Excel Tables composition with JavaScript and HTML

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Abstract—**This paper provides an overview and examples of exporting HTML tables to Excel using JavaScript. The paper will show examples of exporting as well as brief introduction about the tools themselves. In addition, the given code will be commented.**

Keywords-JavaScript; HTML; Excel; CSS

I. INTRODUCTION

Excel as a program it has long been known to the information society as well as to people who deal with entering and sorting data in tables, all with the help of Excel programs. With the help of tables, it is best to display numerical data on web pages, which is one of the methods. If we want the user to download one of the HTML tables, we have to convert it to a file. Exporting data to Excel is very useful in the data list for almost every web application. The export feature helps to download the list of data as a file format for offline use. The Excel format as a product is ideal for exporting data to a file. The server-side method for exporting data is mainly used to execute using PHP. But if you want the client solution of table data to be exported to excel, this can be easily done by using JavaScript. Using JavaScript, HTML table data can be easily exported without refreshing the page. The JavaScript export function can be used in a member list, product list, or other lists to download a list of data in an excel file format. JavaScript is a full-fledged dynamic programming language. When applied to an HTML document, it can provide dynamic interactivity to websites. JavaScript is the most widely used language in the world.Web browsers receive HTML documents from a web server or local storage and generate them into multimedia web pages. HTML semantically describes the structure of a web page and originally includes indications for the appearance of the document.

II. EXCEL

Microsoft Excel is a useful and powerful program for data analysis and documentation. It is a spreadsheet program that contains multiple columns and rows [1]. What is a cell? The cell consists of each intersection of a row and a column. Each cell can contain a group of data or a part of the data. By organizing the information in this way, you can easily find data and automatically download it from the data change [1]. For easier analysis and management of a group of data, it is necessary to group them into an Excel spreadsheet (formerly known as an Excel list). There are three ways provided by Excel where you can sort the data in a spreadsheet, so that you can use it as a database with worksheet formulas:

- Simple tables or “Gray Cell” - they were used since Excel 2.0
- Excel tables were introduced in Excel 2007.
- PivotTables with a Tabular Report Layout, introduced in Excel 2010.

Pivot tables are one of Excel's most powerful features. A pivot table allows you to extract the significance from a significantly large part of detailed data [2]. Pivot Tables can quickly provide an answer to many important business questions. The pivot table is a summary report made from using data from the database. When creating a Pivot table, we cannot have empty cells and each column needs to have a name. Once the table is created, it is easy to change or modify the table by adding or removing dimensions.

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	A	B	C	D
1	Country	Order Date	Order ID	Profit
2	Montenegr	10.7.2015	10247	3,545
3	USA	5.3.2018	10248	7,473
4	Serbia	15.10.2019	10249	2,300
5	Croatia	7.7.2005	10250	3,750
6	Slovenia	22.9.2013	10251	6,400
7	Italy	18.4.2015	10252	4,375
8	Denmark	2.3.2020	10253	5,350
9	Germany	17.8.2019	10254	10,275
10	China	23.12.2019	10255	12,353
11	**Total**			**55,821**

Figure 1. Pivot Table

A Pivot Table is used to summarize, sort, reorganize, group, count, total or average data stored in a table. It allows us to

transform columns into rows and rows into columns. It allows grouping by any field (column), and using advanced calculations on them.

III. HTML

Hypertext Markup Language (HTML) is the standard markup language for documents designed to be displayed in a web browser. It can be assisted by technologies such as Cascading Style Sheets (CSS) and scripting languages such as JavaScript. HTML is awesome. It helps you to build the main structure of a website. It's the main part of a website. Basically, everything we see in a website from the front-end is built with HTML. Web browsers read HTML giving the user a visual representation of a given page, but do not show them the HTML code and scripts used if any. With the advancement of web browsers and technology it is possible for the user to see the HTML code and scripts that are executed. This can be done by clicking on the right side of a given page and then on the "View page Source" option.We can even create amazing pieces of stuff like form, table, lists, and much more using just HTML. HTML can embed programs written in a scripting language such as JavaScript, which affects the behavior and content of web pages. It is possible to export Excel Worksheet as HTML. We can do it like in the example shown down below:

