5th International Workshop on Microsystems

Alexander Campus, International Hellenic University, 16 December 2020

Workshop Proceedings

Introduction

This workshop brings together research and development from a large spectrum of science and engineering fields related to the implementation of microsystems in the new era of distributed information technologies. As cloud computing services and smart portable systems are becoming ubiquitous and more advanced, new possibilities for interdisciplinary research emerge. The microsystems that comprise the so-called internet of things will encompass a wide range of technologies including new energy sources, energy and information electronics, sensor systems, smart and energy efficient control and computing, telecommunications and networking, and also nanotechnology and micro-electro-mechanical systems. Continuing four successful workshops between 2016 and 2019, the 5th International Workshop on Microsystems aims at bringing together related research and development advancements from the academic community and the industry. Scientific topics include but are not limited to:

Energy microsystems	Industrial automation and control
Sensors and sensor electronics	Microelectronics and nanoelectronics
Embedded systems	Micro-electro-mechanical systems
Integrated Circuits and Systems	Computing for microsystems

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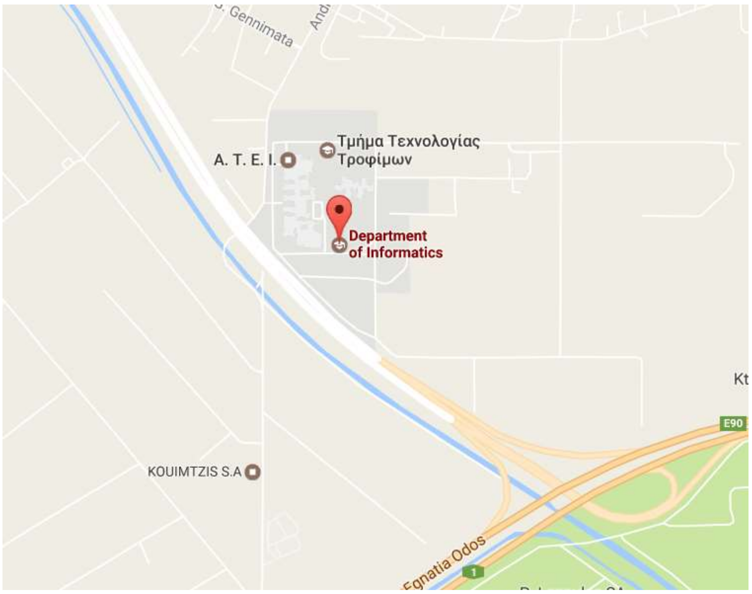
Venue

Online Lecture Theater
Alexander Campus, International Hellenic University, Greece



Date

Wednesday, 16th of December, 2020

Organizer

Michail E. Kiziroglou

Session Chairs

Dr. Vasilis Pavlidis, Electrical and Computer Eng., AUTH
Dr. Dimitris Triantafyllidis, Industrial Eng. & Management, IHU

Reviewing Committee

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Programme

08:45-09:00: Registration

Please check-in or register as you login to: https://zoom.us/j/7293147408

09:00-09:30: Welcome and introduction

09:30-10:45: First Oral Session (Session Chair: Dr. Vasilis Pavlidis, AUTH)

09:30 – 10:15: Towards creating a resilient carbon-neutral power grid. *Dr. Elizabeth L. Ratnam, The Australian National University*, 20WOM-01 (keynote).

10:15: Low-cost DIY kits: remote lab teaching tools for embedded control. *Ch. Yfoulis*, 20WOM-02.

10:30: A novel electrical impedance spectroscopy scanner featuring statistical and machine learning classification to support medical diagnosis of early-stage melanoma cancer (DermaSense), *S. Gilou, C. Dimitrousis, A. Zogkas, P. D. Bamidis and A. Astaras,* 20WOM-03.

10:45-11:15: Coffee Break and Poster Session

An Introduction to Nanotechnology, *D. Bagdatoglou, N. Balp, A. Bantis, R. Beal, Y. Carmichael, C. I. Danaskou, K. Georgiadis, M. Michailidou, A. Nikolopoulos, S. Ntemkas, D. Parastatidou, V. Petitjean, H. Schaefer and N. Traikoudis*, 20WOM-04.

11:15-12:30: Second Oral Session (Session Chair: Dr. D. Triantafyllidis, IHU)

11:15: Deep Process Intelligence – Next generation in Industrial Automation Instrumentation, *Dr. Sunil Kumar, Rheonics GmbH,* 20WOM-05 (Invited).

12:00: Best practices in energy saving, *N. Balp, R. Beal, Y. Carmichael, V. Petitjean, H. Schaefer and F. Stergiopoulos,* 20WOM-06.

12:15: Flux Funnelling for Inductive Power Line Energy Harvesting, *M. E. Kiziroglou, S. W. Wright and E. M. Yeatman*, 20WOM-07.

12:30-13:00: Best Paper Award by Ioannidis Electronics. Concluding remarks.

WORKSHOP ABSTRACTS

Towards creating a resilient carbon-neutral power grid

Elizabeth L. Ratnam
College of Engineering and Computer Science
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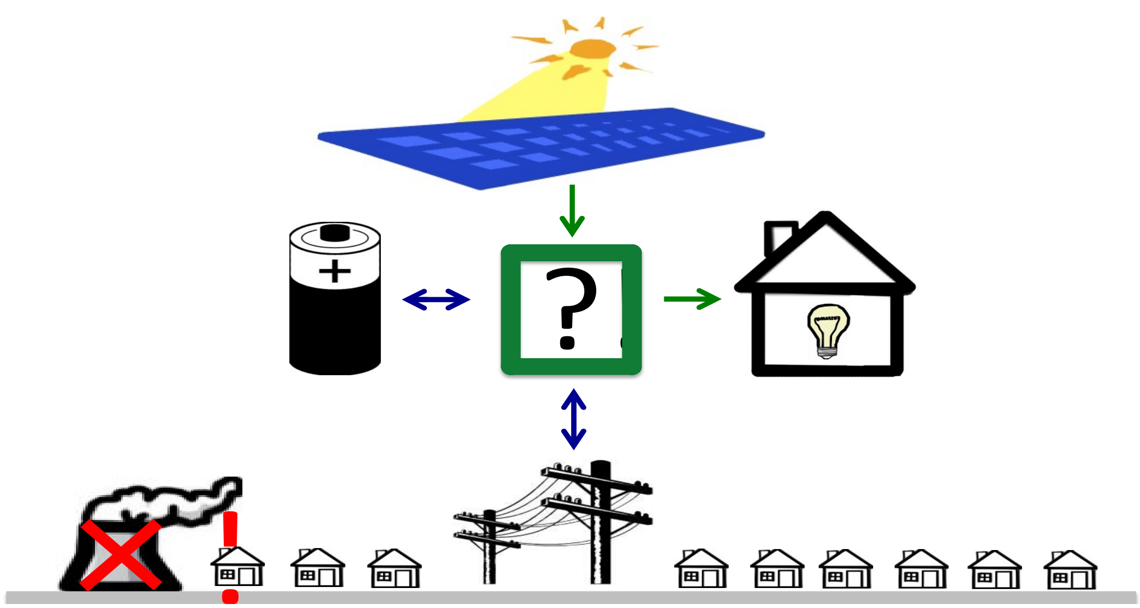
Abstract: In recent years, a dramatic increase in electrical power generation from renewable energy sources has been observed in many countries. The grid-integration of customer-owned solar photovoltaics (PV) has been driven by government incentives and renewable energy rebates, including residential feed-in tariffs and the financial policy of net metering. However, new challenges arise in balancing the generation of electricity with variable demand at all times as traditional fossil fuel-fired generators are retired and replaced with intermittent renewable electricity sources. This presentation considers ways to integrate residential-scale battery storage co-located with solar PV, with a view of creating a resilient carbon neutral electricity grid.

