Cyber Handyman and Nursing for Humanitarian Services and Disaster Relief

Srikanth Jonnada
Department of Computer Science and Engineering
University of North Texas
Denton, TX
srikanthjonnada@my.unt.edu

Ram Dantu
Department of Computer Science and Engineering
University of North Texas
Denton, TX
ram.dantu@unt.edu

Ishan Ranasinghe
Department of Computer Science and Engineering
University of North Texas
Denton, TX
ishanranasinghearachchilage@my.unt.edu

***Abstract*—Calamities cause immense damage to the lives and properties; emergency management and humanitarian support have always been a challenge in the disaster-hit areas due to deficiency of skilled workforce and increase in demand for available experts. Not all the volunteers have the required technical expertise to handle those situations, utilizing the services of the remotely located experts to enhance the skills of the volunteers can help them to handle the situations efficiently. The existing communication mechanisms do not have the capabilities required for collaborating people over physical tasks, which is crucial during the emergency situations. In this paper, we present two novel remote collaboration systems, Cyber-Handyman and Cyber-Nurse using which the less-trained and inexperienced aid workers can enhance their capabilities with the help from remote experts. These units will be deployed in the disaster sites, and the remote experts access and control the sensors on it to guide the aid workers or the victims.**

The efficiency of the collaboration over physical tasks, which is vital during emergency situations, depends on the complexity of the protocols utilized and the efficiency of the collaboration system. We also propose a methodology to evaluate the protocol complexity and efficiency of the system. Our experiments and results show that with our collaboration system a remote helper can successfully guide the workers in performing a physical task with minimum difficulty.

Keywords—remote collaboration, protocol complexity theory, collaboration system, common grounding, Voice Over IP, human-human collaboration, human-machine collaboration, helper-worker collaboration

I. Introduction

Natural and human-made calamities can damage the living and lives of many people, emergency management and humanitarian support in these areas have always been a challenge. A Global Humanitarian Overview (GHO) report estimates that a population of 128 million across the world will be in need of humanitarian aid during the year 2018 [1]. Need for the support is growing at a much higher rate and the currently available human and material resources are not sufficient to fulfill the demand [2]. Deficiency of skilled workforce, increase in demand for available experts and reduced accessibility to the disaster-hit areas are leaving the victims helpless for days and sometimes even for weeks.

Guiding or even monitoring of rescue activities demand the physical presence of the governing bodies on site. One of the major reasons demanding their physical presence is poor situational awareness and freedom to analyze the situation remotely. The aid workers and volunteers, physically present at the disaster location, are sometimes helpless and need guidance from the experienced and knowledgeable in handling a situation. There could be times where collaboration among teams of multiple domains is required.

This paper provides solutions to these problems through two novel remote collaboration systems, Cyber-Handyman and Cyber-Nurse. These systems will be deployed in the disaster sites; a remote helper accesses and controls the sensors on it to guide the victims, aid workers and volunteers to handle a situation. Experts on rescue activities or a particular task can use our systems to guide less-trained and inexperienced aid workers. For instance, our device can inspect and guide a repair of food and water supply trucks, the building of refugee camps, troubleshooting of medical equipment, reconstruction of damaged houses, repair of sanitation, and reestablishing of power and communication services.

It is vital that these remote collaborations be efficient; use of less complex and high-performance protocols along with efficient systems can help the helpers perform their duties faster and accurately. Along with the discussed collaboration systems, we also introduce a novel methodology to quantify

Figure 1: A remote helper guiding a wroker to perform a sink repair [30].

and evaluate the efficiency of the systems and complexity of the human protocols.

II. Problem Definition

Disasters cause massive damage to both lives and properties. At these times, the actual presence of rescuers, experts and volunteers are needed at the location to analyze, troubleshoot and fix the problem or even to provide simple direction to execute recovery tasks. After a disaster, the communities in the affected areas have to set off for a long and hard road to recovery due to the increased demand for available experts, long waiting times, and enormous service charges.

