Integration of Advanced Forensics and Medical Information with Network Visualization Techniques for Rapid Disaster Response

By

Sonya A. H. McMullen (USA)
Dr. Margaret Varga (UK)
Cristin M. Hall (USA)

November 2007

1.0. INTRODUCTION

The Global War on Terrorism as well as the increasing instances of identity theft has brought the issue of personal identification into the forefront. Personal identification is becoming critical for a number of reasons, to include but not limited to:

- Financial Transaction Security
- Border Security and Immigration
- Airline/Airport Security
- Benefits Fraud
- Identification of Terror Victims
- Rapid Medical Response
- General Law Enforcement
- Proper and Legal Distribution of Pharmaceuticals

In the case of terror acts, airline crashes, or natural disasters such as Hurricane Katrina that result in mass injuries and death, the task of treating and identifying victims is a challenging one. Treating injured victims is further complicated when identification cannot be immediately determined and if the victim has complicating medical conditions or allergies. Further, the identification of the deceased is complicated by burns and dismemberment. Forensic techniques have advanced significantly in the latter half of the 20th century. Techniques to identify the victims of crime and natural disasters is more evolved particularly with advancing techniques in data storage and sharing with the use of computers and the internet.

The focus of this initiative is two-fold: (1) provide first responders and Emergency Room personnel with accurate, up-to-date, quick references medical data to properly treat victims; and (2) provide an accurate, easily accessible source for fingerprints, dental records, and DNA to identify victims. One initiative to provide such information involves a three-phase technological solution. The contribution of the NATO IST-59/RTG25 Visualising Network Information group is in two critical aspects of the project: (1) employ existing network visualization techniques to the hereditary risk factors and medical history visualization tool to assist in rapid diagnosis; and (2) integrate this initiative with the developing infectious disease visualization projects to further support Homeland Security. The potential benefits of a fully implemented solution would have far-reaching impacts such as: (1) reduction of health care costs; (2) reduced medical and pharmaceutical errors; (3) impede the proliferation of illegally obtained prescription medications; and (4) assist in law enforcement.

2.0. GENERAL CONCEPT

This project involves two distinct aspects: (1) medical treatment; and (2) forensic identification. The solutions to both problems involve similar technologies although they can be implemented separately. The general concept is to develop a software system similar in nature to Adobe Acrobat such that separate read-only and write-capable software exists and use Commercial-Off-The-Shelf (COTS) technology, specifically USB flash stick technology, to create a personal and national health records system to be used for emergency situations. Each individual would carry critical medical and dental records on their person, contained on a flash stick. A secure back-up system of main frames similar to the U.S. SIPRnet system could be implemented for use to track infectious diseases. Hence, the project has three implementation phases as described below.

2.1. Phase I – Forensic Comparison Personal Data Stick

The forensic comparison personal data stick would contain three critical items of data:

(1) Fingerprint Card
(2) Dental Record for Identification
(3) Nuclear and Mitochondrial DNA Profiles

The intent is for the flash stick to remain stored in a safe location, not carried by the owner, and easily accessible to next of kin in order to assist in the identification of remains as the result of terrorist acts, natural disasters, accidents, and so on. This data would only be used for this person and would remain private. Data contained on the flash stick would be encrypted to prevent unauthorized access. The only data requiring updates are dental records and fingerprint data in the event of severe injury to the hands or arms.

2.2. Phase II – Rapid Access to Medical and Emergency Data (RAMED)

This flash stick would contain encrypted data to assist first responders and Emergency Room personnel in the treatment of the severely injured particularly in instances when by the nature of their injuries cannot respond. This data storage device would also be of assistance for patients who are deaf or suffer from dementia. Data contained on the flash stick would include:

- Personal Consent to View Medical Data in Accordance with the Health Insurance Portability and Accountability Act (HIPAA)
- Personal and Family Medical History and Risk Factor Visualization
- Drug and Other Allergies
- Medical Condition Alerts
- Critical Medical History
- Vaccination History
- Scans of Vital Pathology Information – Malignant Tumors, etc.
- Critical Test Results – Blood Pressure, Pulse Rate, Cholesterol, Blood Sugar, etc.
- Current Prescriptions and Dosages
- Health Insurance Information
- Living Will and Do Not Resuscitate (DNR) Instructions