Bio: Dr Ratnam earned the BEng (Hons I) degree in Electrical Engineering in 2006, and the PhD degree in Electrical Engineering in 2016, from the University of Newcastle, Australia. She subsequently held postdoctoral research positions with the Center for Energy Research at the University of California San Diego, and at the University of California Berkeley in the California Institute for Energy and Environment (CIEE). During 2001–2012 she held various positions at Ausgrid, a utility that operates one of the largest electricity distribution networks in Australia. Dr Ratnam currently holds a Future Engineering Research Leader (FERL) Fellowship from the Australian National University (ANU) and she joined the Research School of Electrical, Energy and Materials Engineering at ANU as a research fellow and lecturer in 2018. She also holds an ongoing affiliation with CIEE at UC Berkeley, and is a research lead in the Battery Storage and Grid Integration Group (BSGIP) at ANU. Her research interests are in developing new paradigms to control distribution networks with a strong focus on creating a resilient carbon neutral power grid.



Low-cost DIY kits: remote lab teaching tools for embedded control

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***Abstract*—Online learning has emerged as an interesting opportunity during the outbreak of the Covid-19 crisis. Although recently a core aspect of teaching has been made available online, switching to online teaching of labs has not been sufficiently addressed in the current university practices. In particular, the medium to large-scale setups which are available in a typical control engineering lab cannot be used in online mode, especially during quarantine periods. In this paper, the use of low-cost miniature setups is investigated as an effective means to cover the student's needs, i.e. to become familiar with the main principles of a digital feedback loop operation and experience the control design process and its real implementation with algorithmic code. Cheap DIY kits, equipped with Arduino-based electronics and compatible sensors can raise the student's interest in control theory and practice, as the time saved in the experimental setup and control, is invested to deeper study of the underpinning theory. Moreover, the project-based learning advantages can be realized even when strict social distancing policies are imposed.**

***Index Terms*—Online learning; Covid-19; remote labs; control education; embedded control; Arduino; DIY kits; project-based learning;**

I. INTRODUCTION

Online learning has been widely adopted during the outbreak of the Covid-19 crisis. Modern computer and IT technology has managed to offer viable solutions so that a core aspect of teaching and learning can be made available online. However, there are some critical questions: How is it possible to switch to online teaching of practicals and labs? This is a key issue that is expected to attract the attention of the faculty members.

Control is the hidden technology [1-2], performed nowadays in the vast majority of cases in a digital embedded form. In a modern control engineering lab it is vital for the students to become familiar with the main principles of a digital feedback loop operation and experience the control design process and its real implementation with algorithmic code. Low-power miniature setups can fulfill these demands and comply with the main requirements described also in early studies [3]. There are four mainstream approaches in the current control engineering laboratory practice:

- *Commercially available real equipment setups*, which are complemented by user manuals but are expensive, hence only a small number of each setup is available in the lab schedule. Also, for the limited time that they are made available to a group of students during the lab sessions, most students have limited access and their operation is not transparent to them.
- *Virtual labs [4]*, where a realistic user-friendly interface resembling a real setup is used and the system's responses depicted are produced by simulation. This is an attractive choice, as these are simple and light applications that can be used at any time by the students. They do not incur any cost and are compatible to home-based learning. However, the students miss the opportunity to interact with a real physical plant.
- *Remote labs [5-8]*, where a real setup is remotely controlled by the student making it possible to share expensive equipment. Unfortunately, the limited number of these devices makes the availability of the system for a large number of students an issue. Another issue is maintenance, especially during a quarantine period.
- *Custom-built low-cost kits* [9-16] is a new popular trend for a number of reasons. The students can come up with their own setup on a DIY basis. They can buy low-cost materials from a list provided by the instructor and assemble them to form a complete control process. They are also free to use their creativity with low-cost or recycled materials.

II. METHODS

The proposed method for dealing with the need for remote control labs is low-cost DIY kits. In particular, our kit introduced in [14], which has been developed to support undergraduate and postgraduate control education in a number of relevant courses ("*Control Systems Principles*", "*Industrial control*", "*Digital control*", "*Modeling and System Identification*", "*Advanced Control systems*"), appears to be rather versatile and flexible. Cheap take-home kits, equipped with Arduino-based electronics and compatible sensors can raise the student's interest in control theory and practice, as the time saved in the experimental setup and control, is invested to deeper study of the underpinning theory.

The kit supports many control experiments, i.e. LED brightness control, temperature control, DC motor speed control, position (servo) control, pendulum (arm) position control, and inverted pendulum control. Different basic control laws (On-off, PID, lead-lag, state-space) [15-16], as well as more advanced nonlinear and optimal control techniques [17], may be tested, covering the needs of both undergraduate and postgraduate students. The equipment can be borrowed to the students for project work at home, or they can easily purchase and assemble their own low-cost set.

The kit (Figure 1) consists of the following pieces of equipment: a breadboard, an Arduino UNO, a Photo Light Sensitive Resistor, a LED, a temperature sensor (DHT 11 or 22), a cheap DC micro-motor equipped with a high-resolution 2-channel incremental encoder (334 ppr), a potentiometer, a 5W light bulb, an H-bridge driver (e.g. L293D), a common 12V/2A power supply, and few Lego parts, wire cables and resistors.

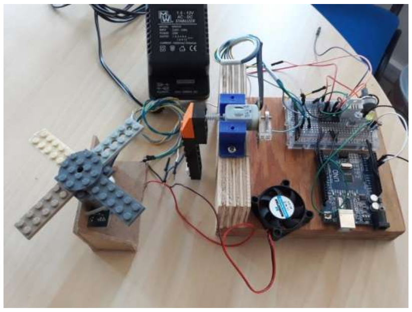

Figure 1. The kit described in [14].

