information.*

The author claims that the subject is able to lift and hold the object by the exerted force of healthy hand as shown in the Fig.4. The NN strategy accurately tracks the reference interaction force between hand and the object using only sEMG measurements [19].

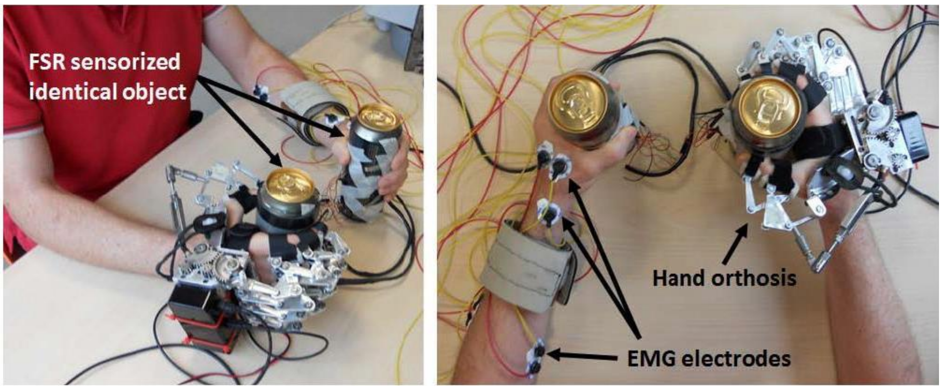

Fig.4. *The setup for the experimental evaluation of the proposed System*

3.2. Bilateral Therapeutic Hand Device for Stroke Rehabilitation

The system is able to assist the stroke patients for extending and flexing the hand's fingers by the plasticity of the human brain.This device can work on metacarpophalangeal (MCP), proximal interphalangeal (PIP) and distal interphalangeal (DIP) joints of the fingers, and interphalangeal (IP), metacarpophalangeal (MCP) and trapeziometacarpal (TM) joints of the thumb of the left hand (impaired hand) following the movements of the right hand (Active hand). The system works on 15 Degrees of Freedom (DOF) and follows the L shaped structure as indicated in Fig.5. This system is used for full flexion of four fingers instead of using spring technique which will provide constant force on the structure and that is stiffness of the spring will vary by the time and may reduce the efficiency of the device. However the four fingers have the same mechanism except the thumb, which somehow follows the index finger strategy with some modifications.

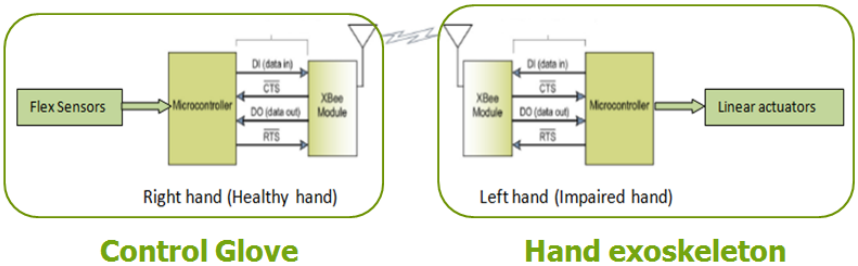

Fig.5. *Data transmission system framework*

To mimic the movements of active hand by the paretic hand, the author represented the hand's DOF in such a way that 1 degree of freedom to each joint and can be flexed by the exoskeleton and can support 15 DOF to achieve movement of fingers.A control glove is used which is weared on the active hand to control the movement of impaired hand's fingers, each finger consists of flex sensor for sensing the movement, the generated output of the sensor is sent to the microcontroller which is attached on arm. The flex sensor follows the variation of resistance, to capture the deflection; a voltage divider is used and also an amplifier to stabilize the impedance. For the control circuitry, the ATmega 328 microcontroller is used which calculates the values of sensors to extend or retract the linear actuator stroke. The data is wirelessly sent to the other micro controller 2.4 GHz XBee radio transmitter which is placed on left hand. In order to communicate smoothly, both XBee modules are assigned a unique identification number, and to make sure that both modules are working in same personal area network (PAN), the device follows the open loop control strategy. The system testing is done on the user as shown in the Fig.6, to succesfully analyse the results [20].