When an individual goes to a doctor's office or to an Emergency Room (ER), the medical staff could access certain portions of the data contained on the flash stick. The first screen that appears would show critical health conditions such as diabetes and drug allergies. Another screen would show current medications and dosages. Additional screens would provide a network visualization of hereditary risk factors. Any treatments or prescriptions are updated by the hospital staff. This data would be stored in a series of encrypted files. The goal is multi-fold:

- Assist individuals that have verbal communication deficiencies
- Assist elderly, mentally retarded, and minor patients provide accurate information to medical staff
- Save significant amounts of time to continually report family history, etc. when going to a new medical treatment facility

- Prevent error and reduce malpractice claims (resulting in future reduction of health care costs)
- Standardize medical record information for rapid interpretation
- Prevent medication interaction errors and reduce illegal prescription drug trafficking as pharmacists would read prescriptions from the flash stick

2.3. Phase III – Rapid Access to Medical and Emergency Data (RAMED) National Health Care Database

Secure national network of patient records for access by hospitals, Center for Disease Control, etc. for the following purposes:

- Provide a secure back-up of patient health care documents to aid in emergency treatment
- Infectious disease tracking and control
- Identification of victims
- Limited medical research, as applicable

The system could employ a secure network similar in design to the U.S. SIPRNET (Secret Internet Protocol Router Network) system with additional encryption and various levels of access to ensure patient privacy.

3.0. NETWORK VISUALIZATION PROJECT COMPONENTS

As health care costs rise, time is of critical importance for providers. In addition, a savings of time may offer the opportunity for providers to treat more patients over the course of a given year. This may have the potential to reduce health care costs and provide opportunities for care to more individuals. The problem of medical information analysis is similar to the problems previously addressed by the NATO Research and Technology Group for Network Visualisation in that medical diagnosis involves a potentially large data set with complex relationships. Moenssens, Starrs, Henderson, and Inbau (1995) report “studies have shown that people retain 87% of the information presented to them visually but only 10% of what they hear” (p. 105). Abraham and Hellar (2005) developed “a research strategy for building visualizations of non-geometric data that are massive in size and dimensionality to help decision makers to achieve data comprehension and eventually to improve problem-solving performance” (p. 1). Although Abraham and Hellar (2005) focused on Naval and Marine applications, the fundamental concepts apply to medical diagnosis and treatment applications. Figure 3.0.1 is an example of a complex decision-making visualization tool. The decision characteristics identified by Abraham and Hellar (2005) may be applied to the medical diagnosis visualization:

- *There are large amounts of non-spatial data with complicated relationships;*
- *The decision-making environment is flexible because many things are negotiable;*
- *Numerical computations are very necessary;*
- *The final decisions are made by human beings, not by computers;*
- *Most decisions have to be made under time pressure; and*
- *Involves high-risk decisions and high workload* (p. 1).

Hence, a visualization of data may be useful to the decision maker and provide a helpful tool to use in the presentation of data to the patient. In addition, visualizations may serve to assist in the treatment of infectious diseases as well.