If we pay attention to the DC motor control experiments, the total cost of the kit is approximately 35 Euros, as detailed in Table 1. For students that possess basic electronic equipment from previous courses (i.e. power supply, breadboard) it can drop to 25 Euros. If the DC motor is borrowed from the lab, the total cost falls to 20 euros.

Table 1. Bill of materials – E-bay prices

Item	Price
Motor	6 €
H-bridge	2.5 €
Power supply	7 €
Breadboard	3.5 €
Arduino UNO R3	16 €
Total	**35 €**

The low price of this setup allows the lab to possess a large number of these units, so that many students can borrow one of them. This is very helpful for both the lab practice and the student's convenience, since the DC motor is the only material from Table 1 that is not directly accessible to the students in the local electronics market (Figure 2). Most of the materials of Table 1 are usually already in their possession from previous electronics and microprocessor courses.

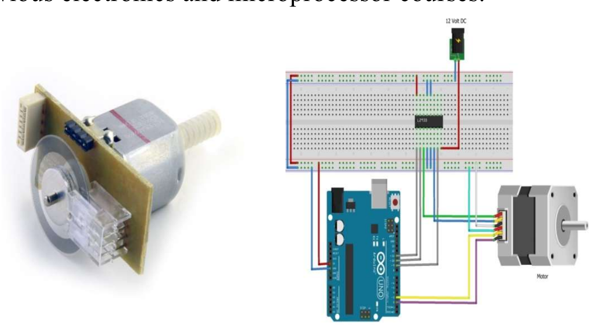

Figure 2. The DC micro-motor and the Arduino hardware setup

This setup is particularly flexible, as loads of different shape and weight can be easily attached on the motor's shaft. The rectangular base shown in Figure 3 can serve as a stand so that the motor orientation changes when sitting on any of the two different sides. A more solid solution is to use a 3-D printed base, which acts as a drawer for the motor (Fig. 5).

The setup can easily support a variety of different important control experiments (servomechanisms). Miniature propellers, antennas-telescopes, bars of different sizes and shapes using e.g. common Lego parts or other custom-built parts from common or reusable/recycled materials can be used to perform a series of experiments demonstrating the efficiency of digital PID control using Arduino, a personal PC and a USB connection. The main experiments are as follows

1) *speed control* with the help of a propeller shown in Fig. 3 (right).
2) *position (servo) control* in a horizontal orientation for the motor (Fig. 4). Apart from the propeller, a bar as well as an antenna-telescope may be used.
3) *Position (arm/pendulum) control* in a vertical orientation for the motor (Fig. 5). In this configuration, several different control problems may be studied, depending on the desired equilibrium point (crane regulation, arm position tracking, inverted pendulum regulation).

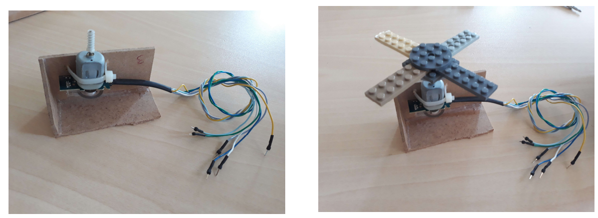

Figure 3. The dc motor sitting on a custom-built wooden stand without load (left) and with load -propeller with simple Lego parts- (right)

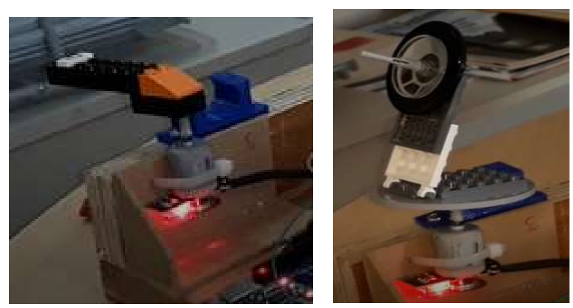

Figure 4. A LEGO assembly -a stick in a horizontal configuration or an antenna-telescope - for position (servo) control.

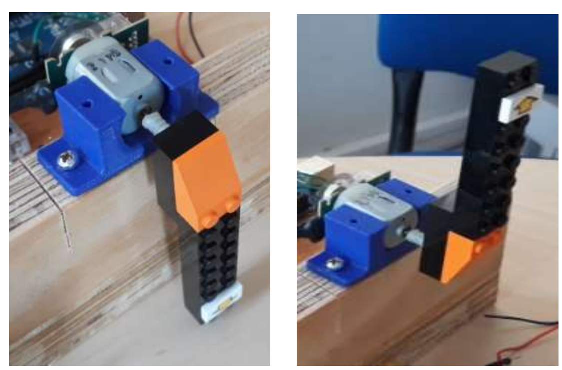

Figure 5. A LEGO bar-rod attached to the motor shaft vertically -in two different configurations- can form a load for position (pendulum) control. Left: arm/pendulum (downwards), Right: inverted pendulum (upwards).

The advantages of the lab kit proposed are numerous: it is low-cost, covers a large number of representative experiments and relies on fully open-source software and hardware. Furthermore, it is fully transparent, as all components of a modern digital control system -i.e. an embedded control system- are directly accessible to the students, and they witness the process of assembling them to a fully functional hardware including the programming task of writing and modifying the control code. This is a solution that allows the realization of many good practices and project-based learning advantages [18-19]. Moreover, in time periods where strict social distancing policies are applied, this approach takes a DIY character. The main advantage of the proposed kit compared to commercial kits [20-22] that can serve the same purpose and offer similar functionality, is its low price that guarantees availability at home for students of every capacity.

III. DISCUSSION

The majority of universities worldwide have managed to respond quickly to the COVID-19 challenge and most of the courses have been offered on a remote basis using a number of different platforms. With the exception of simulation-based labs, the unexpected outbreak of the crisis didn't leave enough margin and time for the faculties to organize a proper replacement with remote lab courses during the semester.

It is inevitable that remote lab teaching methods will start to appear soon, perhaps even in this academic year. Nevertheless, proper remote lab sessions and exams are difficult to conduct online, unless each student has direct access to the equipment from home. This is the case with the proposed kit. The labs can be organized on a blended learning basis. In the initial meetings, the students assemble their setup according to the written instructions, and then the setup is checked with on-line Zoom group meetings by the instructor. In the number of lab sessions that follow, the basic control techniques are explained and evaluated by the instructor live on his kit. The students have the opportunity to experiment in parallel, but they avoid the pressure to complete the lab exercise during the on-line meeting. They can continue their study afterwards asynchronously at their own pace and time, and experiment freely as much as it is necessary before writing their reports.

Similarly, the student's assessment includes two modes. Their project work is asynchronously evaluated, and then a synchronous oral examination (midterm or full term) follows. The instructor arranges Zoom meetings with the students either individually or in groups and tests their competence, understanding and progress by watching their on-line real experiments performed live on their kit at home. We plan to work systematically on these ideas and their pilot testing starting from the next spring semester in February 2021.

