ABSTRACT
In this paper, we present information about two related software tools which solves two healthcare problems. In the first case, we have developed a Connected Health software solution, Homesafe Care, to monitor long-term conditions, through connecting a patient to his / her General Practitioner – a one-to-one relationship. Through discussion with an Indian-based charity, Varanasi Children’s Hospital, we then realized that the software could be updated to support their cause, improving children’s nutrition. However, this meant that the system had to be changed to support many-to-one relationships, where many children were being supported by one single care worker, and this information would be submitted to a central office.

CCS Concepts
Applied computing→Life & Medical Sciences→Health care information systems

Keywords
Connected Health, Diabetes, Malnutrition, Software system.

1. INTRODUCTION
Connected Health is where patient-centred care results from process-driven health care delivery undertaken by healthcare professionals, patients and/or carers who are supported by the use of technology (software and/or hardware) [1]. Through our research on Connected Health within Lero – the Irish Software Research Centre and ARCH – the Applied Research in Connected Health Technology Centre, we have recognised that software systems, when used in conjunction with modified processes, technology and people, can be used to make patient care pathways more effective [2]. Due to the first author spending a Science Foundation Ireland funded Industry Fellowship within a small Irish company, HomeSafe Care, we have been investigating how a software tool originally developed for use by a General Practice in rural Ireland can be used in rural India by an Irish-run, Indian-based charity, Varanasi Children’s Hospital.

2. BACKGROUND
There is a need for new innovations in managing health and social care. The global population has been ageing for several decades and therefore there is a growing need for healthcare. The median age of EU member states was 41.9 years on January 1, 2013 [3]. This can be attributed to increased longevity, in other words, life expectancy has risen and birth rates have fallen. Additionally, studies over the last number of years suggest that healthy life expectancy has increased, but not to the extent of total life expectancy [4]. Thus, there is a loading effect on the healthcare system, and long-term care for the elderly is a vital issue that Connected Health can help alleviate. Another driver for the need of Connected Health is the ever increasing cost in managing healthcare. One reason is increased "current service spending" [5], costs in labour and constant inefficiencies of healthcare organisations. Connected Health can aid in decreasing the expenditure of healthcare by making the process more effective and convenient.

There is also a global shortage of qualified health professionals. In 2011, the shortage of healthcare workers stood at 7.2 million globally [6]. This figure is set to reach almost 13 million by 2035. The main reasons for this include: an ageing health workforce, a lack of young people entering the profession and the growing demand of people around the world with risk of noncommunicable disease. In our geographical area of interest, rural Ireland, this is indeed true, and General Practitioners are becoming more and more difficult to recruit [7].

Consequently, Connected Health innovations are important – where health workers can be supported by technology and new healthcare processes. The benefits of Connected Health has been has been identified in many studies including [8] who discussed smartphone applications for melanoma detection, [9] who conducted research into telehealth for blood pressure reduction, [10] who evaluated connected health in primary care, and [11] who developed a decision support system for diabetes.

Connected Health solutions which are emerging are normally the result of convergence of medical devices, diagnostics and sensors paired with information and communication technologies. These devices are utilised by clinicians, patients and home-care
specialists alike. The global medical device market was reported at $296 billion in 2010 [12]. The key growth areas are varied depending on the sub-segment, but it is expected that technology intensive segments will grow strongest.

3. CH SOLUTION: IRELAND

Homesafe Care is a small company located in rural Ireland. It is over 50 miles from the nearest city, and had intermittent access to broadband, which is not uncommon in rural Ireland [13]. The local population includes a large number of older people, many of whose families have migrated away from home, either within or outside of Ireland. Through its parent’s company involvement in security systems, the owners saw a gap in the market for home care support for older people, and have developed a number of services through which people can feel more secure and cared for in their homes. For example, they have developed activity monitors which can detect inactivity – if an older person has not risen by a certain time during the morning, and alarm can be activated. Touch mats can also be used to detect and send alerts if a person has fallen when getting out of bed.

