The Photonics IoT and Health

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Abstract: A general view of the internet-of-things (Iot) is presented, focusing on examples around the medical industries given these are increasingly playing a role that is extending beyond the traditional medical domain of a hospital or clinic and pathology service. This largely Photonics IoT is reaching into the consumer domain where diagnostics and field-based analysis is becoming more and more critical.

1. Introduction

The internet-of-things (IoT) is garnering extraordinary attention, promising to revolutionise communications as we know it today. Moving away from point-to-point data transfer, it will functionally become a massive network brain collecting and analysing in the cloud billions of sensor inputs from around the world. The potential scale and ramifications for this transformation is mind-boggling, often reflected in the conservative focus on creating an IoT that appears largely focussed on wireless (5G) and simple sensors such as thermocouples, strain and other essentially electronic components. Ignoring that the global telecommunications network backbone is largely optical fibre, given that portable or mobile transmission depends largely on wireless and much less on satellite, this may seem reasonable but it ignores many aspects that could potentially rewrite how the network is configured.

2. Latency

The finite time it takes to send signals back and forth is impacted by coding requirements for identification and hand shaking between the network and every “little” sensor, generating an increasing proportion of “junk” data other than the signal that is desired. This increases the overall delay times at all intersections in a junction as well as inflating the total volume of data compared to the current percentage dedicated to coding for current network communications. In the medical domain, 4K volume transmission of live images during surgery is critical for remote assessment, diagnostics and treatment, benefiting improved operator outcomes on a patient as well as reaching further out to remote communities. Wireless is not fast enough so light fidelity (LiFi) is increasingly used [1,2]. Photonics clearly can speed this up – for the endless bits of small streams of sensor data, however, ultimately coding and signal handshaking must be done less and less in the software and more and more in the hardware. Photonics can do this too – for example, identification in the spectral domain using wavelength division multiplexing (WDM) removes the need for data dedicated to coding. The ultimate limit, however, is of course the speed of light, something that may one day be overcome using quantum teleportation-based data transmission, itself most likely to occur on photonic chips.

3. Signal Transmission Impacts on Health

The spectre of increased health concerns creating the next tobacco-like industry, where IoT interests continue to claim zero health impacts of microwaves and longer wavelengths on the body. Given 5G will have vastly increased wireless intensities/cm^2 whilst reducing overall net system powers, these concerns are likely to be much more substantive. The fact that water absorption and its consequences on the human body are not fully understood is striking – current tests asserting 4G has no impact rest solely on raised body temperatures of less than 0.1 ^{o}C. They ignore the fact that water in the body is not the same as bulk water dominated by thermal motion but has components in the cells that rely on some polar orientation, which is temperature dependent, to allow processes such as osmosis which impacts all areas, including nutrition and brain chemistry. In fact, this water orientation is accompanied by restricting of the water into stable ordered layers with large non-linear coefficients that may even explain anomalous poling reported decades ago [3]. Together with the evolution of

LED bulk based LiFi that is demonstrating surprising effectiveness in competing with wireless and is already in place in major hospitals in the US [1,2], the IoT is increasingly turning to Photonics.

Figure 1. Example of an early custom prototype test strip analyser for malaria detection (Courtesy AusSI Systems).

4. Advanced Sensors and Devices

The development of more advanced sensors and sensor systems that are capable of moving into the field is already going to change the way the IoT operates. Imagine using a smartphone-based analyser that can auto-archive date in the field measured by a test strip, analyse this in the cloud and in real time provide feedback of growing cluster measurements to WHO operatives all over the world – the first steps to real-time mapping and tracking, and therefore vastly improved containment, of disease. Commercial systems, largely colorimetric based measuring changes in signal colour and/or fluorescence, that be either generic or customised for particular diseases and industries are becoming available with an explosion of start-ups worldwide. An example is illustrated in Figure 1. Precursor demonstrations include pH mapping of water quality around Sydney [4]. Adding spectroscopy to these technologies can further enhance capabilities – for example, identifying and monitoring fruit and vegetable bands as a way to monitor for health and ripeness [5,6] as well as potentially identify their origin and point of sale or distribution, essential underpinnings of any global based online marketplace. This will require international standards bodies to assure quality assurance has global reach – at present this does not exist, so companies will need to coordinate national bodies and link them up in the meantime. Technologies also need to deal with practical logistics – simply having a smartphone app will not cut it: for example, in the field there is variable illumination leading to varying error in data. This requires customized modules that ensure constant and controlled illumination is maintained anywhere. One of the best solutions to this is the use of endoscopes in the field [6,7], a technology that can be applied equally well in the clinic or surgery and on the farm. An image of this is shown in Figure 2.