IV. CONCLUSION

It is evident that remote education, which is a notable facet of the last major shift in engineering education [8] is here to stay and will continue to grow in the near future. Nobody can predict the future of the Covid-19 outbreak. However, there is no doubt that even after the epidemic passes, remote education practices will be widely adopted, e.g. in the form of the *blended learning* policies that are likely to emerge.

This article communicates some recent ideas that could pave the way towards the development of viable control engineering remote lab courses. These ideas could also have a more general applicability to other related engineering fields, for which low-power setups are sufficient, such as electronics, microprocessors-microcontrollers, mechatronics, mobile robotics, and embedded systems.

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A novel electrical impedance spectroscopy scanner featuring statistical and machine learning classification to support medical diagnosis of early-stage melanoma cancer (DermaSense)

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***Abstract*—** Electrical impedance scanning is a technique which has been successfully applied in medical applications during the past few decades, particularly in the form of tomography, spectroscopy and rheography supporting the medical fields of Cardiology, Neonatology and Pulmonary Medicine. Project DermaSense involves the development and testing of a prototype biomedical scanner which exploits electrical impedance spectroscopy to provide a medical decision support tool in Dermatology [1]. The device is non-invasive, portable and power-autonomous and provides scanning results in under a minute. It applies an imperceptible alternating current through various pairs of electrodes which are placed on the patient's skin, measures voltage drop across different frequencies and subsequently extracts a differential impedance absorption spectrum. Through pilot studies currently underway, the absorption spectra from different patients and medical conditions are being statistically associated with probabilities of underlying dermatological conditions [2]. The primary disease being targeted is melanoma cancer, which in its early stages can appear similar to regular nevi (skin moles). Furthermore, we have successfully conducted 171 sets of measurements on 25 human subjects, covering clear patches of skin, suspected malignant nevi and 5 measurements on verified melanoma cases. Based on the measurements of clear patches of skin and suspected melanoma, we have developed an Artificial Neural Network which performs classification (clear patch of skin vs nevi) which at this point in development has demonstrated 77.4% accuracy, 94.7% sensitivity, 50% specificity and an F1 score of 83.7%, based on data from an initial pilot study. For the purpose of statistical analysis, as the normality assumption was fulfilled, we addressed paired sample T-Test between melanoma, nevi and clear patches of skin which were obtained from the same subjects.

***Index Terms*—** artificial neural networks, biomedical engineering, dermatology, electrical impedance spectroscopy, machine learning, melanoma cancer, medical instrumentation

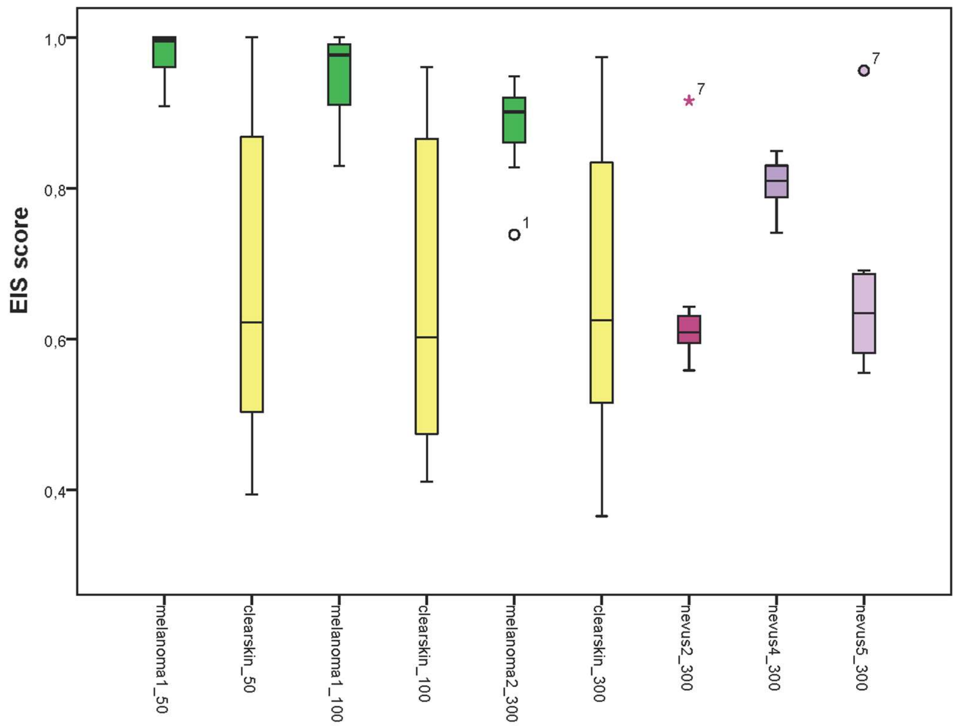

Figure 1: Boxplot of measurement data obtained from a single patient suffering from cutaneous melanoma located in the area of their shoulder blade. The data presented in this graph was selected among several dozens of measurements, using a statistical significance evaluation (paired T-Test). Green colour indicates melanoma, yellow clear skin, purple and red melanocytic nevi (skin moles which can appear similar to early stage melanoma).

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From Microtechnology to Nanotechnology

Bagdatoglou D.[1], Balp N.[2], Bantis A.[1], Beal R.[2], Carmichael Y.[2], Danaskou Ch. I.[1], Georgiadis K.[1], Michailidou M.[1], Nikolopoulos A.[1], Ntemkas S.[1], Parastatidou D.[1], Petitjean V.[2], Schaefer H.[2], and Traikoudis N.[1]

International Hellenic University[1], École Catholique d'arts et Métiers de Lyon[2]

***Abstract*—Nanotechnology, the study of materials and artificial structures in the nanoscale, is an upcoming field of science and engineering that could allow humanity to discover and utilize previously-unknown materials, invent and make use of alternative technologies in the industrial sector and medicine, increase energy efficiency, and help create a cleaner world. In this paper a brief overview of various different aspects of nanotechnology is presented. In particular, these aspects are nanomaterials, spintronics, quantum computers, nanomedicine, renewable energy technologies, and the MEMS comb drive actuator.**

***Index Terms*—carbon nanotubes, comb drive, graphene, nanomedicine, nanotechnology, NEMS, quantum computers, spin transistor, spintronics.**

I. Introduction

THIS paper was created as a result of the authors' research projects in the Nanotechnology course of the department of Industrial Engineering & Management of the International Hellenic University, during the winter semester of the 2020-2021 academic year. It briefly presents some of the results of the aforementioned research projects for the 5th International Workshop on Microsystems.