As part of this offering, Homesafe Care have developed a software-based monitoring system. This system, which is text-based on a mobile phone, can be used by patients and the General Practice, which normally constitutes a General Practitioner and Practice Nurse, to monitor physiological measurements such as blood pressure, blood sugar levels, weight and temperature. As an example, a user can text has noted a blood pressure reading of 70/120 BPM. The user sends a text to the server using the following format:

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BP – 70-120
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The data sent is compared against an expected reading which has been set up for the particular patient. The identification number of the patient is his/her mobile phone number. If the expected reading is abnormal in comparison to the expected reading, an alert can then be sent to that user. The alert informs them that their reading is much higher or lower than expected and they should follow the suggested preventative advice, for example to seek medical advice. These alerts can also be used to ensure that data is collected. An alert can be sent to individual users to remind them that their results are due soon or they can also be sent if a user has not sent their results at the time expected.

In addition, the General Practitioner can monitor each patient’s readings on a regular basis, and also receives alerts if someone’s readings go out of control. In this case, if the patient has not contacted the practice following their personal alert, the Nurse can make a phone call to the patient to discuss their current healthcare regime, and may advise the patient to call to the surgery. The implementation of this simple Connected Health solution has had the effect of introducing technology which can be used by the patient and the General Practice, through modifying their healthcare process. The patient no longer has to attend the practice on a regular basis, for example, weekly, and yet the Doctor and Nurse can effectively monitor the patient. The consequence of this is that the patient can be monitored without having to leave their own home, while the queues and load for the medics in this rural practice has been alleviated.

A further benefit of this type of system is that the Health care professional can log in to the server and view their patient’s record in a simple fashion, for example, a line graph of that patients blood pressure over a period of time. Therefore, a trend is created. The data is quick and easy to access. Medical interventions can be made in a convenient fashion. The relevant Healthcare professional can advise on the healthy management of conditions, such as high blood pressure, without physically meeting the individual. This tracking of data is what enables the text alerts to be established. The local pharmacist may also become involved if relevant.

4. CH SOLUTION: INDIA

Through involvement with a local Irish charity, the company recognized how its system could be potentially used in India to help alleviate the issue of child malnourishment and subsequently infant mortality. India accounts for 27% of all newborn deaths globally. This is the result of poor access to healthcare particularly in the poor, rural areas of the country. The Indian government is currently running an initiative to balance the availability of affordable healthcare across the country. India's healthcare IT market is expected to reach $1.45 billion by 2018. The medical device market was valued at $1 billion in 2010 and has over 700 active companies.

The high infant mortality rate in India is a result of several factors. These include a lack of qualified birth attendants, malnutrition and gaps in the healthcare system. Varanasi Children’s Hospital is a charity in India who have implemented a program for malnourished children. To identify children, carers check the child’s weight, height and mid-upper arm circumference (MUAC). Prior to system implementation, identification information along with the measurements were recorded by hand. Paperwork was sent to the central office, and data entered to Excel. If measures indicate that the child requires nutritional assistance, Varanasi Children’s Hospital instigate a specialised food programme, which is usually undertaken for two months and is expected to result in a weight gain of 30 grams per day. Children are re-muasured every two weeks while on the programme, and this updated information was also recorded on paper before being entered to the Excel system. The paper-based system has been cumbersome, time-consuming and difficult to manage. In particular, as data was often input too late into the system to make any, real-time decisions about a child’s progress could not be taken. Typically, children will spend an average of 8 weeks on the programme, some may finish after 4 weeks, and some stay on the programme as long as 12 weeks.