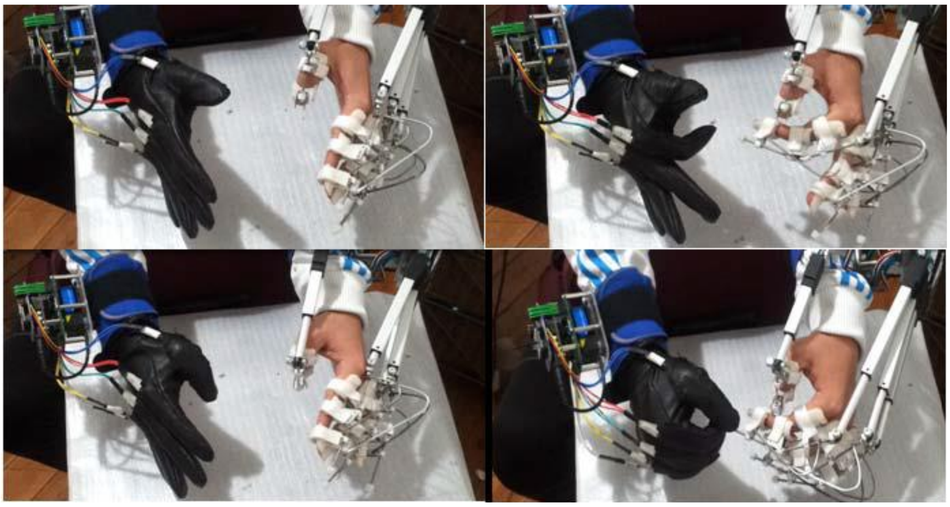

Fig.6. *System Testing*

3.3. Development of an EMG controlled hand exoskeleton: towards an application for post-stroke rehabilitation

This system is using sEMG signals in which patient wears the exoskeleton device in the impaired hand, which is controlled by the patient’s forearm that initiates the movement from unimpaired hand by these signals. It also permits the opening and closing of individual and 2 fingers at once. For acquisition and processing, the biosignal board BITalino Plugged is used to capture the data, it consists of 6 analog input ports and 4 digital output ports. For wireless communication; Bluetooth 2.0 is used along with Lithium Polymer rechargeable battery along with 3 EMG sensors. The placement of electrodes is maintained according to the direction of muscles, whereas, amplifier is used for bandwidth acquisitaion. The classification is done from easiest to complex movements of hand, like extension and flexion of index finger, middle finger and ADL to hold any object. The authors tested 4 different classifiers; K-Nearest Neighbors, Naive Bayes, Partial Least Squares Discriminant classifers and Suport Vector Machine to analyse the best one. For testing the device, an experiment is conducted as indicated in Fig.7, in which the exoskeleton is organized on the patient’s arm for the sEMG data acquisition. The First arm is for sEMG acquisition and other one is for wearing exoskeleton and experimentation is done individually on fingers. For the index finger, extension and flexion the Partial Least Discriminant Classifier is chosen. The motor is used with a particular angle to analyse the movement of the finger. Certain threshold values are set to perform extension or flexion, for example, If the angle was below 80 degrees considering the resting time as well, the exoskeleton will flex the finger, and if the value is above this range then it will extend the finger [21].

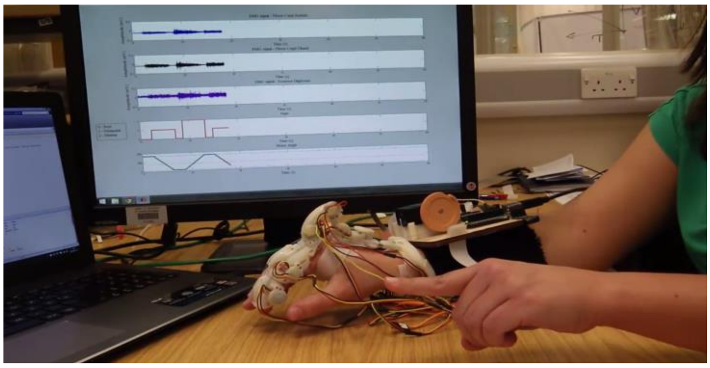

Fig.7. *Real time experiment with the index finger exoskeleton*

4. Virtual Reality Technology

A new approach is being used for treating stroke patients and gaining popularity in the rehabilitation process is Virtual Reality (VR). It's a technique which consists of a computer, special interactive software and hardware that replicate the real time environment and is able to modify it with the user's actions. The use of VR in stroke rehabilitation has significant aspects to consider as they can be used as training tool in an effective way.The patient's are encouraged to involve in task oriented activities, furthermore, It can be helpful to assess the performance in terms of recovery rate [22]. By combining VR and clinical therapies, the slow rate of stroke recovery showed the tremendous improvement [27]. The study conducted by researchers demonstrated that VR have improved results as compared to the conventional therapy [28, 29].