At the present time, microsystems are an integral part of daily life for numerous humans. From integrated circuits to microelectromechanical systems not only for professional use in medicine, robotics, and automation, but also for personal use in devices such as mobile phones, wearables, and more. Several fabrication techniques for microsystems already exist. These techniques include, but are not limited to, deposition techniques such as epitaxy, sputtering, and chemical vapour deposition; patterning methods such as photolithography and electron beam lithography; etching methods such as plasma etching, reactive ion etching, and vapour etching; as well as semiconductor ion implantation techniques, nano-imprinting, and self-assembly. The scaling of MEMS and ICs introduces not only new challenges in fabrication, but also new frontiers in nanotechnology.

II. Nanomaterials

Carbon nanotubes appear as concentric, hollow tubes, with an internal diameter of approximately one nanometre and a micrometre-scale length. Those structures are optionally closed at their ends with carbon pentagons. In history, until 1985, the only known crystallized forms of pure carbon were graphite and diamond. The discovery of the carbon nanotube is attributed to S. Iijima (NEC, Tsukuba, Japan) who identified it in 1993 while observing a by-product formed in a carbon-arc chamber, under an electron microscope[1]. Since then, various specific synthetic methods have been developed and have enabled the laboratory study of the structure and the physical and chemical properties of these microscopic objects. There are two ways to synthesize carbon nanotubes: through electric arcs and with the chemical vapour deposition method[2].

There are two main categories of nanotubes: single-walled carbon nanotubes and multi-walled carbon nanotubes[3]. There are three types of single-walled nanotubes which depend on the winding mode of the graphene sheet: The zig-zag nanotube (number 1), the armchair nanotube (number 2), and the chiral nanotube (number 3). These different structures are illustrated in Figure 1.

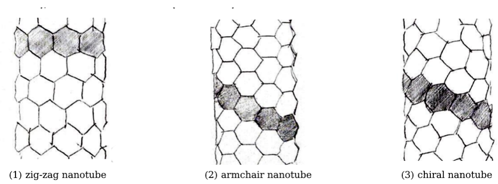

Figure 1: An illustration of zig-zag, armchair and chiral nanotubes.

The type of the nanotube depends on its bending and on whether its edges are in contact. If the two armchair edges are connected, it is a zig-zag nanotube. If the two zig-zag edges are connected, it is an armchair nanotube. The chiral nanotube is obtained by translating one edge of the graphene sheet relative to the other, parallel to the axis of the tube. Multi-walled carbon nanotubes are composed of several concentric single-walled nanotubes that do not have the same chirality. The major advantages of the nanotube are that it is 100 times stronger than steel and yet it is lighter than it, and also, its unusual resistance to high temperatures. Their electrical, mechanical, and thermal properties suggest many applications, especially in the fields of microelectronics, materials, clothes, sports, and medicine[4].

Graphene, a material discovered by Andre Geim and Konstantin Novoselov in 2004, is a two-dimensional sheet of graphite. It is a carbon-based structure in which the atoms are positioned in a hexagonal pattern. Graphene is illustrated in Figure 2. Its high electrical conductivity, thermal conductivity, its strength, and its flexibility, paired with its small mass

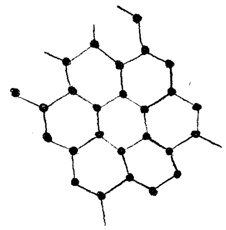

Figure 2: An illustration of graphene.

and dimensions, are some of its most significant properties[5].

Of all the existing formulas to synthesize graphene, the primary method for large scale and high-quality production is the Chemical Vapour Deposition (CVD) process[6].

III. Spintronics

The silicon transistor is the smallest logical element in practically all modern electronics and is one of the greatest inventions of the 20th century. In contrast to silicon transistors, spin transistors do not utilize electric currents to change their state, but instead use the electron's spin, which is semi-permanent, and can either have the value of spin-up ($+\frac{1}{2}$) or spin-down ($-\frac{1}{2}$). These two spin values can be encoded as a logical "1" or "0". Spin transistors could potentially store more data and use less power than silicon transistors — both being highly critical properties, considering the computational and energy demands of the 21st century. However, spin-based transistors are still in development, even though the concept itself was first introduced by Datta and Das in 1990, because of critical technical challenges such as the low spin-injection efficiency caused by resistance mismatch, spin relaxation, and the spread of spin precession angle. However, the theory planted the idea of utilizing spin as a means to carry and manipulate information and created the field of spintronics[12][13].

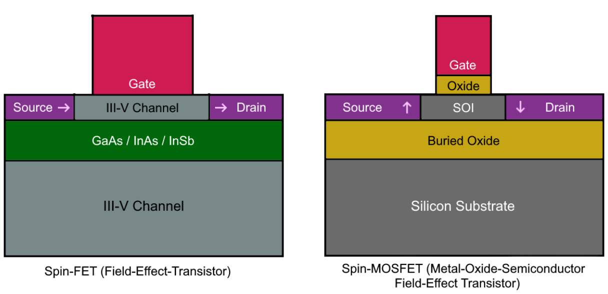

Figure 3: The Spin-FET and Spin-MOSFET.

Two promising technologies are the Spin-FET (Field-Effect Transistor) and Spin-MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor), both shown in Figure 3. The former, proposed by Datta and Das[12], uses a fixed ferromagnetic source (S) as a polarizer and a fixed ferromagnetic drain (D) as a detector and exploits the spin-orbit effect to determine the spin state the drain will detect. For this purpose, materials with a strong spin-orbit interaction (such as InGaAs and InAs) are utilized. The magnitude of this effect can be controlled by the gate's (G) voltage. The substrate and channel are composed of III-V molecules[14]. The Spin-MOSFET instead uses a silicon substrate and channel and a ferromagnetic source and drain. The spin's state is determined by the polarization of the ferromagnetic layers. Spin-MOSFETs are controlled in the same manner as silicon MOSFETs, thus being logically compatible with technologies like NMOS, PMOS, and CMOS[14][15].

IV. Quantum Computers

Quantum Computing is a quickly growing field, and it might soon make an impact on our lives. It was invented in the early 1980s by the physicist Paul Benioff, who invented a quantum model of the Turing machine. The main difference between the quantum and the classical computer is that the former uses quantum bits (qubits), whereas the latter uses bits. While bits can be either "0" or "1", qubits are not as simple. They can be "0", "1", or any value of both, in-between. This condition is called superposition. Another property is entanglement, or, as Albert Einstein called it, Spooky Action at a Distance[18]. In quantum entanglement, qubits are interconnected, and when the state of one of the entangled qubits is measured, the other qubit's state is instantly defined as well. Such a computer's architecture utilises quantum gates that implement operations (such as transformations) into a pair of qubits. The qubits can be measured in their final state and from these measurements, a final computational result is derived. A comparison of the bit and the qubit is shown in Figure 4[16][17].