In collecting requirements within the charity, and recognized that the existing Homesafe Care system could be modified to support the nutrition programme. We recognized the parallel between the diabetic process and the nutrition process – in particular that monitoring had to be undertaken, and that ‘out of control’ trends were important in both cases. From a design perspective, the original system has been written with a one-to-one relationship in mind – a single patient submits data to one General Practitioner. In this case, the identifier was the patient’s mobile phone number. For the Varanasi Children’s Hospital system, this relationship needed to change to a many-to-one relationship – data from many children would now be entered by a single carer, and submitted to one central office. The system allows a single person to collect similar datasets of multiple groups of people and send the data to a central point. The modification required was to change to a composite identifier consisting of a combination of the carer’s and child’s unique identifier.

Additionally, the company needed to understand the cheapest and most convenient method by which the data could be transmitted. In rural Ireland, given that there is often limited and sporadic internet access, the solution is to text data via mobile phone. In
rural India, internet access is relatively stable, and cheaper than using a mobile phone. Therefore, the Homesafe Care system was modified to be available via internet. Entering data in this manner means that once a child is registered with Varanasi Children’s Hospital, their information is immediately available to the central office. The effectiveness of the program can be monitored on a regular basis, and children who are not progressing as expected can have their food source changed early on in the program, and interventions by the central office can happen quickly. This is important as the system is of most benefit in rural areas of India, many of which have poor health infrastructure. Therefore, infant mortality rates are affected positively in the long-term.

5. SOFTWARE SUPPORTING NUTRITION PROGRAM

The Varanasi Children’s Hospital system is a web-based system with data stored on a secure system in Ireland. Security levels include Administrator for Varanasi Children’s Hospital central office, Doctor who can access in the case of medical issues, Nurse who monitors the nutrition program centrally, and Carer, who adds children to the system in the rural villages. To set up the system, the administrator inputs the physiological measures to be taken. In the case of the Indian nutrition program, MUAC, weight, height and age are collected. These are used to determine whether a child is malnourished. When a child joins the program their identification information and a photograph is added to the system, and they are given an Identifier. They are measured every two weeks and the data is added to the system. Figure 1 shows relevant screen shots from the system.

As shown in Figure 2, by using the system reporting, a centrally-based Nurse can track lower weight gains and can determine changes to a child’s programme. For example, Jerry has been on the program 63 days, has had 50 of a proposed 60 packets of food, and he has gained 600g. His MUAC gain per packet is 0.14. However, it is expected that a child should gain 30g per packet. Liam is the only child in this sample to have had this weight gain, with Ita and Paul tending towards the requirement. But, Pat and Jerry require some intervention. This may be a greater number of food packets, or it may be some further health intervention, for example, it is possible that a child may have an underlying infection, which is preventing weight gain.

6. BENEFITS OF SYSTEM

This system is a low-cost solution which can effectively support the nutrition program. Being web-based, it is dependent on the availability of internet access where it is being used, but, within the area in which the system has been implemented in India, the access is sufficient. In a very short time (it was implemented in January 2016), the system has demonstrated that the availability of data is supporting decisions about individual children’s nutrition and allowing real-time changes to be made to the program. This is expected to benefit children’s progress and health.

Additionally, Varanasi Children’s Hospital will be enabled to determine whether the standard food programme that they are implementing is indeed the correct one for the general population. They will be able to track progress, and the data can be used to demonstrate their success to funders.

In the field, the system is efficient, as carers can enter data onto mobile devices connected to the internet. They do not have to submit duplicate paperwork to the central office, and therefore they can focus more on locating and identifying children that was previously the case.