1. In Excel, navigate to File > Save As.
2. In the Save as type list, select *.htm, *.html.

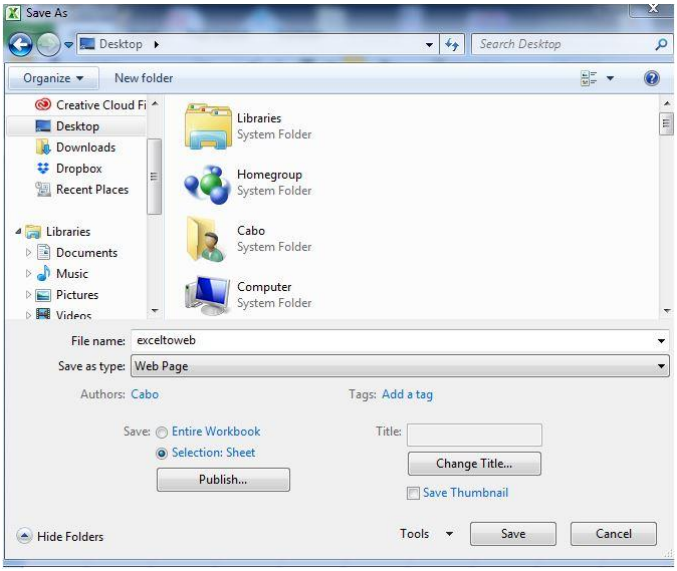

Figure 2. Save as procedure

3. Under Save, choose Selection: Sheet and click Publish. The Publish as Web Page window will open.

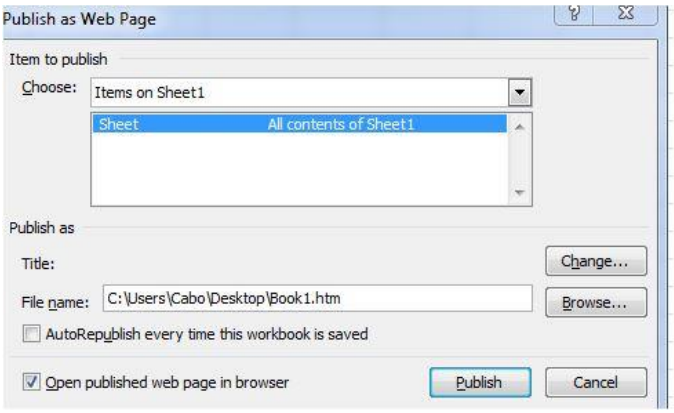

Figure 3. One step before publishing.

4. Select the sheet(s) you wish to publish.
5. Use the Browse button to find and select your server (in the example screenshot, the HTML file is being placed into a public dropbox folder).
6. Check the AutoRepublish web page box.
7. Click Publish.

One way is the example above shown in Fig. 1-3, but there is another way where you can create a table directly in HTML with HTML code. The following example will be presented on how to do so.

```
<!DOCTYPE html>
<html lang="en">
    <head>
        <title>Export To Excel with  JavaScript</title>
        <link rel="icon"
        href="https://cdn0.iconfinder.com/data/icons/fatcow/32x32/table_exc
        el.png" />
        <link rel="stylesheet" href="style.css" />
    </head>
    <body>
        <div>
            <table id="exTable" border="2">
                <thead class="Thead">
                    <tr bgcolor='#92a8d1' style='height: 75px; text-align:
                    center; width: 250px'>
                        <th style="width:35px">Num</th>
                        <th>Name</th>
                        <th>Last name</th>
                        <th>Email</th>
                        <th>Phone</th>
                        <th>Country</th>
                    </tr>
```

Figure 4. HTML and CSS code for table (part 1)

```
                </thead>
                <tbody>
                    <tr>
                        <th>1</th>
                        <td>Marko</td>
                        <td>Petkovic</td>
                        <td>test@test.com</td>
                        <td>+382 69********</td>
                        <td>Montenegro</td>
                    </tr>
                    <tr>
                        <th style="height:0px">2</th>
                        <td>This row will not be shown in excel</td>
                        <td>Hidden data</td>
                        <td style="font-style:italic"> With right click you
                        can unhide in excel</td>
                        <td>+385 65********</td>
                        <td>Croatia</td>
                    </tr>
                    <tr>
                        <th>3</th>
```

Figure 5. HTML and CSS code for table (part 2).

```
                    <td>Test 123</td>
                    <td>Last name test</td>
                    <td style="text-decoration: underline;">Underline
                    text</td>
                    <td style="background-color:blue;color:white"
                    colspan="2"> Nebesko plava boja u spojenim
                    celijama</td>
                </tr>
                <tr>
                    <th>4</th>
                    <td style="height:140px; padding:15px">
                        <img src="user.png" height="100" width="100" />
                    </td>
                    <td>Avatar</td>
                    <td style="font-weight:bold">test@gmail.com</td>
                    <td>+1 41******</td>
                    <td>USA</td>
                </tr>
                <tr>
                    <th>5</th>
                    <td>sp char as - !"#$%&'()* WILL NOT BE
                    TOLERATED</td>
```

Figure 6. HTML and CSS code for table(part3)

```
                    <td>Only letters</td>
                    <td style="text-decoration: line-through;">line
                    through text</td>
                    <td>+91 29********</td>
                    <td>Swiss</td>
                </tr>
                <tr>
                    <th>6</th>
                    <td>
                    Ovo je pokusaj da se napravi Cv u tabeli i na kraju
                    da se exportuje putem dugmeta u excel tabelu<br />
                    Kroz primjer su korisceni razni fontovi i tagovi
                    kako bi se dobili,<br />
                    razliciti rezultati.Navedene info su uzete random
                    za potrebe ovoga projekta.
                    </td>
                    <td>Prezime pokusaj</td>
                    <td>pokusaj@gmail.com</td>
                    <td rowspan="2">Merge row 2 and 3</td>
                    <td>Pakistan</td>
                </tr>
```

Figure 7. HTML and CSS code for table (part 4)

```
                <tr>
                    <th>7</th>
                    <td>James</td>
                    <td>Khurt</td>
                    <td>test1@gmail.com</td>
                    <td style="color:red">Canada</td>
                </tr>
                <tr>
                    <th>8</th>
                    <td style="font-weight:bold; height:0px;">Obac</td>
                    <td>The Great</td>
                    <td>obac123@outlook.com</td>
                    <td style="font-weight: bold;" colspan="2">This is
                    admin row and it will be hidden</td>
                </tr>
            </tbody>
        </table>
        <input type="button" value="export"
        onclick="exportToExcel('exTable')" />
    </div>
    <script src="exportToExcel.js" defer></script>
</body>
```

Figure 8. HTML and CSS code for table (part 5)