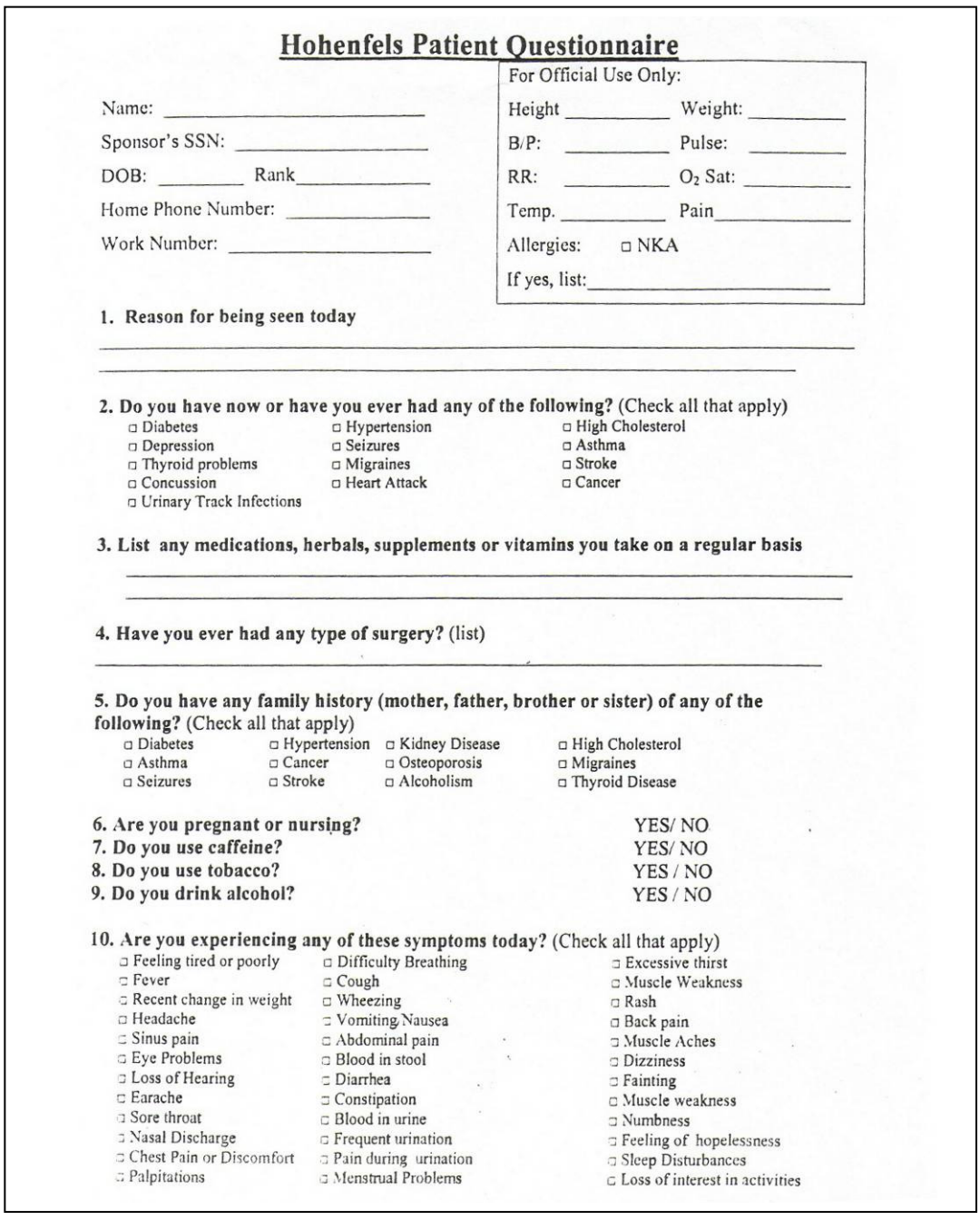
Figure 3.0.1. Battlespace Situational Assessment Visualization Tool (Hall, 2007).

3.1. Visualization of Hereditary Risk Factor and Other Data Required to Form a Diagnosis

As part of a routine medical examination or visit to a health care provider, patients are asked to fill out one or more forms related to their current and past medical history as well as the conditions that impact other family members. Depending on the patients' circumstances, this can be a lengthy process. Figure 3.1.1 shows an example of a basic questionnaire for a patient to complete prior to a periodic visit to a health care provider. In addition, multiple medical conditions experienced by several related family members can be difficult to recall and report particularly if the patient completing the form is ill or injured. According to the U.S. Surgeon General, Dr. Richard Carmona, "the medical history is one of the most powerful tools we have to assess risk in patients – and knowing your family [health] history can literally save your life, yet it is often underutilized" (Darves, 2004, p. 1). The American Medical Association (AMA) in a brochure titled "Family Medical History in Disease Prevention" identifies some of the ways in which data regarding family medical history can improve patient care:

- *Early identification of families with increased risk for chronic diseases such as heart disease, diabetes, and certain cancers can often improve, delay, or even prevent adverse health outcomes to individual members.*
- *Risk assessment is unique for each disease and requires periodic re-evaluation based on changes in medical history and lifestyle choices.*
- *Personalized prevention programs for treatable disorders should be based on individual risk assessment.*

- *Examples of prevention and treatment options include increased surveillance, lifestyle changes, prophylactic medical measures, surgical intervention, or genetic testing.*
- *Encouraging patients to generate and update their family history promotes a sense of responsibility and partnership in health care management* (AMA, 2004, p. 1).