Victims in the disaster-hit areas need medical attention, and it is vital to take the necessary steps to avoid spreading diseases. Moreover, due to the increase in the elderly population [3], there will be a drastic growth in the requirement of nurses to take care of the elderly as well. The association and availability of these nurses with the elderly are critical, but the availability of a nurse 24/7 is not practical. The lack of availability can be very hard during an emergency situation, especially at times where regular monitoring is required. Therefore, it is vital that we think of the methods to meet the demand for rescuers and nurses during emergencies.

Our remote collaboration systems provide a solution to these problems, with the ability to provide services through experts of any geographical location. Using these systems, the government officials, medical specialist, experienced aid workers can remotely monitor and control the activities in the disaster-hit areas and help the victims for a fast recovery.

Searching for the survivors in a flooding area and rescuing the victims after a massive earthquake is a trauma. After a disaster, a rescue worker may not have access to some places to save the victims. It will be beneficial if there is a device which can move to such places and fetch the required information or provide the necessary instructions. The device we are proposing can go to places where people cannot.

III. Experimental Setup

These collaboration systems are equipped with a remotely controlled pan-tilt high definition web camera to obtain visual information of the service recipient's environment. It also provides zoom in/out feature to the remote helper (device operator) for a close-up view of the target objects. Moreover, the device is loaded with LED lights, which a helper can control and utilize in poor lighting conditions. Just a pan-tilt capability of the camera may not provide the required situational awareness to the remote helper, to overcome this problem all the components are stationed on a remotely-controlled wheeled platform.

A proper common grounding between a helper and a worker can reduce the complexity of their collaboration. Common grounding is described as establishing a common understanding of both the content and the process among the collaborators[4]. The device is developed for full-duplex audio and equipped with a speaker and a microphone to facilitate an easy grounding. It uses Voice over IP (VoIP) technology for the voice communication. Along with the voice communication, gestures play a crucial role in the grounding. To facilitate the device with remote gesture capability, a laser diode is mounted over a set of pan-tilt servos. By remotely controlling these resources on the device, a helper can fetch required information and provide necessary instructions.

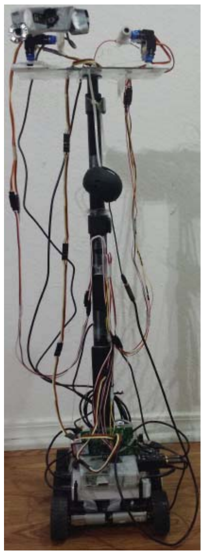

Figure 2: A Sample Device Deployed at Local Work-Site

The proposed methodology has many decisive advantages over many similar robot applications available today. Since the remote-helper is a human being, the helper can provide guidance regardless of the worker's environment. The remote helper (device operator) can guide the worker (service recipient worker) according to the worker's skill level. Thus, the proposed system is automatically configured to the worker's skill level. More importantly, unlike many robot applications, our devices can be used to perform new (unknown) and unscripted tasks.

IV. Methodology for Evaluating Human-Human Protocol

The success of a task can be defined based on its outcome, but when it comes to the helper-worker collaboration, the efficiency of the collaboration is equally important as the outcome. It is vital that the helper and worker follow a protocol, an exchange of requests and responses, in their collaboration. A protocol is efficient when a helper can establish common ground with the worker and execute a task with minimum steps possible. In other words, a protocol is efficient when the collaboration is minimally complex.

A. Background

Motivated by Wood's [5] representation of a task, extended version of Wood's work [6], and other related works [4], [7] – [25] we represent the helper-worker protocols as a network of events. An event is an utterance or an action by a helper or a worker; events generate information-cues which may be processed by other events. This representation of events and information-cues forms a graph structure. By calculating the complexity of this structure, the complexity of a protocol can be determined.

Bonchev [26] states that one can obtain a complexity measure of a graph by using the vertex degree magnitude based information content. Bonchev [27] utilizes Shannon's information theory to estimate complexity based on entropy. He assumes the distribution of N elements in k groups as {N1, N2, N3, …, N_k} and probability for a randomly chosen element of the set to belong to the group I is Pi = Ni/N. Shannon's entropy H` of probability distribution {P1, P2, P3, ..., Pk) is defined as,

$$\acute{H} = -\sum_{i=1}^{K} P_i \log_2 P_i = -\sum_{i=1}^{K} \frac{N_i}{N} \log_2 \frac{N_i}{N}\, bits/element \quad (1)$$

