Digital Epidemiology and Beyond

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CCS CONCEPTS

• **Software and its engineering** → *Software system structures*; • **Networks** → *Network architectures*;

Respiratory and other close-contact infectious diseases, such as tuberculosis (TB), measles and pneumonia, are major killers in much of the developing world. Mathematical models are essential for understanding how these diseases spread, and for understanding how best to control them. Although central to modelling, few quantitative real-world data on relevant contact patterns are available. Capturing human interactions provides an empirical, quantitative measurement of social interaction patterns to inform mathematical models of the spread of close-contact diseases. We have developed various systems to collect human contact/mobility data. The recent emergence of wireless technology (e.g. mobile phones and sensors) makes it possible to collect real-world data on human proximity. Capturing human interactions with wireless sensors will allow us to understand complex patterns of human activities. For example, in one experiment people will carry tiny wireless sensors that record dynamic information about other devices nearby.

A post-facto analysis of this data will yield valuable insight into how communities are formed, how much time people spend together, and how frequently they meet; such data exhibits complex network-like structures that are similar to social and biological networks. The analysis can also identify specific individuals who act as coalescing hubs of the network at different points in space and time, and who influence data flow. By neutralising these hubs, we can potentially prevent the spread of viruses and bacteria. Various modelling work has investigated the use of human proximity networks to identify the symptoms of epidemics, which provides a way to treat individuals who would otherwise be buried in the infectious population.

One of our remote sensing platforms uses Radio Frequency Identification Tags (RFID) to measure the proximity of people. The recorded interactions are stored in Raspberry Pi (small, inexpensive computer board) that forms a network via WiFi. All equipment is battery powered and can be deployed anywhere without power supply or Internet access. This is important because the power supply in rural villages can be limited or absent, and it is challenging to measure human interactions without standalone settings of sensors and networks. A set of Raspberry Pi computers forms a decentralised network based on a Delay Tolerant Networks (DTN) called RasPiNET [1], where each Raspberry Pi node equips WiFi communication capability together with a battery pack. Sensing devices such as RFID tags or mobile phones can store the sensed data to the nearby RasPiNET node, and the DTN can deliver the collected data to the data processing computer. Furthermore, the satellite devices can be integrated to the RasPiNET node. RasPiNET can be deployed in remote regions or developing countries. Using mobile phones is not realistic without coverage of cellular networks.

The use of sensors has key advantages over other methods of collecting contact data (such as diaries and interviews), because they can be programmed to gather proximity data automatically, allowing detailed longitudinal studies with no re-call bias, no barriers due to problems of literacy or understanding, and minimal disruption to the participants. This approach therefore offers a unique opportunity to collect information on social contact patterns that would greatly advance our understanding of relevant patterns of disease spread. Raspberry Pi can be equipped with other sensors such as carbon dioxide or air-quality sensors; together with the human contact information, the flow of air can be modelled using the collected data. We name our approach **Digital Epidemiology**, with the goal of understanding infectious disease spread using new technologies, large amount of real-world data, and studying the dynamicity of human contact networks.

Our remote sensing platform and the explored methods in Digital Epidemiology can be used in many different environments. For example, we plan to establish a smart greenhouse monitoring solution using image recognition to readily pick up pest and disease infestations and alert farmers. The image data is captured by the camera in Raspberry Pi, and the resulting plant images will also be used to advice on proper feeding patterns to ensure leaves remain green and healthy. The collected data will be aggregated at the gateway-node in the greenhouse, where data can be partially analysed and sent to the main station by wireless communication. At the main station, the aggregated data will be analysed using advanced data analysing techniques such as machine learning. The whole operation will be integrated as a pest/disease alert system to proactively communicate with farmers. The proposed technology for smart monitoring of greenhouses will greatly benefit small-holder farmers, with wide-reaching implications for quality of farming.

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