In Fig. 4-8 we can find the HTML and CSS code that we used to create the table on the web. We used some standard HTML tags that help us to create a table with rows and columns. In this example we created table with 9 rows and 6 columns.The <tbody> tag is used to group the body content in an HTML table [2].The <tbody> element is used in conjunction with the <thead> and <tfoot> elements to specify each part of a table (body, header, footer).The <td> tag defines a standard data cell in an HTML table[2,6]. Text in <td> elements are regular and left-aligned by default. Text in <th> elements are bold and centered by default. The <tr> tag defines a row in an HTML table.You can notice that we used the tag <style> in the code. Tag <style > is used to define style information (CSS) for document. In practice, a CSS file is created separately for document styling, which is not the case in this example. Styling tags are used directly in HTML code. The only separate CSS file is made for the EXPORT button. We can see the code below.

```
input[type="button"]{
    margin: 30px 0px 20px 210px;
    width: 250px;
    height: 60px;
    text-transform: uppercase;
    font-weight: bold;
    font-size: 25px;
    text-align: center;
    cursor: pointer;
    background-color:darkcyan;
    color: #f4ce01;
    border: 2px solid #f4ce01;
}
input[type="button"]:active{
    color: #13b236;
    border-color: #13b236;
    background: gold;
}
input[type="button"]:hover{
    border: 3px solid;
}
table tr td{
    padding: 5px;
}
```

Figure 9. CSS code for “EXPORT” button.

In the CSS file from Fig. 9 we can notice some elements that we used to beautify and customize the buttons to export the HTML table to excel format. With the help of CSS elements, we adjusted the margins, width, height, as well as whether the cursor will change if we move the cursor over it. We did this with the "cursor: pointer" option, we can see this option in line code number 9. We also played around a bit with the colors of the buttons as well as the colors that will be used to print the text in the button itself. We can see these options in the code line 10 and 11. We also added a few elements for the option if the user clicks the button. What will happen when you click the button and what effects will be applied, we defined by using CSS commands between lines 14 and 18. When you click the button, the color of the text, the color of the button border and the background color will change to gold. If the user just moves the mouse over the export button, the borders will be bolded and will be larger. We achieved this with the help of the "border: 3px solid" option. With the <style> tag we can adjust various things like height, length, background color, text color, whether the cursor will change when you click the button and much more. When we save the file from above its executed. We will find the table with some data like: name,last name, email, phone and country.

IV. JAVASCRIPT

What is JavaScript? JavaScript (often abbreviated in JS) is a high-level object-oriented scripting language [3]. It is mainly used when creating web pages with the help of HTML and CSS. JS is not only related to web design and browsers, its low consumption of memory and speed compared to other languages which contribute to the fact that we can apply it for many other purposes. JS's primary role was to "revive the website". JS was created in 1995, inspired by the Java programming language. At the time, internet connections were much more modest than they are now. Sending any query to the server page for any client entry was not practical at all. JS is performed on the client side of the server or the web, which we can use to design, program and behave web pages. With the advent of JS, new possibilities of data processing on the client's side were introduced, which significantly improved the performance of the former websites. JS allows us to implement complex features on web pages - every time a web page does more than just sit and displaying static data. JS represents the third layer of standard web technologies. We covered the other two HTML and CSS articles above. These layers pile up nicely on top of each other. We can say that by combining these three layers we get Dynamic HTML (DHTML).. Let's make an example code for the HTML code above so we could export our HTML table to Excel. In the following we can see the JavaScript code:

```
function exportToExcel(tableId){
    let dataTable = document.getElementById(tableId).outerHTML;

    dataTable = dataTable.replace(/<A[^>]*>|<\/A>/g, "");
    dataTable = dataTable.replace(/<input[^>]*>|<\/input>/gi, "");

    dataTable = dataTable + '<br /><br />Code witten by Luka.'


    let a = document.createElement('a')
    let dataType = 'data:application/vnd.ms-excel';
    a.href = `data:application/vnd.ms-excel, ${encodeURIComponent(dataTable)}`
    a.download = 'Obac_3' + rand() + '.xls'
    a.click()
}
function rand() {
    let rand = Math.floor((Math.random().toFixed(2)*100))
    let dateObj = new Date()
    let dateTime = `${dateObj.getHours()}${dateObj.getMinutes()}${dateObj.getSeconds()}`

    return `${dateTime}${rand}`
}
```

Figure 10. JavaScript code for exporting table.

After implementing the JavaScript code from Fig.10 together with HTML code and CSS from Figure 4-9, we are ready to export our table to Excel. In Fig. 8 we can see the example of JavaScript code. In the given code, we created a couple of variables and created a function that helps us to easily enter data into an excel spreadsheet. Between lines 16 and 22 I made a function "rand" and in it I used the mathematical function Math.floor ((Math.random (). ToFixed (2) * 100)). Using this function we take numbers between 0 and 1 and round them to two decimal places, then multiply the obtained number by 100 to move the decimal point by two places to the left and, Math.floor rounds the obtained number into a whole. In dateObj we enter a new date a, in dateTime time in the order of hours and minutes. Js code allows us to Export an HTML table to Excel using the code from Fig. 8. I also added my personal signature at the end as a small sign of drawing attention to the author. Clicking on the Export table button will save the document in .xls format called "Obac_3". I have added some more options to get rid of special characters as well as input parameters.

TABLE I. DEMO OF OUR TABLE FROM GIVEN CODE (PART 1).