4.1. CyberGlove

This is known as haptic glove and is capable of controlling the whole hand movement. There are two types of Cyberglove models; one is 18 sensors based and other is having 22 sensors.The mechanism targets the MCP and PIP joints along with abduction sensors for thumb, wrist and palm. For error free sensor data, the calibration is done by the VirtualHand software which is capable to stabilize the differences in movements. It matches the motion of physical hand to the virtual one by few parameters like gain and offset. This software includes number of packages which are specific for design, motion, animation and calibration; namely, computer-aided designs (CADs) and character animation [VirtualHand for V5 (CATIA), VirtualHand for MotionBuilder,and VirtualHand SDK]. The added wireless feature enhances the performance as it makes the movement hassle free in the large space environment. [23, 24].

Fig.8. *CyberGlove; Courtesy of CyberGlove Systems LLC, California*

4.2. CyberGrasp

Another important contribution which provides the hold for the virtual object, the mechanism follows the force feedback system that provides a feel and grasp for the imaginary objects. The exoskeleton comprises of a network, which consists of the tendons and five programmed actuators for each finger that provides force of up to 12N. The designed system for actuators is placed on the desktop. As this device is ungrounded so it needs a point of reference to operate, for this purpose the CyberGlove is required to achieve further task orientation. It allows the full hand motion due to grasp force as indicated in Fig.9, which is perpendicular to each fingertip throughout the range of motion [23, 24, 30].

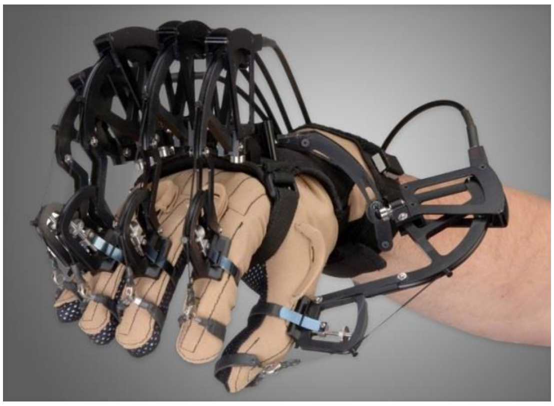

Fig.9. *CyberGrasp; Courtesy of CyberGlove Systems LLC, California*

4.3. L-EXOS (Light-Exoskeleton)

A device follows the force feedback structure and is capable to exert the force of 100N. It allows the different pattern and joint configurations for stroke patients. The systems consists of 5 DOF, 4 for arm location and one for wrist. For Virtual settings, it consists of 3 virtual frameworks along with a VR display.The screen is placed in front of the patient for number of rehabilitation exercises. The robot having the counter balancing strategy for supporting the weight of an arm. However, this robot provides the assistance for the execution of task followed by impedance control method [24- 26].