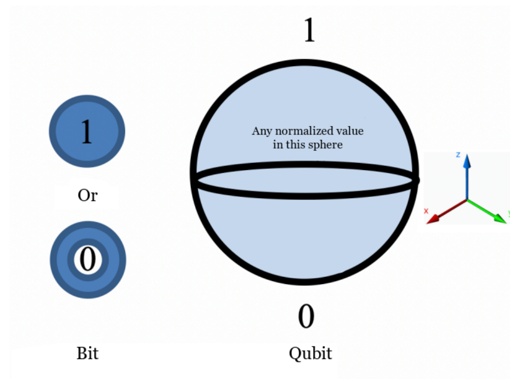

Figure 4: The bit and the qubit.

An operator is, in quantum mechanics, a linear mapping of a Hilbert* space into itself. The term is a specialization of the mathematical concept of an operator. An observable* is a Hermitian operator. In classical mechanics, the motion of particles (or of a system of particles) is completely determined by the Lagrangian (x, $\dot{x}$, t). There are many operators, such as translational symmetry, temporal translational symmetry etc. Quantum mechanics is based a lot on postulates built over the concept of operators. A state in quantum mechanics is represented by a unit vector (with a total probability equal to one) in a complex Hilbert space. The temporal evolution in this vector space is given by the application of the temporal evolution operator. All quantities that can be measured in experiments (observables) are associated with a linear operator. The operator must give real values so that they correspond to experimentally measured ones. In this purpose, the operator has to be Hermitian*. The probability of each value being observed is linked to the projection of the entangled qubit's state on the sub-state of the aforementioned value. Examples of operators include acceleration operators and annihilation operators. An example of a logical circuit inside a quantum computer is shown in Figure 5, containing two Hadamard gates (H), a Pauli-Y gate, a Pauli-Z gate, and two Controlled-NOT gates[16][17].

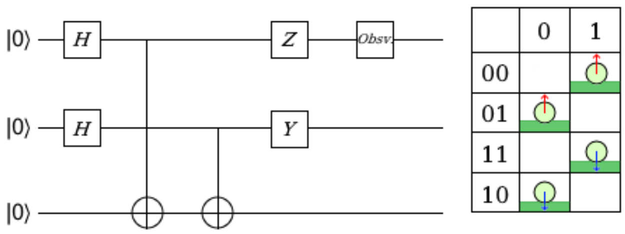

Figure 5: Example circuit in quantum computing.

There are undeniable advantages with quantum computers. Some of the advantages of quantum computers are higher processing speed, larger memory capacity, energy reduction due to quantum tunnelling. Another important reason is the current demand for better and more widespread cryptography for the protection of private data. These advantages make this technology eagerly awaited in the future. Quantum computers have the potential to carry out such operations exponentially better and introduce new and better forms of encryption. Currently, quantum computers are far from replacing our computers as they are still in a research phase, with companies like Google and agencies like NASA having constructed early versions of the quantum computer[19]. However, if scientists are struggling to make this technology accessible to everyone, that is because there are problems - the main problem being decoherences. These may appear because of temperature fluctuations, electromagnetic waves etc., and they can destroy the quantum properties of a quantum computer[16].

V. Microelectromechanical Systems

Micro-Electro-Mechanical Systems (MEMS) and Nano-Electro-Mechanical Systems (NEMS) are microscopic machines that can perform a variety of tasks. Through devices such as personal computers and smartphones, MEMS technologies already are an integral part of daily life for many humans[23]. From actuators, oscillators, and energy harvesters to a large assortment of sensors[21], these technologies are expected to become increasingly important in the near future and are anticipated to be scaled down to even smaller sizes[22][23]. The following section will describe the comb drive, a MEMS actuator.

The so-called "comb" mechanism is often used as a microscopic electromechanical actuator. Applying a voltage bias between the static and moving combs will generate a capacitance, creating an electrostatic force that moves the combs. The actuator's force is

$$F = \frac{1}{2}\frac{\partial C}{\ell \partial x}V^2 = \frac{-1}{2}\frac{nt\epsilon_0\epsilon_r}{\ell}V^2$$

where V: voltage, C: capacitance, ε0: permittivity of free space, εr: relative permittivity of the dielectric material, ℓ: the distance between the comb's electrodes, n: the number of electrodes, and t: the width of the former. If an integrated mirror exists in the comb drive, it can be used for optical purposes. Such a mechanism is pictured in Figure 6. Without a mirror, the comb drive is just as useful. Capacitive MEMS actuators are used in measuring devices (sensors), such as gyroscopes and accelerometers. They are also found in mechanical displacement devices and in the field of energy harvesting[24][26][28][29].

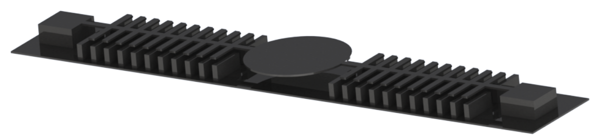

Figure 6: A Solidworks render of a comb drive.

The comb drive's mathematical background is vast, with equations not only for the intrinsic properties of the materials, but also for the external environment, the principle of conservation of energy, mechanical and chemical imperfections, and control systems[25][26][27].

A fabrication process flow for a comb drive is described below, as an example. First, two silicon wafers of the appropriate size are chosen and are subjected to an RCA cleaning procedure. Then the two wafers are merged with the SIMOX[37] procedure, creating a microscopic SiO_2 layer in between. A photoresist is applied to each side, in order to create a mask with photolithography. Both sides undergo Inductively-Coupled-Plasma Reactive-ion Etching (ICP-RIE) to create the required geometry for the combs and the mirror. Afterwards, the photoresist is removed with a Fuming Nitric Acid (FNA) bath and the excess oxide is dissolved with Buffered Hydrofluoric Acid (BHF). The RCA cleaning procedure is once again applied. In the final step, the mirror and the electrical contacts are created with aluminium deposition using the sputtering method.

VI. Nanomedicine

Nano-medical science is the application of nanotechnology in the field of healthcare, as it specializes in high precision operation at the nanometre (nm) scale. It contributes to the valid prognosis, diagnosis, treatment, and monitoring of many diseases, with the fewest possible side effects and with the best results. With the use of nanotechnology, we synthesize matter from its base, achieving new, improved properties of materials[7][8].

Various means are used for diagnosis and treatment such as quantum dots, gold nanoparticles, magnetic nanoparticles, carbon nanotubes, fullerenes, etc[9][10]. Scientists have turned their attention to research in the field of nano-biochips and nano-bots, due to their ability to perceive heat, light, chemical molecules, and other stimuli, combined with their ability to interact with matter at the nanometre scale, give hope for future applications for the detection and neutralization of toxic infectious or carcinogenic agents[11].