Num	Name	Last name	Email	Phone	Country
1	Marko	Petkovic	test@test.com	+382 69********	Montenegro
2	This row will not be shown in excel	Hidden data	*With right click you can unhide in excel*	+385 65********	Croatia
3	Test 123	Last name test	Underline text	Nebesko plava boja u spojenim celijama	

TABLE II. DEMO OF OUR TABLE FROM GIVEN CODE (PART 2)

4		Avatar	**test@gmail.com**	+1 41******	USA
5	sp char as - !"#$%&'()* WILL NOT BE TOLERATED	Only letters	~~line through text~~	+91 29********	Swiss
6	Ovo je pokusaj da se napravi Cv u tabeli i na kraju da se exportuje putem dugmeta u excel tabelu Kroz primjer su korisceni razni fontovi i tagovi kako bi se dobili, razliciti rezultati.Navedene info su uzete random za potrebe ovoga projekta.	Prezime pokusaj	pokusaj@gmail.com	Merge row 2 and 3	Pakistan

TABLE III. DEMO OF OUR TABLE FROM GIVEN CODE (PART 3)

7	James	Khurt	test1@gmail.com		Canada
8	**Obac**	The Great	obac123@outlook.com	**This is admin row and it will be hidden**	

EXPORT

After clicking on the button "EXPORT" we will get the table in Excel, In Fig. 6 we can see the converted HTML table into an Excel table. In TABLE I-III we can see all data that have been put in columns and rows.

TABLE IV. EXPORTED HTML TABLE IN EXCEL (PART 1)

Num	Name	Last name	Email
1	Marko	Petkovic	test@test.com
3	Test 123	Last name test	Underline text
4		Avatar	**test@gmail.com**

TABLE V. EXPORTED HTML TABLE IN EXCEL (PART 2).

Email	Phone	Country
test@test.com	+382 69********	Montenegro
Underline text	Nebesko plava boja u spojenim celijama	
test@gmail.com	+1 41******	USA

TABLE VI. EXPORTED HTML TABLE IN EXCEL (PART 3)

5	sp char as - !"#$%&'()* WILL NOT BE TOLERATED	Only letters
6	Ovo je pokusaj da se napravi Cv u tabeli i na kraju da se exportuje putem dugmeta u excel tabelu Kroz primjer su korisceni razni fontovi i tagovi kako bi se dobili, razliciti rezultati.Navedene info su uzete random za potrebe ovoga projekta.	Prezime pokusaj

TABLE VII. EXPORTED HTML TABLE IN EXCEL (PART 4).

	~~line through text~~	+91 29********	Swiss
	pokusaj@gmail.com	Merge row 2 and 3	Pakistan
7	James	Khurt	test1@gmail.com

Code witten by Luka.

In Table V-VII we can see the exported Table in excel with all data that have been put with HTML code.

CONCLUSION

In this paper, various programs have been used, tools as well as scripting languages such as JavaScript. Throughout the paper work we can notice images of codes written in JavaScript, HTML and CSS. The given codes show the solution and the required result. In the paper itself, we can see two examples of how a table is created and exported as a required result. In the first example we can see how the table is passed to the web from Excel and in the second example we can see how with the help of tools such as HTML and CSS as well as the JavaScript scripting language, I have created a table on the website and converted it to XLS extension so it could run in Excel. Also, the functionality of the code example can be expanded according to your needs. The idea of this project was to create a CV or biography in the table with some basic information.

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Iontophoresis Device: A Review of Technologies and Limitations

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Abstract— **This paper presents a review of the development of iontophoresis devices and their applications in medicine, including various medical fields such as cancer research and hyperhidrosis. Iontophoresis is a non-invasive drug delivery method that uses an electric current to drive charged ions through the skin and into the body. The technique has been used in a variety of medical fields and is gaining popularity due to its ability to deliver drugs directly to the site of injury or disease, reducing systemic side effects.**

The review covers the historical background of iontophoresis, including early experiments and the evolution of the technology over time. It also discusses the different types of iontophoresis devices available on the market, their mechanisms of action, and the advantages and disadvantages of each. In addition, the review provides an overview of the current clinical applications of iontophoresis, with a focus on the fields of cancer research and hyperhidrosis.

The review concludes with a discussion of the current challenges and future directions of iontophoresis technology. The information presented here will be useful to researchers, clinicians, healthcare professionals, and electrical engineers interested in the latest developments in iontophoresis technology and its applications in medicine.

Keywords: electrotherapy, iontophoresis, home therapy, portable devices, medicine, non-invasive drug delivery

I. INTRODUCTION

In modern times, when talking about the use of drugs for the treatment of a disease or condition, the aim is always to have a targeted effect on the designated area, controlling the dose, the duration of the delivery of the drug, as well as to report as few side effects as possible. Therefore, it is not surprising that iontophoresis as non-invasive method for drug delivery, is being mentioned as promising potential in various fields of medicine.

Iontophoresis (Greek, "ion"-going; "phoros" -bearer, carrier) is a non-invasive medical procedure that involves the use of electrical current to deliver ions of medication or other therapeutic agents through the skin and into underlying tissues. It is a method of enhancing the transdermal delivery of drugs by applying an external electrical potential that promotes the movement of ions across a membrane. Topically applied drugs have an absorption sequence: first, the drug is released by transdermal drug delivery, absorbed by the first skin barrier, the stratum corneum, then the epidermis and dermis to the bloodstream and transported to the site where it is expected to have a therapeutic effect. [2]

Iontophoresis exhibits several advantageous features that make it an attractive option for drug delivery compared to other methods of drug delivery, as illustrated in Figure 1. First, the possibility of using a wide range of drugs - analgesics or anti-inflammatory drugs. Furthermore, since iontophoresis acts directly on the target surface, a smaller dose of the drug is required than would be the case with other types of drug intake - orally or by injection. The smaller the dose of the drug introduced into the body, the lower the possibility that the body will respond with a side effect to that same drug. On the other hand, the targeted action of the drug is an advantage in cases of tumor treatment, for the treatment of pancreatic tumors, breast tumors, and other solid tumors. Then it acts directly on the tumor without disrupting the functioning of untreated surfaces, which allows the body to fight the vicious disease more easily.

targeted delivery	medication is delivered directly to the affected area- less side effects, the medication does not enter the digestive system
reduced dosage	the medication is delivered directly to the affected area, so lower doses of medication are needed
non-invasive	it does not require injections or incisions, suitable for patients who have a fear of needles or who cannot withstand more invasive treatments
convenience	clinical setting, or at home usage, depending on the device and condition
cost-effective	in the long run - reducing the need of visits to the doctor, or more invasive treatments

Figure 1: Advantages of iontophoresis compared to other methods of drug delivery.