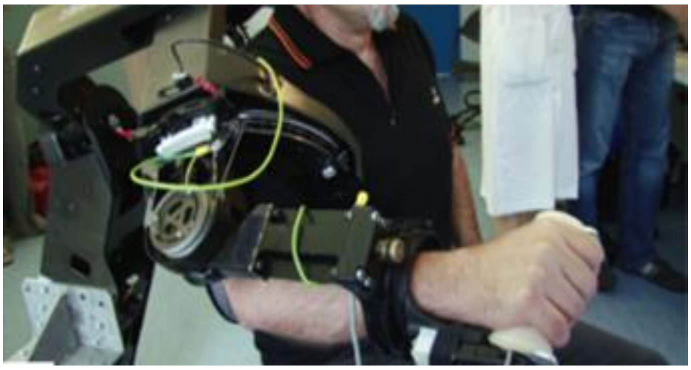

Fig.10. *The Patient wearing L-EXOS*

5. Conclusion

In this work we reviewed the stroke hand Rehabilitation technologies and different ways to control the stroke hand and gives the insight for exact exercises to recover. The rehabilitation technologies can improve the quality of life for people with disabilities. Students have designed, built, and delivered a variety of custom assistive devices and applied their engineering skills to address a real need for an individual response. Although there has been no formal evaluation of success. The field of robotic exoskeleton for hand rehabilitation is still far from being perfect, but continues to grow. The role of a robot-assisted therapy in stroke rehabilitation currently works hand-in-hand rather than a replacement of traditional rehabilitation therapy. In the application for post stroke patients, telemedicine is one of the promising technology to improve access and increase treatment availability for stroke patients, who live in remote areas where rehabilitation centers may not be readily available. Not only therapies and rehabilitation strategies should be more effective, but also must be cost effective and efficient. Overall, the field of hand rehabilitation has a bright future, Doctors, patients and researchers involved in hand rehabilitation will benefit and have further tools in the coming years.

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International Mechatronic Student Micro-Conference

Bánki Donát Faculty of Mechanical &Safety Engineering,

Budapest, 20th of December 2016.

EPSON SCARA – Selective Compliance Assembly Robot Arm

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Abstract

As international Erasmus students following the course Introduction to the Mechatronics the students are invited to attend the International Mechatronic Student Micro-Conference 2016 in Budapest, Hungary. The assessment is writing a scientific paper about a mechatronic topic. EPSON SCARA – Selective Compliance Assembly Robot Arm is a paper that gives a global introduction to the SCARA of the brand EPSON.

Keywords: *Teamwork, Mechatronics, SCARA, Scientific Paper writing*

1. Introduction

On the 20th of December 2016 the International Student Micro-Conference will take place in Budapest, Hungary. Students of the Banki Faculty of Mechanical & Safety Engineering of the Óbuda University will participate in the conference. The students will write an essay on a topic related to Mechatronics. On the day itself the students will presentate their essay.

This essay is an introduction to the SCARA. SCARA is a robot arm that functionates by four joints. In the next chapter the SCARA machine will be explained. In the third chapter some of the history will be explained. The reason why it is developed and the developments since the beginning. The functions of the SCARA will be explained in chapter five. The used sources are given in chapter six.

2. What is SCARA?

A scara or Selective Compliance Assembly Robot Arm is a pick and place unit. The scara unit has 4 joints as you can see in *Figure 1 – SCARA-unit*. Joint 1 is able to rotate around his own axis (z). There is an arm connected between joint 1 and joint 2. Joint 2 is also able to rotate around his axis. With joint 1 and joint 2 the robot already has a wide work area. Joint 3 is able to move vertically (y) so it can go up and down to come closer to the product. Joint 4 is also able to rotate. So if the robot picks up a product it is able to rotate it.

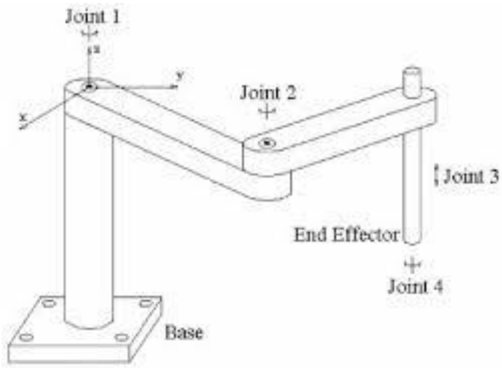

Figure 1 – SCARA-unit joints

With al these joints the scara creates a big work area. As is seen in *Figure 2 – Arm circle*. When the arm is fully streched it can reach the outer circle and because joint 2 can rotate it can reach every spot between the outer cyrcle and the iner circle as you can see in *Figure 2 – Arm circle* as the marked area. The scara unit cant turn 360 degrees because there are 2 nips preventing him from turning around. The function of these 2 nips are that the scara unit cant damage itself, his cables or materials outside his quality assured working space [1].