Hohenfels Patient Questionnaire

Name: _____
Sponsor's SSN: _____
DOB: _____ Rank_____
Home Phone Number: _____
Work Number: _____

For Official Use Only:
Height _____ Weight: _____
B/P: _____ Pulse: _____
RR: _____ O_2 Sat: _____
Temp. _____ Pain_____
Allergies: □ NKA
If yes, list:_____

1. Reason for being seen today

_____
_____

2. Do you have now or have you ever had any of the following? (Check all that apply)

□ Diabetes □ Hypertension □ High Cholesterol
□ Depression □ Seizures □ Asthma
□ Thyroid problems □ Migraines □ Stroke
□ Concussion □ Heart Attack □ Cancer
□ Urinary Track Infections

3. List any medications, herbals, supplements or vitamins you take on a regular basis

_____
_____

4. Have you ever had any type of surgery? (list)

_____

5. Do you have any family history (mother, father, brother or sister) of any of the following? (Check all that apply)

□ Diabetes □ Hypertension □ Kidney Disease □ High Cholesterol
□ Asthma □ Cancer □ Osteoporosis □ Migraines
□ Seizures □ Stroke □ Alcoholism □ Thyroid Disease

6. Are you pregnant or nursing? YES/ NO
7. Do you use caffeine? YES/ NO
8. Do you use tobacco? YES / NO
9. Do you drink alcohol? YES / NO

10. Are you experiencing any of these symptoms today? (Check all that apply)

□ Feeling tired or poorly □ Difficulty Breathing □ Excessive thirst
□ Fever □ Cough □ Muscle Weakness
□ Recent change in weight □ Wheezing □ Rash
□ Headache □ Vomiting/Nausea □ Back pain
□ Sinus pain □ Abdominal pain □ Muscle Aches
□ Eye Problems □ Blood in stool □ Dizziness
□ Loss of Hearing □ Diarrhea □ Fainting
□ Earache □ Constipation □ Muscle weakness
□ Sore throat □ Blood in urine □ Numbness
□ Nasal Discharge □ Frequent urination □ Feeling of hopelessness
□ Chest Pain or Discomfort □ Pain during urination □ Sleep Disturbances
□ Palpitations □ Menstrual Problems □ Loss of interest in activities

Figure 3.1.1. Example of a Basic Health Care Questionnaire (Hohenfels Army Health Clinic, 2007).

To assist patients in providing family medical history data to health care providers, the AMA (2004) has developed the "Family Medical History Pocket Information Card" that can be created by the patient. An example of this information card is shown in figure 3.1.2. below. Note that the visualization relies on simple shapes indicating family members (nodes) and the links represent relationships to the patient. However, the medical conditions impacting each member are denoted by text near the each node. Although this basic visualization provides the basic information to the health care provider, because it is generated by the patient, the format will not be standardized among all patients seen by the provider and therefore may take time to interpret. Using the techniques developed by the members of the NATO Network Visualization Group, standardized family history visualization could be automatically generated when patients enter family history information into a computer database which could then be stored on the RAMED flash stick and in the patient's medical file at the provider's office. The resulting visualization would use a known protocol and hence could be rapidly interpreted by the health care provider.