II. IONTOPHORESIS IN MEDICINE

A. Historical Background

The therapeutic potential of electricity was first discovered thousands of years ago, as evidenced by its use in ancient Egyptian, Greek, and Roman civilizations. These cultures recognized that electric shocks produced by certain fish species could alleviate pain, including headaches and arthritis. In the 16th to 18th centuries, various electrostatic devices were employed for pain relief. Even though the first proposal for the current medicated drug delivery has been mentioned in the mid-18th century, the 19th century is noted as the period of memorable progress in this field.

The movement of charged particles in an electric field was first observed as long ago as 1807 by the Russian chemists Pyotr Ivanovich Strakhov (1757–1813) and Ferdinand Frederic Reuss (1778–1852) at the Moscow State University. [3] Before 1908, when Frankhauser used the term "iontophoresis", drug delivery using electrical current was known as "cataphoresis". The first transdermal system that was approved for use in the United States (1979) was a three-day patch that delivers scopolamine to treat motion sickness. [4]

B. Clinical applications of iontophoresis

Iontophoresis is a promising electrotherapy technique for drug delivery that has gained considerable research interest in various medical fields and is being explored for delivering medicines in cases of different conditions. Iontophoresis could be an effective drug delivery approach for the treatment of oral diseases such as tooth decalcification and hypersensitivity and periodontal diseases such as gingivitis and periodontitis. [5]

Ophthalmology is another area where it is necessary to deliver drugs in a controlled and tolerable way. There are in vivo experiments related to this and developed iontophoretic device that could do the work with some limitations, or side effects. [6][7] The clinical uses of iontophoresis via low intensity electric fields have been reported in both animals and humans. Even though the delivery of chemotherapeutic drugs into the tumor is still not well defined, the efforts are being made to enhance its effectiveness.

Iontophoresis has demonstrated notable therapeutic benefits in diverse areas, including musculoskeletal pain, inflammation, dermatological conditions such as psoriasis, and hyperhidrosis. Specifically, the treatment of hyperhidrosis using iontophoresis with tap water or other medicaments has exhibited promising outcomes and there are multiple solutions on the market.

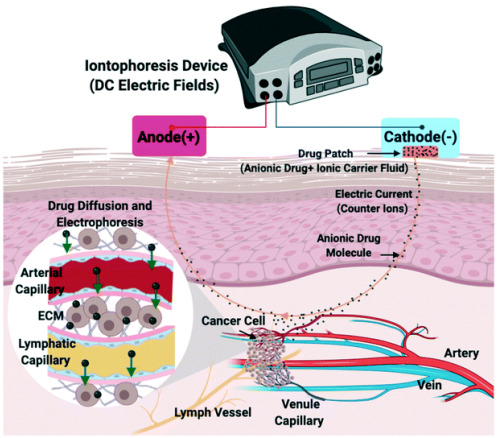

Fig. 2 Iontophoretic transdermal drug delivery into the tumor vasculature in vivo. The schematic shows the in vivo transport of an anionic drug from the artery to the tumor where it eventually drains into the lymph vessel. Iontophoretic transdermal drug delivery includes insertion of the cathode along with the drug patch on the skin from where the anionic drug molecules move to the tumor facilitated by the transport of the counter ions (from carrier solvent) to the anode [9]

III. ANALYSIS OF EXISTING TECHNOLOGIES

There are many variables that can influence iontophoresis. That includes: the cross-sectional skin area and skin as the biggest limiting factor, the time of application of the current and its intensity (Faraday's law), then drug concetration and also physicochemical properties of the drug molecules that are to be delivered. Some of these variables can be adjusted, some should be considered if iontophoresis is a chosen treatment.

The two types of current that are usually utilized in iontophoresis based on the objectives of the treatment and clinicians' preferences are direct current (DC) and pulsed direct current (PDC). [13][14]

A complete circuit forming an iontophoresis device typically consists of electrodes and a DC voltage delivery system, which are connected with wires. Then the adjustments of desired duration of treatment and the current itself. Some solutions offer the choice to choose between DC and PDC. During iontophoresis, the current is conducted from the device through the electrode and the drug solution, leading to the movement of drug ions towards the skin via an ionic flow. The drug molecules are then driven through the trans-appendageal structures and the aqueous pores of the stratum corneum by the repulsive forces. The size of the electrode plays a critical role in determining the required current density for efficient drug transport, and hence, larger electrodes demand higher current supply from the device. Power sources used for these types of devices can be electricity, batteries, or rechargeable power sources.

The machines available in Europe include: Hidroxa [16], SWEAT GUARD®[17], KAWE SwiSto3 [18], MedLight io-

dry [19] etc. These devices can be used as a treatment for hyperhidrosis. Depending on the manufacturer and device, they are used on various parts of the body, for example face, palms, foot. The power source is mostly electricity or rechargeable power source.

In United States, there are also commercial iontophoresis patches, such as Iontopatch[20] most commonly used to treat near surface musculoskeletal conditions. Since they do not need power source, because they have integrated battery, this is their advantage, but they are typically designed for one-time use only and the dose and duration of treatment cannot be manipulated.

