Chapter 4.14
Ubiquitous Computing for Microbial Forensics and Bioterrorism

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ABSTRACT

Microorganisms are ubiquitous in their presence. They are present in air, soil, water, and all kinds of living creatures. Varieties of microbes have been linked to diseases of humans, animals, and plants. Advances in molecular biology, electronics, nanotechnology, computer sciences, and information technology have made it possible to hybridize these to create ubiquitous devices and biosensors that would indicate presence of microbial agents in water, foods, air, hospitals, animal farms, and other environments. Analyses of microbial genomes and phylogenies have become increasingly important in the tracking and investigation of events leading to spread of microbial diseases and biocrimes. The capability of microorganisms to communicate with similar as well as different microorganisms, the ability to react to the environmental changes, and most of all, the intelligence to manage themselves without the need for supervision during deployment and operation; makes them attractive agents for use in Biosensors. Biosensors such as genetically engineered bacteria have been proven useful. It appears possible to develop biosensors that could detect the presence of biocrime/bioterror agents in diverse environments. Ubiquitous computing technology has the potential to develop integrated small devices which could detect bioterrorism agents. Similarly, pervasive computing could be a tool to monitor the microbial pollution in water, milk, and other edible commodities. Microbial forensics has become an important field for re-

search and development due to increased threats of biocrimes. Microbial forensics requires utilization of diverse data that are acquired through standard processes in distributed locations. Technologies for data production are evolving rapidly, especially with respect to instrumentation and techniques that produce high-resolution data about the molecular constituents of living cells (DNA, mRNA, proteins, and metabolites) that are used as microbial signatures/fingerprints. Both bioinformatics and computational biology have grown over the last 20 years, and diverse database systems and analytical tools have been developed and deployed. Some public domain resources, such as GenBank, have become very important resources of research on a global scale. Effective responses to natural, accidental, or intentional outbreaks of infectious diseases in humans, livestock, and agricultural crops, will require that the information be easily accessed in real-time or near real-time. Flexible, decentralized, modular information system architectures, able to adapt to evolving requirements and available on the Internet, are needed.

INTRODUCTION

Dimensions of microbiological research are changing rapidly, largely due to emergence and re-emergence of globally important human, animal and plant diseases, biocrimes and threats of bioterrorism. Powerful new technologies, including novel imaging techniques, genomics, proteomics, nanotechnology, rapid DNA sequencing, and massive computational capabilities have converged to make it possible for scientists to develop pervasive devices that could detect dangerous microbial pathogens and potential bioterror agents quickly. It is a challenge to maintain the microbial quality of our plant and animal origin foods and water in a rapidly changing crowded and complex world. Bioterrorism and the distinct possibility that anthrax (Davis & Johnson, 2000) or other highly pathogenic infectious agent could be used as a

bioweapon against people, animals and crops have frightened people world-wide. Bioterrorism can be defined as the "unlawful use of viruses, bacteria, fungi, toxins or other pathogenic materials against a government, the civilian population, livestock, crops or any segment thereof, in furtherance of political, social and/or economic objectives." An apparent increase in the emergence of novel infectious diseases, including avian influenza, severe acquired respiratory syndrome (SARS), and others, has also brought microorganisms into sharp focus.

Microbial forensics is a relatively new scientific discipline dedicated to analyze microbiological evidence from a crime for attribution purposes (McEwen et al., 2006). The majority of microbial infections in humans, animals and plants occur naturally, without malicious intent or criminal negligence. However, recent reports of bioterrorism indicate that microorganisms and their products could be deliberately released to cause human deaths and economic losses due to loss of animals and crops. For example, in 1997 some unknown persons illegally introduced rabbit haemorrhagic disease virus into New Zealand, apparently to control the large wild rabbit population that was posing a problem for farmers (Thompson & Clark, 1997). Similarly, in 2001, *Bacillus anthracis* spores were deliberately distributed through the postal system of USA in the form of 'anthrax letters', resulting in at least 22 human cases of anthrax, five of them fatal (http://www.asm.org/Academy/index.asp?bid=17994). These are some of the examples of intentional release of infectious agents; however, illegal activity may also lead to unintentional exposure. For example, in 2004, Thai eagles infected with highly pathogenic H5N1 strain of avian influenza were smuggled into Belgium (Van Borm et al., 2005). One of the unique features of bioterror and biocrime incidents such as those mentioned earlier is the requirement for attribution of responsibility. Attribution is defined as 'the information obtained regarding the identification

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