<table>
<thead>
<tr>
<th>Child Username</th>
<th>Name</th>
<th>Days</th>
<th>Packets (Less last)</th>
<th>Weight Gain (g)</th>
<th>Weight Gain per day (g)</th>
<th>Weight Gain per packet (g)</th>
<th>MUAC Gain (mm)</th>
<th>MUAC Gain per day (mm)</th>
<th>MUAC Gain per packet (mm)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEC-15-02</td>
<td>Ita</td>
<td>41</td>
<td>30 (20)</td>
<td>500</td>
<td>12</td>
<td>25</td>
<td>5.00</td>
<td>0.12</td>
<td>0.25</td>
<td>Active</td>
</tr>
<tr>
<td>OCT-15-32</td>
<td>Pat</td>
<td>66</td>
<td>70 (60)</td>
<td>720</td>
<td>11</td>
<td>12</td>
<td>8.00</td>
<td>0.12</td>
<td>0.13</td>
<td>Active</td>
</tr>
<tr>
<td>OCT-15-47</td>
<td>Jerry</td>
<td>63</td>
<td>60 (50)</td>
<td>600</td>
<td>10</td>
<td>12</td>
<td>7.00</td>
<td>0.11</td>
<td>0.14</td>
<td>Active</td>
</tr>
<tr>
<td>NOV-15-08</td>
<td>Paul</td>
<td>88</td>
<td>60 (50)</td>
<td>1050</td>
<td>12</td>
<td>21</td>
<td>8.00</td>
<td>0.09</td>
<td>0.16</td>
<td>Active</td>
</tr>
<tr>
<td>NOV-15-07</td>
<td>Liam</td>
<td>47</td>
<td>50 (40)</td>
<td>1250</td>
<td>27</td>
<td>31</td>
<td>2.00</td>
<td>0.04</td>
<td>0.05</td>
<td>Active</td>
</tr>
</tbody>
</table>

Figure 1. (a) Top level menu (b) Adding child’s details, including photograph (c) Adding information for a child, including number of food packets for that child (d) Information about existing patient including photograph

Figure 2. Output from system: children on program over 40 days
7. CONNECTED HEALTH REGULATION AND LEGISLATION

Regulation of Medical Devices in Ireland is based on EU legislation, and in the EU many Connected Health solutions can be considered as Medical Devices as they diagnose, prevent, monitor, treat or alleviate disease. Relevant laws are described in the Medical Device directive 93/42/EEC and S.I 252/1994 [14], and whether a technology is a Medical Device or not is dependent on product use as assigned by the manufacturer. The stated use must also be supported by data. The classification is presented to the National Standards Association of Ireland (NSAI).

While there are a number of regulating agencies in India [15], the Department of Science and Technology (DST) and the Ministry of Health and Family Welfare have developed an Indian MDs regulatory framework which was submitted to government in June 2015. This proposes to regulate and monitor design, testing, evaluation, manufacture, packaging, labelling, import, sale, usage and disposal of MDs. Although an official definition of MDs and a risk classification scheme was released in 2009, the MD industry is unregulated in practice [16]. We recognize that this lack of regulation is a threat to the Indian population.

Therefore, as a company, if Healthsafe Care intend on expanding into India and other developing countries, they will need to undertake to have it ratified within those countries. This will add to the cost of implementation, but we have already seen the positive effects of the product, and would expect that quality ratification will open the doors to a global market expansion.

8. CONCLUSION

While initially, the company set about developing the software for Varanasi Children’s Hospital as a philanthropic exercise, they have now seen that the developing economies of the world pose opportunity for technology firms in the CH industry. There is a need in these nations for low-cost digital health technologies. For the purpose of this paper, infant mortality in India is an example of how this type of product can benefit developing economies.

Connected Health solutions need to involve people, processes and technology and is causing a change in the way in which healthcare is delivered. In this paper, we discussed how technology developed by a company, Homesafe Care based in rural Ireland to support diabetes monitoring for older people and General Practitioners was subsequently modified for use in rural India to support nutritional programs for children and healthcare workers within a charity, Varanasi Children’s Hospital. It was not only important for the company to involve the people for whom they were developing the product, but also to understand the healthcare process they were supporting. Interestingly, we have noticed that the particular condition (diabetes / nutrition) were not fundamental to developing the solution – once we identified parallels between the requirements, we were able to design and implement a workable and efficient technical solution.

9. ACKNOWLEDGMENTS

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10. REFERENCES