So, what the existing solutions have in common is that a greater ability to control the parameters of iontophoresis is needed, as well as the mobility of the device, and the possibility of using the technical solution more than once, because the iontophoresis treatments usually take longer time than one usage of patch, for example.

IV. CONCLUSIONS: CHALLENGES AND PERSPECTIVES

Iontophoresis is a promising drug delivery technique that has garnered significant research interest across various medical fields. It has shown potential in treating oral and ophthalmological conditions, as well as in delivering chemotherapeutic drugs to tumors. Additionally, it has demonstrated therapeutic benefits in treating musculoskeletal pain, inflammation, dermatological conditions, and hyperhidrosis. Specifically, iontophoresis has proven effective in treating hyperhidrosis with tap water or medicated solutions, and multiple solutions are available on the market.

Iontophoresis is influenced by many factors, such as skin area, current intensity and duration, drug concentration and properties, and electrode size. Direct current (DC) and pulsed direct current (PDC) are the two main types of current used in iontophoresis, and the complete circuit of an iontophoresis device consists of electrodes, a voltage delivery system, and wires. The size of the electrode affects the current density required for efficient drug transport. Existing devices use power sources such as electricity, batteries, or rechargeable power sources, and vary in terms of their ability to manipulate treatment parameters, mobility, and potential for multiple uses. A greater ability to control iontophoresis parameters, mobility, and multi-use options would improve current solutions.

As research delves deeper into the capabilities of iontophoresis, it is anticipated that advancements in technology and application will continue to broaden its utility in the medical field. The availability and pricing of current solutions present potential areas for further development. Future work in this field may encompass the integration of mobile applications for regulating iontophoresis parameters with simple iontophoresis devices that could include having contact with clinician, with the aim of increasing controllability and accessibility to wider group of people. Moreover, iontophoresis devices hold immense potential for utilization in home therapy for a wide range of treatments. There is also potential for device solutions that combine iontophoresis with other therapeutic modalities since iontophoresis is the most effective when combined with other treatments, or/and a device that enables switching between DC and PDC current, but also being able to have independent power source.

Therefore, this is an area where there is room for further development of the device solutions.

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Portable device for transcranial direct current stimulation (tDCS) for use in home electrotherapy

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Abstract— **This paper briefly describes several important approaches in electrotherapy treatment, with special reference to the methods of applying non-invasive direct currents of small strengths in treatments of transcranial direct current stimulation, then presents the initial research that will serve scientifically and in the practice of further work as a basis and necessary preparation for developing and making a prototype of portable electrotherapy device for transcranial stimulation using direct currents, feasible in home conditions. The paper presents previous experimental results and provides an overview of possible future achievements and further development in suggested direction.**

Keywords— electrotherapy, transcranial direct current stimulation (tES, tDCS), cortical excitability, brain-derived neurotrophic factor (BDNF), brain disorders, neurodegenerative diseases, home therapy, portable device

I. INTRODUCTION

A. Definition

For the last two and a half centuries, doctors, scientists, philosophers and even laics tried to improve the ancient medical science with various medical and supermedical methods, successful and unsuccessful scientific research, experiments on living and non-living human beings and animals, as well as by using various recognized medical treatments. The latest treatment trend that shows fast and good results is based on a completely "natural" resource and is just in the initial slow stages of research and application. The word here is about the treatment with electric current, called electrotherapy.

Electrotherapy is a segment of physical therapy that refers to medical treatments that use electric currents for the purpose of treating certain conditions and injuries of the patients. By applying electricity to the injured tissue, the blood vessels expand thus increasing blood and lymph circulation, nerve endings are better stimulated, pain pathways are inhibited, while the overall tissue metabolism is stabilized and improved. [1]

The historical origins of transcranial electrical stimulation (tES) use as a therapy follow the history of the discovery of electricity itself. Though with dose bearing little resemblance to modern techniques, early attempts utilized electrosensitive animals such as torpedo fish and examined the effects of electrical discharge over the scalp on headache pain reduction. With the development of man-made electric sources, studies in the 19th and early 20th centuries implemented the use of non-invasive direct - galvanic currents in the treatments of psychiatric disorders and similar brain disfunctionalities. [2]

Transcranial electrical stimulation (tES) is a non-invasive brain stimulation technique that applies electric current through the brain cortex with the aim of influencing brain function, resulting in inhibition or enhacement of brain activity. By applying two or more electrodes to the patient's scalp, mostly placed in saline-soaked sponges to ensure better conductivity, a non-invasive weak current reaches the soft tissue and skull, resulting in a relaxing effect with expected benefits.

Transcranial electrical stimulation (tES) comprises a number of different techniques, including transcranial direct current stimulation (tDCS), alternating current stimulation (tACS) and random noise stimulation (tRNS). Whilst these techniques are similar in most ES applied patterns, their methodology, behavioural and neuronal outcomes, differ. In contrast to transcranial magnetic stimulation (TMS), the current delivered in these tES techniques is not in high enough intensity to elicit an action potential and is maintained at subthreshold levels to effect cortical excitability only. [3]

B. Transcranial direct current stimulation (tDCS)

Cortical excitabilty, as a fundamental aspect of human brain function, is defined as the strength of the response of cortical neurons to a given stimulation. According to many so far research, cortical excitability can also be defined as the electrical reactivity of cortical neurons to a direct perturbation and is directly affected by the duration of wakefulness of the patient and is significantly modulated by circadian phase that reffers to the rhythms of physical, mental, and behavioral changes in a 24-hour body activity cycle of a patient. [6]