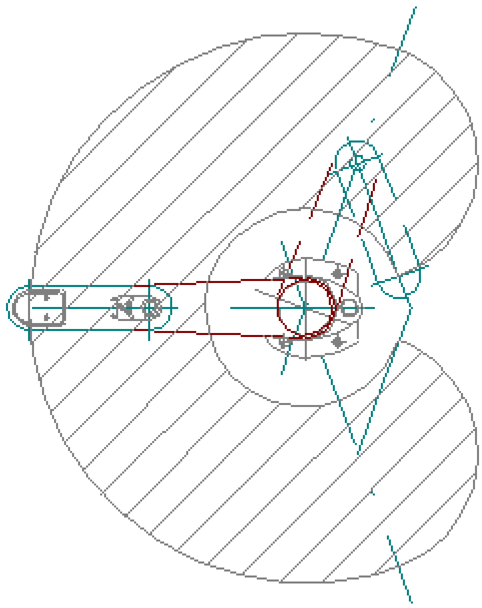

Figure 2 – Arm circle of the scara

3. Development of SCARA

In the years before 1981 there was a demand for a machine that worked automatically and was able to bring materials or goods from one place to another. The companies NEC, Pentel and Sankyo Seiki presented an idea of this machine and a new concept for assembly robots. The first SCARA was rigid in the Z-axis and pliable in the XY-axis. Because of this combination it was able to adapt to holes in the XY-axis.

This was a revolution in the robotic machinery. Before the SCARA were mostly available for processing puposes such as spot welding. The assembly work procedures were reviewed and the engineers succeeded in another great succes. They limited the number of simultaneous contol axes to four as a max.

Over the years it was necessary to make the SCARA faster and the quality better. The SCARA had to be assured with no-failure. It was impossible to have a failure in the functions of the arm. The quality had to extremely good because goods and materials should be safe in the neighbourhood of the arms length. Nowadays the SCARA is a thrustworthy device. In the supply chain it can be the bottleneck of the operations but also the unmissable factor [2] [3].

4. Different types

The epson scara robot has a lot of diffrenent type. Every type has their own benefits. They are divided in three series with every serie as a different types. The series are the G-, RS- and LS-serie. The G-Series are the normal scara's. The RS-serie hang from the ceiling. And the LS-serie is almost the same as the G-serie when watching the specifications. The G-series cost more than the LS- but the specifications of the G-series are better.

4.1. G-series

The G-series has five different types (G1, G3, G6, G10, G20). These are the normal type scara units. G1 has the smallest arm and the lowest payload. How higher the number of the type how longer the arm and bigger the payload. G20 has the longest arm and the biggest payload. The specifications of the different types are shown below in *table 1 – G-series* [4].

Tabel 1. G-Series specifications

G-Series					
Types	G1	G3	G6	G10	G20
Max payload [kg]	1	3	6	10	20
Arm length [mm]	175, 225	250, 300, 350	450, 550, 650	650, 850	850, 1000
Max operating speed [m/s]	2.65, 3.00	3.55, 3.95, 4.35	6.44, 7.17, 7.90	8.80, 11.00	11.00, 11.50

Figure 3 - G-series

4.2. RS-series

The RS-series (RS3, RS4) are hanging from the ceiling. The advantage of this is that they can turn 360 degrees untherneath their first joint. Which creates a new dimension to work in The specifications of the RS3 and the RS4 are shown in *table 2 – RS-series*.

Tabel 2. RS-Series specifications

RS-Series		
Types	RS3	RS4
Max payload [kg]	1	3
Arm length [mm]	350	550
Max operating speed [m/s]	6.23	7.40

Figure 4 - RS-serie

4.3. LS-series

The LS-Series (LS3, LS6, LS20) are almost the same as the G-series. The main diffrence is in comparison with the G-series is that the costs are lower and their specifications. Their speed is slower, the payload is lower and the arm length is shorter. It is still a good machine and may be perfect as a cheap sollution. The specifications are shown in *table 3 – LS-series.*

Tabel 3. LS-Series specifications

LS-Series			
Types	LS3	LS6	LS20
Max payload [kg]	3	6	20
Arm length [mm]	400	500, 600, 700	800, 1000
Max operating speed [m/s]	6.00	6.15, 6.80, 7.45	9.94, 11.25

Figure 5 – LS-series

5. Conclusion

In the end the EPSON SCARA unit is a good choice if you want a pick and place robot. It has a lot of different types to work with, each with their own special abilities. With the unique design the robot has a high working area, high operating speed and a payload up to 20 kilograms. This makes it a suitable pick and place unit for all different kind of jobs.

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