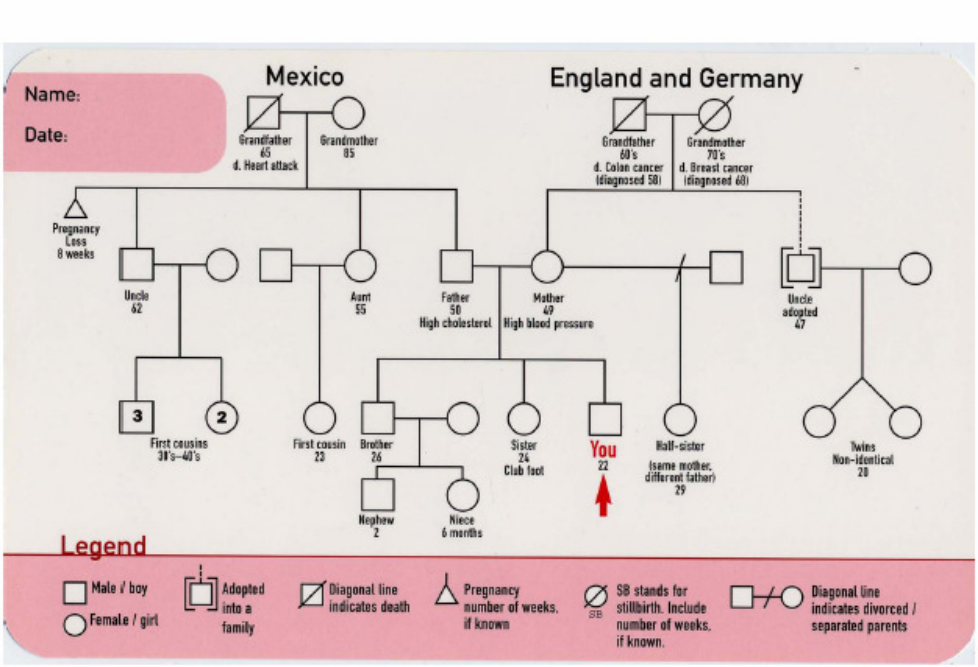


Figure 3.1.2. Example AMA Family Medical History Pocket Information Card (2004, p. 9).

One potential visualization protocol to implement for this problem is to use a system similar to the AMA presented concept in that family member relationships are clearly defined. In this visualization solution, family member relationships would be indicated by spatial orientation to the patient within the visualization field. Nodes would represent medical conditions of interest and links would represent shared conditions or risk factors. Information gathered about the patient would begin with a questionnaire regarding family members and relationships. An example is shown in Table 3.1.1. Table 3.1.2 shows an example family medical history data matrix for a fictional patient. From this data, visualization would be generated in a format such that all icons, links, etc. would be in a standard format easily interpreted by the health care provider.

Table 3.1.1. Family Members and Relationships

Family Member	Race/Country of Descent	Relationship (i.e. blood/half or step/adopted)	Age Died	Children	
				Sex	Age Died
Maternal Grandmother	Caucasian/Germany	Blood	79	Female (Twin)	53
				Male (Twin)	N/A
				Female	N/A
Maternal Grandfather	Caucasian/Germany	Blood	N/A	Female (Twin)	53
				Male (Twin)	N/A
				Female	N/A
Paternal Grandmother	Caucasian/Ireland	Blood	77	Male	N/A
				Female	N/A
				Male	N/A
Paternal Grandfather	Caucasian/England	Blood	81	Male	N/A
				Female	N/A
				Male	N/A
Mother	Caucasian	Blood	53	Female	N/A
				Female	N/A
Father	Caucasian	Blood	N/A	Female	N/A
				Female	N/A
Children	N/A	N/A	N/A	N/A	N/A
Aunt (as applicable)					
Uncle (as applicable)					

Note: Software would generate additional fields for data related to children of aunts and uncles as applicable

Table 3.1.1. Example Patient Family History Matrix

Medical Condition		Self	Mother	Father	Sibling(s)	Child(ren)	Maternal		Paternal		Aunt(s)	Uncle(s)
							Grandmother	Grandfather	Grandmother	Grandfather		
Arthritis			X				X	X	X		X	X
Asthma (Chronic Respiratory Disease)					X							
Birth Defects												
Dementia									X			
Depression												
Diabetes												X
Cancer	Breast						X					
	Colon											
	Endomtrial											
	Ovarian								X			
	Prostate							X				
	Thyroid											
	Other		X									
Hearing Loss		X						X		X		
Heart Disease												
High Cholesterol									X		X	X
Hypertension (High Blood Pressure)									X			
Infertility												X
Mental Retardation												
Multiple Miscarriages												
Obesity							X				X	
Osteoporosis			X				X		X			
Physical Abnormalities												
Stroke									X			
Vision Loss												

3.2. Infectious Disease Management

Infectious diseases have caused havoc in the health systems world-wide, for example, the recent episode of the Severe Acute Respiratory Syndrome (SARS). SARS was a newly recognised severe febrile respiratory illness caused by a previously unknown corona virus - SARS-associated corona virus (SARS-CoV). SARS emerged in the southern Chinese province of Guangdong in November 2002, but the worldwide epidemic was triggered in late February 2003 when an ill physician from Guangdong infected several other guests at a hotel in Hong Kong. These infected people subsequently became the index patients for large outbreaks of SARS in Hong Kong, Vietnam, Singapore and Canada.