Transcranial direct current stimulation (tDCS) uses a low direct current of intensity of just 0.5–2 mA, where mostly only current of intensity above 1.5mA have satisfying

results, and is generating an electrical flow from one or more active anodes, through the applied area of the head, to a reference cathode, where this flow of electrical energy, considered just as a needed portion out of the big amount applied in the treatment, quickly results in cortical excitability. In this way, the motor potential of the cortex increases, whereby the low intensity of the applied electric field allows the neuronal transmembrane potentials to be modified and trigger excitability, thereby bringing the underlying neurons closer to their firing threshold without causing depolarization. Depolarization of neurons means that under the influence of some outside stimulus, sodium channels are opening, leaving the Natrium ions enter the neuron membrane, thus changing the polarity of membrane potential from negative to positive. In this process of depolarization of neurons strong nerve impulse are being generated which is resulting in big brain excitability and thus inhibition of symptoms of many neuropsychiatric diseases or unwanted movements as part of rare neuro disorders. Numerous studies have investigated the mechanisms that can affect brain in right healthy doses while treating neuro diseases of different levels and types. Specifically, tDCS has been shown to act by altering γ-aminobutyric acid concentrations (GABA) in charge for producing a calming effect for brain activity and playing a major role in controlling nerve cell hyperactivity associated with anxiety, stress and fear. Besides this, tDCS method is also increasing levels of brain-derived neurotrophic factor which promotes the survival, growth, maturation and maintenance of neurons. [4] [5]

Brain-derived neurotrophic factor (BDNF), also known as abrineurin protein, is in charge for regulating glucose and energy metabolism, while decreased levels of this protein cause neurodegenerative diseases with neuronal loss, such as Parkinson's disease, Alzheimer's disease, multiple sclerosis and Huntington's disease. [7] One of the research showed that BDNF increase is connected with anodal tDCS-induced enhancement of synaptic plasticity, where synaptic plasticity is defined as a process in which neuronal activity results in changes where connections between neurons are strengthening with aim to improve learning and memory within the hippocampus. While the anodal tDCS treatment is improving brain activity, on the other hand, cathodal tDCS shows good results in decreasing the neuronal excitability of the area being stimulated which is commonly used in treating psychiatric disorders with symptoms of hyper-activity of certain brain area. That is why tDCS plays a major role in improvement of brain function, thus being a right and least harmful medical treatment for many brain disorders.

II. METHOD

It is known that for a long time tDCS has been widely studied as an alternative pain control approach in the treatment of various neuropsychiatric syndromes and pathologies. Pharmacological approach is a common strategy in treatments, however, there are numerous reasons why mentioned alternatives are used more often, and they are: patients getting used to the drug, creating addiction, lack of effectiveness etc. In this context, tDCS represents a promising and safe alternative to medication.

In 2015, the British National Institute for Health and Care Excellence (NICE) introduced tDCS methodology to be both effective and safe treatment for depression. Analysis from 2016 in 2017 has showed that at least 40% of people treated with tDCS in order to treat depression, showed at least 50% symptom reduction.

In its setup, the tDCS procedure, in addition to the main device, requires the main – target electrode and the reference electrode, soaked sponges, saline solution or gel for the electrodes for a better conductivity, with the surface of the electrodes being 25 to 35 cm^2 (5 × 5 cm and 5 × 7 cm), and the distance between them at least 8 cm, in order to ensure the best possible passage of current through the cortex.

In most stimulations therapy lasts between 5 and 30 minutes. Longer sessions may cause changing polarity of neuron membrane, as previously mentioned in this paper, and thus lead to unwanted greater impulses and brain activity. The most common side effects observed with tDCS are mild tingling (70.6%), moderate fatigue (35.3%), sensations of light itching (30.4%), slight burning (21.6%) and mild pain (15.7%) under the electrodes.[9]

Research suggest that in order for stimulation to actively modulate cortical activity it should be above a minimum threshold of 0.017 mA/cm^2. Many studies had been using currents of intensity of 1.5 mA and 100 cm^2 size of reference electrode and 35 cm^2 size of target electrode, thus gaining current density of 0.043 mA/cm^2 which had resulted in an appropriate below threshold current density for the reference electrode, and above threshold for the active electrode.[8] Applied current density and the intensity of the therapy effects also depend on the duration of the stimulation, so before every treatment all of these factors should be examined in order to create perfect conditions for a pacient as an individual. At the same time and in order to deliver the exact and worthful therapy procedure, it is necessary to examine patient factors which include alertness, body rhythm, caffeine intake, wakefulness, etc. so that the threshold level can be approximately defined, as the polarity is in narrow relation with individual's current state. Treatments of tDCS do not cause depolarization of neurons and at the same time are dealing with controlling the strong enough current intensity so that the expected effects could be seen.
Setup of the tDCS device should be always including a brain of the device, CPU unit that is receiving all the signals and then works with the results for different purposes.

Home therapy is announcing few new approcahes in the field of electrotherapy, but still not widely spread when it comes to transcranial methods in electrotherapy as they

mostly require presence of a professional with aim to keep the safety and effectivness of the applied treatment to the highest levels possible. Among all the established methods used in transcranial electrotherapy, tDCS devices made for home therapy and independent use by a patient are commonly used, as the weak currents applied in these treatments cannot produce negative effects. Building the kind of electrical device that will fit up to these safety requests as well as succeed in generating strong enough intensity of needed current, and at the same time being easily used by a final user – patient is at the starter phases of research and studying presented in this paper.

III. DEMONSTRATION

There are few models of devices for tDCS treatments feasible in home conditions that can be currently found on the market, such as: so-called brain drivers – simple devices with rechargable battery and well adjusted hardware with the interface intended for easy setting the desired current intensity and stimulation duration, tDCS starter kits available both for home therapy and research, popular forehead bandages aimed for simple stress relief which are being used during gaming or studying, then anti-depression tDCS devices, etc.