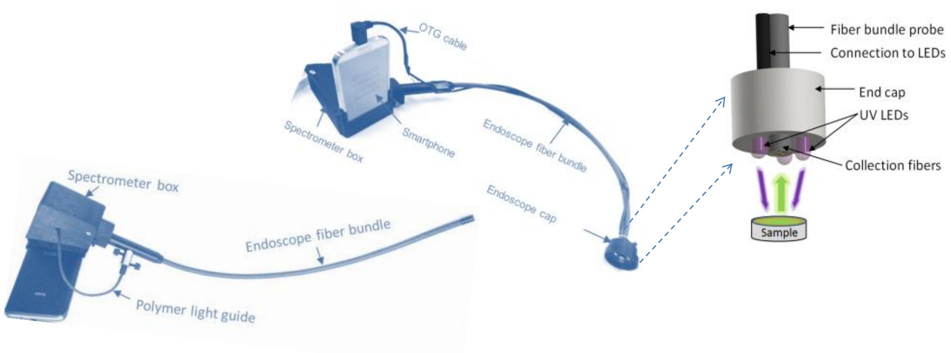

Figure 2. Examples of smartphone fibre endoscopic absorption and fluorescence measurement devices [6,7].

4. Health, Photonics IoT and the Consumer

Perhaps one of the most interesting and well-known consumer health products linked to the IoT is the wrist band heart monitor, "pioneered" arguably by Fitbit. Where did this technology spring from? In fact, it was originally a photonic solution to a very serious problem in surgery. Before the mid-eighties much patient oxygen monitoring during surgery was performed by removing blood samples and using standard pathology practices, requiring a ten-minute turnaround – given irreversible brain damage occurs beyond 5 minutes, it was not atypical of surgery patients having sustained brain damage or death. The solution had existed for some time as oxygen blood measurements go back to at least 1940 but the application as we know today came in 1972 from Japan,

exploiting the absorption differences of blood with and without oxygen at two different wavelengths [8]. In 1975 Susumu Nakajima, a surgeon, and his associates first tested the device in patients. It was finally adopted worldwide by the early eighties, with measurements taken at the finger, driven in part by strong commercialisation activity between competing parties both in Japan and in the US. Patient mortality plummeted virtually to zero ever since. The modern Fitbit has taken oximetry to a whole other level and introduced the concept of personal diagnostics and healthcare, the most visible example of consumer medicine in the field. Ironically it uses instead of red and near IR, green wavelengths following the original work of 1940, perhaps to circumvent lingering patent and intellectual property issues as well as use low cost, low energy light emitting diodes (LEDs).
Green light absorption of oxygen has also been used across many fields to detect oxygen generally – we used it to demonstrate for the first-time oxygen formation and release within nanovoids during femtosecond laser irradiation [9], a process that could in theory occur in the human body with the trend towards more and more laser surgery. In this case, we predict bubble formation may yet be an unidentified potential ailment arising from laser surgery, particularly when high intensity pulses used to cut tissue are employed, that needs future consideration – such bubbles can be transported around potentially creating future hazards.
Oximetry does not stop with Fitbit and developments continue – the use of smartphone ophthalmology is one example. Changes in oxygen level in the back of the eye can provide much earlier and more sensitive measurements of changes in the body's health. Diseases such as dementia, Alzheimer's and so on are anticipated to correlate with small changes in oxygen content as a result of other processes and material being present, opening up an entirely new area of research. Figure 3 illustrates a demonstration of the principle by an undergraduate engineering student at UTS [10].

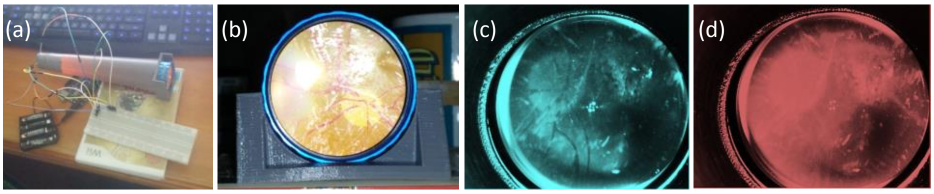

Figure 2. Undergraduate UTS student capstone project demonstration of differential scattered light from red blood capillaries in a dummy eye using green and red LED light. (a) Student built unit; (b) optical image of dummy eye; (c) green LED image and (d) red LED image. Absorption of the green is seen highlighting the vessels [10].

5. Conclusions

Quietly deceptive, the Photonics IoT is here. From fibre-to-the-home (FTTH) to photonics-in-the-field (PTTF), the Photonics IoT is revolutionizing the network and the intelligence it hopes to build with levels of sensing that are no longer simple data streams but involve complex spectral and colorimeter analysis and more – analogous to the sensory networks of organisms. Given that much of this must occur at the end interface of the IoT (the sensor end), distributed intelligence will be key. What all of this will lead to is not so clear, but we can see evidence in the medical domain already of a transformation that is driving much of the motivation behind many deep technology start-ups (many of which may never advance beyond the start-up phase as new technologies appearing faster and faster make them obsolete. They nonetheless remain historically important drivers of technology) – the notion that one can continue working on optical sensing in isolation of this disruption appears less justifiable from a funding perspective.

6. References

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