Scientists have also turned their attention to research in the field of nanochips and nanorobots. Nanorobots may use the da Vinci System, which contributes to the precision and non-invasiveness of medical and surgical procedures[30]. They may be composed of glass nanoparticles, i.e. capsules equipped with valves for drug administration[31], biocompatible and biodegradable DNA sheets, and more. They can be used for the detection and neutralization of cancer cells[32][33]. Some functions of nanochips include the molecular diagnosis, and cancer detection, and tissue nanotransfection that aims to replace or repair the injured or aged tissue of the patient's organs, blood vessels, etc. Figure 7 portrays such mechanisms inside the human body[10][34][35].

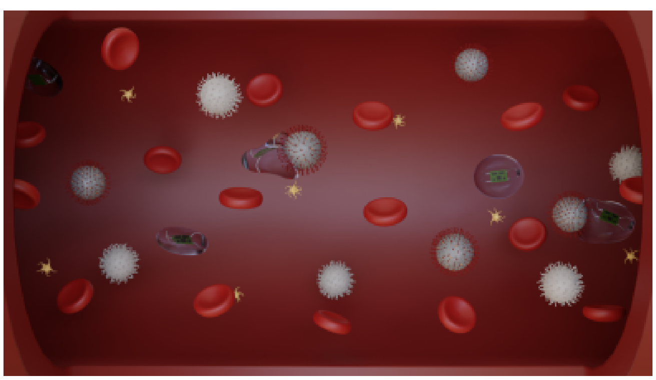

Figure 7: An artery containing red and white blood cells, platelets, the SARS-CoV-2 virus, and medical nanostructures. Rendered by *Tsavdaridis-Rigas Theodoros-Rafail* for exclusive use in this publication.

VII. Renewable Energy and Green Technologies

No doubt, the current challenges of humanity as well as the rapid development of technology have created greater energy requirements, leading to an increase in energy consumption per person. This phenomenon has already caused several environmental changes, such as damage to the quality of air, water and soil, and even in biological diversity.

The energy-focused applications of nanotechnology could decrease the magnitude of the aforementioned problems, focusing not only on energy production and storage but also on helping the environment. Some of the environmentally-friendly applications in renewable energy sources include the use of solar radiation in photovoltaics, "passive solar energy" technologies that minimize energy losses, thermoelectric systems such as thermoelectric generators (TEG) and heat pumps (PET), artificial photosynthesis for the production of carbohydrates or hydrogen through water depletion, and sustainable storage for electrical energy, such as rechargeable batteries and supercapacitors[36].

Through the use of the appropriate nanomaterials, flexible photovoltaics can be fabricated to be adaptable and recyclable. In addition, energy production can be achieved with hydrogen cells, which, through the use of materials such as zeolites and carbon nanotubes, store the hydrogen used for energy production through combustion. For energy storage, there exists, for example, a bio-renewable technology that replaces the graphite in Li-ion batteries with silk nanofibers. Through such applications, designed with nanotechnology and green technologies in mind, advantages such as increased efficiency in lighting, heating, and electric storage capacity have been achieved, and pollutants have been reduced[38][39].

Appendix A

*Hilbert space**: In mathematics, a Hilbert space is a real (or complex) vector space endowed with a Euclidean scalar product which allows to measure lengths and angles and to define orthogonality. This space is complex in quantum mechanics.

*Observable**: The quantum equivalent of, for example, position or energy measures in classical mechanics.

*Hermitian**: in a Hermitian space, matrices can be described as an extension of real symmetrical matrices.

Acknowledgment

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Deep Process Intelligence – Next generation in Industrial Automation Instrumentation

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Current large-scale industrial process monitoring, and control is focused heavily on use of sensors for operational condition monitoring using temperature, pressure, flow rate, level measurement instruments. This leads to process control based on pre-defined recipes as the information on the process fluids is not monitored in-situ, real-time during processing but often in lab either before or after the processing.

To achieve true industry 4.0 machine connectivity and enable real process knowhow that can then be used to deliver on-demand products and manage changes to raw materials and optimize energy and end-product quality, producers needs deep process knowledge – this needs instruments that directly monitor the process fluids during manufacturing.

For real-time, in-situ process monitoring, we need instruments that can measure property of the fluid undergoing processing – these are physical & chemical properties like viscosity, density, chemical composition, thermal characteristics, texture, etc. Amongst these, density is perhaps the most developed with a variety of instruments that cover inline installations. Remainder have been at early stage with very low level of penetration. At Rheonics, we focus on the development and commercialization of inline viscosity monitoring. Viscosity is a property that is affected at the molecular level and has tremendous amount of information about the process but has been hard to quantify reliably with existing instruments.

Rheonics developed technologies for inline fluid monitoring over 30 years along with its team at ETH Zurich ultimately leading to the proprietary balanced resonator that provides a platform for developing multiple instruments for physical property measurements. This talk will discuss some of the key steps in the development focusing both on the mechanical and electronics aspect of viscosity sensor development from the balanced resonator platform, route to customer adoption and commercial scaling of these intelligent sensors in multiple industrial applications.

Keywords: automation, sensors, process intelligence, viscosity, density, industry 4.0, IIoT, Deep ML

A brief review of good practices for energy saving

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I. Introduction

TODAY, saving energy is one of the major challenges of the 21st century. Indeed, man has realized that the energy sources on which he had based his evolution are fossil-based which are diminishing and are not infinite.

To this is added the problem of global warming which is beginning to worry scientists, and which is getting worse from year to year. Since 2000, an increase of 2 degrees has been recorded in global temperature. These figures are alarming, and scientists predict a lot of complications that are to appear following global warming (rising ocean level, disappearance of animal species, decrease of rains in dry areas, etc.).

It is for these reasons that it is important to find other sources of energy but above all to implement systems allowing to save energy. Beyond the ecological aspect, saving energy makes it possible to save a lot of money. Today, industry is the most responsible for greenhouse gas emissions. Therefore, in this paper we are going to present several ways to save energy in industry.[1]

II. Description of various systems and approaches used in industry to save energy

A. Systems of renewable energy

An energy renewable system reduces the impact and energy loss of a system. For environmental or economic reasons, the use of this kind of technical solutions has allowed great advances in the world of industry, but not only. Needs of new energy management strategies arise for renewable systems at all levels [2]

B. Building Insulation

Large energy losses are produced due to bad insulation, in fact, according to a study, good insulation can reduce electricity bills by 10% in summer and 46% in winter. For walls which are responsible for 40% of the losses there exist 2 types of insulation:
-From the inside: Installation of a partition with an insulating material in the middle. This solution costs around 100 €/m^2
-From the outside: Several layers of materials are applied to the exterior face of the wall. This solution costs around 250 €/m^2
It is also possible to insulate the roofs which are responsible for 35% of the losses. Insulation is applied with the installation of insulating boxes to the ceiling, thanks to the installation of insulating materials in the attics. Finally, the insulation of the doors is also important because it represents 30% of energy losses. This can be done with the installation of double glazing, by changing the seals or with the installation of insulating shutters [3]