Recognition of this new microbial threat prompted the World Health Organization (WHO) to issue a historic global alert for SARS on the 12th March 2003. An intense worldwide response led to control measures that contained the outbreak within 4 months. The official end of the global public health emergency took place on 5th July 2003. It showed the effectiveness of the control measures, but also the need for continued surveillance and awareness of the situation. The speed of the spread of the disease and the high levels of morbidity and mortality associated with SARS call for careful monitoring for the reappearance of SARS-CoV or the emergence of other infectious diseases and the preparations for the rapid implementation of the appropriate control measures.

The SARS outbreak showed that undetected SARS cases can trigger rapid non-social and community cluster transmission of SARS-CoV. This was shown to generate substantial health, social and economic consequences. Identification of any further single cases of SARS-CoV must trigger an immediate public health response. Given the probability that outbreaks of SARS or other infectious disease are likely to happen again and again there is a need to be able to detect and control disease transmission as early as possible and thus minimise the impact of the outbreaks.

Effective public health surveillance can act as an early warning system by detecting microbial, environmental, behavioural, occupational, and other health threats. It can also concentrate resources, focus interventions and facilitate future projections.

The outbreak of SARS triggered the current, critical examination of information system. Questions arise regarding the quality, type and availability of critical data. The ability of organisations to generate and communicate information has also come under discussion. The level of preparedness and the ability of the health community to respond to unexpected large or even small events remain topics of concerns [National Health Information Infrastructure 2003].

The relevant information to be managed for disease control can be said to form a Network of Information. That is a large number of different but related or connected items of information from a variety of sources and in a variety of locations or systems.

There is a need for a framework that is able to manage comprehensively and cohesively the network of disease information, provide facilities to analyse the available data and information and communicate the resultant information to relevant bodies; so that effective control measures can be defined and implemented to halt or contain transmission and spread.

Currently there are multiple systems in place that support communications for public health laboratories, the clinical community and government health departments. Each has

demonstrated the importance of being able to exchange health information. However, many of these systems operate in isolation, not capitalising on the potential/necessary synergy of data and information exchange. A cross-cutting and unifying framework is needed to better monitor the data streams for early detection of health issues and emergencies.

The health information network must be able to provide consistent exchange of disease, health and response tracking data between all relevant health and government partners. It must minimise provider burden in the provision of information as well as enhance both the timeliness and quality of information provided. This will only be possible, however, through defined data and vocabulary standards and strong collaborative relationships. Ensuring the security of this information is also critical as is the ability of the network to work reliably in times of national crisis.

The essential components of a Network of Information Disease Management System able to detect outbreaks rapidly, as well as monitor and manage the health of a nation, are the following:

1. Detection and monitoring - disease and threat surveillance.
2. Analysis and interpretation - facilities for extracting information from the massive amount of data and for real-time evaluation of live feeds.
3. Information resources and knowledge management - providing access to reference data and integrated distance learning content.
4. Alerting and communications - dissemination of data/information, emergency alerting and routine collaborative activities.
5. Decision support (and potentially logistics support).
6. Response: management support of recommendations, vaccination etc.

To be fully effective this requires a single network of information that functionally and organisationally integrates public health partners. There are, however, very significant problems that need to be addressed in order to achieve the above objectives, namely:

1. Multiple incompatible disease specific systems that exist currently.
2. Incomplete and delayed data.
3. Burden on health care systems to report disease.
4. Overwhelming volume of data to be managed by health departments.
5. Lack of state-of-the-art information technology.

In summary, the goal of a disease surveillance programme is to be able to monitor and assess disease trends, i.e. provide situation awareness [Grégoire, & Beaudoin, Brigg], and use this information to guide prevention and intervention programmes. In addition, to inform public health policy and policy makers and protect confidentiality as well as providing/presenting information to those who need to know.

A wide variety of network visualisation tools have been developed specifically or can be adapted for health related tasks [Alberts et al.]. However, none of them provide the capabilities that encompass all the requirements for managing the dynamic and unpredictable scenario of detecting, monitoring and managing the possible outbreak of infectious disease. Much work is still required to develop an infectious disease network visualisation tool that can manage the dynamic and unpredictable nature of any potential infectious disease outbreak.