In the following the schemes of two tDCS devices for electrotherapy treatments are presented. (Figure 1, Figure 2). Electric circuit of proposed tDCS device should be consisted of constant current source for proper current regulation which must be operated on batteries or a stable voltage source that can also be provided by USB port. There are three current switches for regulating the output current in Figure 1. Different treatment needs different current flow through the cortex. So, depending on the switches states, there are 4 different outputs: when all switches are OFF – open, the output current on the electrodes is 1 mA, when S_1 is ON, output is 2 mA, with switches S_1 and S_2 ON, the output is 3 mA, while with S_1 and S_3 ON, output current is 4 mA. Electrodes should be 4 x 4 cm and soaked in saline sponges. LED is a signal point that marks when the treatment starts, while the capacitors serve as circuit memory stations, holding the switches level in order to generate constant current on the output for the long enough time. (Figure 1)

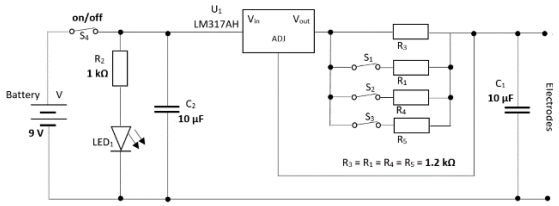

Figure 1: tDCS scheme, battery powered device

Figure 2 shows the scheme of USB powered tDCS device which uses voltage converter along with voltage regulator, where boosted voltage of intensity of 12 V is being regulated so that the output current could be in 0.5 – 2 mA range.

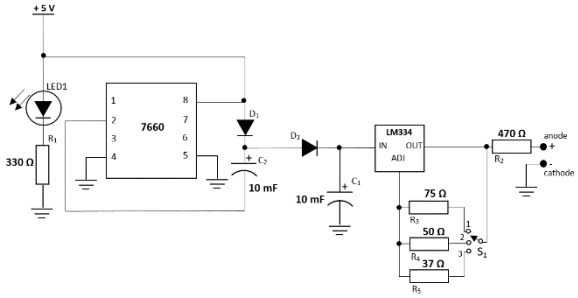

Figure 2: tDCS scheme, USB port powered device

IV. RESULTS

Paper observed both medical and tehnical backgrounds that would serve in further study and building one of a kind simple tDCS device prototype that will be easy accessible for home therapy of treating several brain diseases including Parkinson's disease, Alzheimer's disease, different types of depression, etc.

In the Figure 3 example of FDG-PET image is shown, where it refers to fluorodeoxyglucose (FDG)-positron emission tomography (PET), taken from a patient underlying tDCS treatment, with two different images representing two patient's conditions: before therapy treatment (pre-therapy) and after therapy (post-therapy), in order to map glocose metabolism. The white arrow indicates the right thalamus, the area with the greatest difference between the images. The color bar describes increasing FDG uptake with increasing signal intensity, from black, indicating no glucose uptake, to red, indicating the greatest glucose uptake. [10]

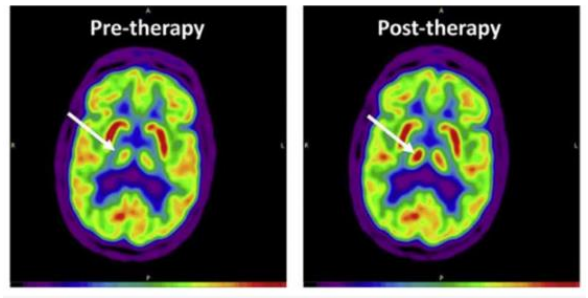

Figure 3: tDCS FDG-PET transaxial image acquired pre- and post-tDCS therapy [10]

Proposed approach results in aim to build such easy portable device for independent performing of tDCS treatment in home conditions, by an individual that is actualy a patient himself, but at the same time paying attention to provide high levels of safety along with constructing and programming the simple

interface with light and compact hardware packaging. Proposed example is shown in Figure 4.

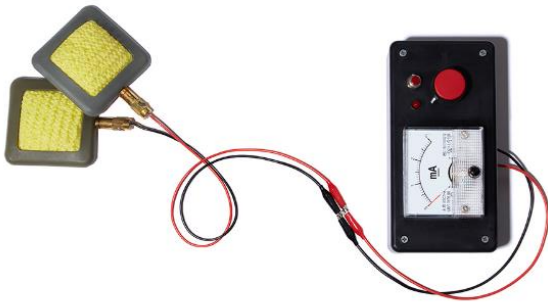

Figure 4: Proposed example of tDCS portable device for home therapy medical treatments [11]

V. CONCLUSION

Telemedicine approach now enables easy communication with patient and performing adequate treatment from any distance, but also monitoring patient's condition in any measurable cycle, which does not require effort for either the patient or the doctor, while on the other hand numerous electronic functions perform precise measurements of the patient's condition, while storing loaded data. In the field of physiotherapy, which uses electronic devices to perform the treatments, the use of simple devices for performing electrotherapy in home conditions, which are completely safe and cannot have a harmful effect on any segment of the body, is still not widespread. Future work on this topic will deal with the creation of a prototype of a portable device for performing tDCS treatment in electrotherapy, which can also have a convenient interface for communicating with the doctor, i.e. connecting to smart mobile devices that the patient uses on a daily basis, such as a mobile phone, personal computer, tablet device. Further work in this direction would require the improvement of the hardware itself, in order to make the device more compact and suitable for unhindered use by all generations of users of various medical treatments.

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