C. Equipment optimization

Nowadays, in industry, a lot of pieces of equipment are old or even obsolete. Old devices may have lubricant leaks or oil leaks etc. It is not the best way to save energy. If a part is processed without lubricant, the tool may heat a lot and the energy of heat will just be dissipated. Also, the tool may break and again it costs energy to produce a new one. A way of avoiding these things is to optimize the equipment. It can take place with complicated plans as the Device Software optimization or just by changing old bulb lights by led. [4]

D. Recovery of exhaust gas

A thermal engine peak efficiency is around 35%. It means that around 65% of the entire energy content in gasoline is lost as heat. An exhaust gas heat recovery system permits to reduce the fuel consumption of a vehicle by 30%. It converts the thermal energy from the exhaust gases into electricity or transfers the thermal energy to the engine coolant and eventually to warm up the passenger compartment. This system brings comfort and reduces fuel consumption as the same time as recovering energy and therefore, fits perfectly into the context of today's climate issues. [5] [6]

E. Burn/transform wastes

Waste processing is one of the most important priority of our time. Billions of tons of waste are collected every year and it represents a real problem because we don't know what to do with them apart from burning or bury them. Fortunately, some incineration plants were created to collect the heat and reuse it for thermal application or for electricity. For some materials such as plastics, ceramics and metals, we can simply reuse them after a process, so to avoid reproduction.[7].

F. *Educating people about energy uses*

The solution of employee training is often underestimated they can be in the form of webinars, advertising, compulsory courses, highlighted online. Indeed, this solution is easy to set up and does not require rethinking the way the plant works. In addition, this solution makes it possible to involve the employee in this fight to save energy rather than to impose a solution on him. However, this kind of training cannot ensure results. They depend heavily on the way they are presented and the workers. This solution can be implemented in addition to other solutions [8]

III. PRESENTATION OF "SHINING" EXAMPLES

A. *Laws about energy consumption for industry*

In France, industry represents 19% of energy consumption. The chemical, agri-food and steel industries are the most demanding. Support and restrictions are put in place for industries such as:

- Regulatory GHG (greenhouse gas) balance
- CO2 quotas
- Norms such as ISO 50 001
- Energy Savings Certificates, smart solution to reduce energy consumption in industry etc.

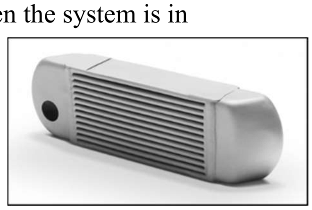
Even if it is still not enough, efforts are put in place in order to save more energy and to be cleaner for the environment, in France and all over the world. [9] [10]

B. *KERS*

Kynetic Energy Recovery System is a renewable energy system used in Formula 1 to optimize energy management during the race. In order to guarantee maximum efficiency, the technical solutions implemented in this system are state-of-the-art. A significant power gain is obtained by reusing the energy recovered during braking. Technologically advanced sports like Formula 1 invest in this kind of system every year, later they can be interesting to use on a larger scale. [11]

C. *Exhaust gas heat recovery system*

BOSAL company is one of global manufacturer of automotive and industrial equipment that has developed an exhaust gas heat recovery system. Their system is composed of a double valve and a heat exchanger core. When the system is in recovery mode, the rate of effectiveness is up to 75% and permits to heats up the engine and the passenger compartments. Thus, the compacity and the efficiency of such a system permits to reduce the fuel consumption by 4% to 10%. [12]



D. *Recovery of methane from agriculture*

Forty percent of methane, a gas which sorely contributes to global warming, is released from agricultural sources. Some solutions have been found to produce energy and to respond to farmers' needs. The methane recovery has many benefits and it doesn't only concern the energy production. [13]

IV. CONCLUSION

Through this short presentation, we hope to be able to approach this era of necessary climate change with the best possible ideas. Indeed, solutions at different scales are necessary, small as well as big changes are not to be neglected in the effort to better control our energy consumption. After this in-depth reflection, we can also ask ourselves how to produce and also store in the most optimal way, in order to have a completely redesigned chain of use.

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Flux Funnelling for Inductive Power Line Energy Harvesting

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The magnetic field around electrical power lines and current-carrying structures such structural elements, which are used as the return current path in vehicles, offer an opportunity for collecting energy to support wireless sensors. Such sensors include current flow monitors for metering and quality services as well as environmental sensors. In this work we present the development of a power supply designed for sensors in the vicinity of aircraft structural beam. An inductive transducer is designed and fabricated to meet industrial specifications based on a realistic current flow scenario, and to cover the power demand of a wireless current sensor node in duty cycled sensing and communication operation. A flux funnelling technique and an optimised coil-core transducer design are employed [1]. Numerical simulation shows that the skin effect can lead to significant current concentration at edges, providing a five-fold power benefit at such locations, even at frequencies below 1 kHz. The adoption of funnel-like core shapes allows the reduction of core mass and coil frame size, leading to significant further power density enhancement. Magnetic field simulation and coil analysis demonstrate a power density increase of ×49 by ferrite funnels, in comparison to a coreless coil. A prototype based on a 10,000 turn, 60 μm wire diameter coil and an H-shaped flux funnel is fabricated and tested. Experimental results from a spatially distributed 45 A current amplitude at 360 Hz demonstrate power density of around 40 μW/g. The total experimentally demonstrated power output is 0.34 mW, 0.54 mW and 1 mW for 360 Hz, 500 Hz and 800 Hz respectively, before rectification, meeting the sensor node average power demand of 0.22 mW.

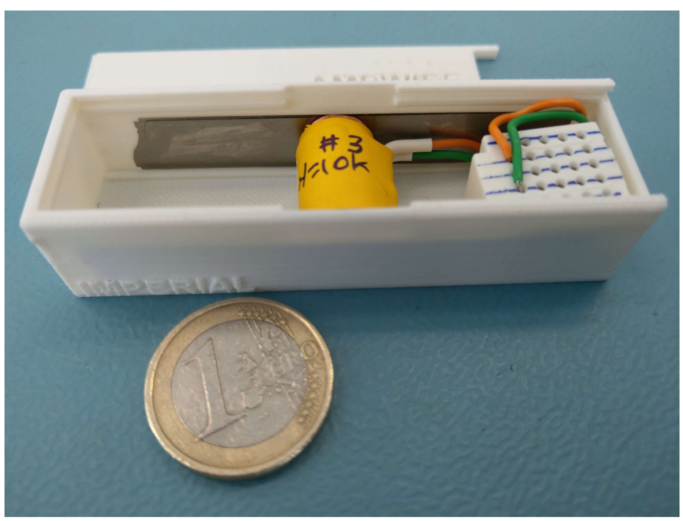

Figure 1. Picture of the coil-core transducer in its package. A sliding lid is shown at the back.

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