4.0. CONCLUSION

The benefits of the work of the NATO IST-059/RTG25 for Network Visualisation have a potential far-reaching impact into applications beyond Homeland Security and Defense. The variety of interests and expertise of the members of the NATO Visualisation Group have aided in the identification of new areas in which to use visualization techniques to solve complex data analysis problems. Not only are these techniques being used to track terror networks, aid in battlespace situation analysis, monitor computer networks, and aid in the treatment of infectious diseases but in the near future may serve to improve routine health care and medical first-response in order to save lives.

5.0. REFERENCES

(2005). Dental records beat DNA in tsunami IDs. New Scientist.

Abraham, J. and Hellar, B. (2005, September 23). Decision support for dynamic target engagement: Active decision spaces. College of Information Sciences and Technology, The Pennsylvania State University.

American Medical Association (AMA), Science, Quality, and Public Health Group. (2004). Family Medical History in Disease Prevention [Brochure]. Retrieved on 12 September 2007 from http://www.ama-assn.org/ama1/pub/upload/mm/464/family_history02.pdf.

Darves, B. (2004). New Medical Record Initiative Complements History-Taking. Medscape [On-line]. Retrieved on 12 September 2007 from http://www.medscape.com/viewarticle/493614.

Dentition. (n.d.). *Dictionary.com Unabridged (v 1.1)*. Retrieved June 26, 2007, from Dictionary.com website: http://dictionary.reference.com/browse/Dentition

East Shore Technologies, I. (2007). Civil fingerprint identification (cid) / authentication systems.

Geradts, Z. R., A. (2003). Extracting forensic evidence from biometric devices, *Society of Photo-Optical Instrumentation Engineers Investigative Image Processing 2003*.

Hastings, B. (2006). A statistical investigation of fingerprint patterns, *15th School of Computer Science & Software Engineering Research Conference*. Yanchep, Western Australia.

Inman, K., & Rudin, N. (2001). *Principles and practice of criminalistics: The profession of forensic science*. Boca Raton: CRC Press.

International Biometrics Group. (2003). The Henry classification system. Retrieved March 24, 2007, from http://www.biometricgroup.com/Henry%20Fingerprint%20Classification.pdf

James, S. H., & Nordby, Jon J. (Eds.) (2005). Forensic Science: An Introduction to Scientific and Investigative Techniques, Second Edition. Boca Raton, Taylor & Francis.

Keiser-Nielsen, S. (1963). "Dental Investigation in Mass Disasters." Journal of Dental Research **42**(1): 303-311.

Moenssens, A. A., Starrs, J. E., Henderson, C. E., & Inbau, F. E. (1995). Scientific evidence in civil and criminal cases (4th ed.). Westbury, New York: The Foundation Press, Inc.

Nye, P. J., Tytle, T.L., Jarman, R. N., & Eaton, B.G. (1996). "The Role of Radiology in the Oklahoma City Bombing." Radiology **200**(2): 541-543.

Office of the Provost Marshal, U. S. A., Europe and Seventh Army. (September 2002). Installation access control program.

Seattle-Post-Intelligencer. (n.d.). "Flawed national database leaves dead nameless." Retrieved June 2, 2007, from http://seattlepi.nwsource.com/dayart/pdf/20030226Missing_NCIC_Dental.pdf.

Sweet, K. M. (2004). *Aviation and airport security: Terrorism and safety concerns*. New Jersey: Pearson Education, Inc.

Grégoire, M. Beaudoin, L. Visualisation for Network Situational Awareness in Computer Network Defence, Proceedings of the NATO IST-043/RWS-006 Workshop “Visualisation and the Common Operational Picture (COP)” Workshop September 2004.

Brigg, P. Situation Awareness, Defence Situation Awareness Seminar, DSTO Salisbury 1998.,

Alberts, D. S., Garstka, J. J., Stein, F. P.,. Centric Warfare, second edition, September 1999.
Towards a Theory of Situation Awareness in Dynamic System, M. R. Endsley, Human Factors, 1995, 37(1), pp 32-64.

National Health Information Infrastructure 2003, Developing National Action Agenda for NHII. Homeland Security Track. Framework of the homeland security track, Version of May 27, 2003.

NOTES:

- The work described in this paper is cleared for presentation to NATO audiences at a NATO/PfP UNCLASSIFIED level.
- If work is sponsored by a Government Agency, identify the organization and attest that the organization is aware of submission.
- The abstract is technically correct.
- The abstract is NATO/PfP UNCLASSIFIED.
- The abstract does not violate any proprietary rights.