Here log is taken as base 2 to calculate entropy in bits. The entropy of all the elements is given by,

$$H = N \times \acute{H} = N \times (-\sum_{i=1}^{K} \frac{N_i}{N} \log_2 \frac{N_i}{N}) \quad (2)$$

$$H = N \log_2 N - \sum_{i=1}^{K} N_i \log_2 N_i \quad (3)$$

As per Bonchev, the entropy of a structure H is maximum when the second term in the above equation is zero; this corresponds to distributing system elements into groups of one element each. The information content of a graph is the difference between maximum entropy H_max and the value H of the system entropy.

$$I = H_{max} - H = \sum_{i=1}^{K} N_i \log_2 N_i \quad (4)$$

Bonchev [26] states that information content of a structure can be used to calculate its topological complexity. This equation, derived for information content, can be used for calculating the complexity of a structure.

B. Modeling a Helper-Worker Protocol

Representing a protocol as a graph structure helps understand its information-content and complexity. The protocol is modeled as a graph by representing events and information-cues in the form of vertices and edges respectively.

In a helper-worker collaboration, the helper provides instructions and descriptions of the task to the worker, and in response, the worker performs actions or utters questions or provides acknowledgments. We represent these instructions, descriptions, actions, and utterances as events and are pictured as vertices of a graph. In the protocol, an instruction by a helper acts as an information source for the worker to act. For instance, when a helper describes an object, it acts as an information source for the worker to provide an acknowledgment or pose a question. So, every event generated by a helper acts as an information signal for the worker to perform his next event, and every event by a worker serves as an information signal for the helper to perform his next event. We represent these information signals as edges in the protocol graph structure.

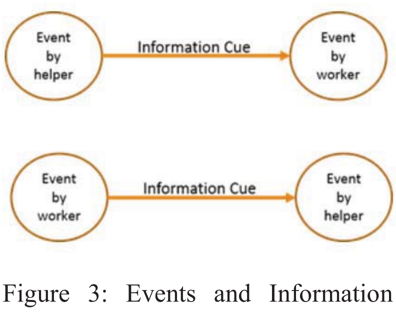

Figure 3: Events and Information Cues

In a helper-worker protocol, the helper follows a step-by-step procedure in guiding the worker for completing the task. Each step starts with an instruction from the helper and ends with successful task completion or grounding of the worker. An instruction from a helper can lead to multiple events. A set of events and information that are required for grounding a helper and a worker, and for the worker to complete the helper's instruction successfully is termed as an atomic task.

C. Modeling complexity of a protocol

A protocol is a combination of atomic tasks. The information content of a graph provides its structural complexity. When one represents a protocol as a graph structure and measure its structural complexity, it provides the complexity of the protocol. The vertex degree in a graph provides the number of edges associated with the vertex. In a protocol structure, it represents the information signals generated or processed by an event. To calculate the protocol complexity, we calculate the complexity of each event by considering the information-cues associated with it. Summing up the complexities of all vertices provides the complexity of the overall graph, thereby providing the complexity of the protocol.

$$IC_i = InDegree(node_i) + OutDegree(node_i) \quad (5)$$

The complexity of an event is given by,

$$EC = IC \log_2 IC \quad (6)$$

Complexity of a protocol is given by,

$$PCI = EC_1 + EC_2 + EC_3 + \ldots\ldots\ldots\ldots. + EC_k \quad (7)$$

$$PCI = IC_1 \log_2 IC_1 + IC_2 \log_2 IC_2 + \cdots . + IC_k \log_2 IC_k \quad (8)$$

$$PCI = \sum_{i=1}^{K} IC_i \log_2 IC_i \quad (9)$$

Where PCI is the protocol complexity index; K is the total number of vertices or events in the protocol; IC_i is the number of information cues associated with an event or vertex i.

V. CYBER NURSING PROTOCOL

Hydro-meteorological disasters like flooding or human-made disasters like terrorist attacks can result in the displacement of people to overcrowded camps. To control the spreading of infectious diseases, the victims need proper medical attention. Most disasters are sudden, and rescue camps usually do not have enough medical officers and nurses to handle the situation. Moreover, due to the conflicts among the countries such as Syria and Iraq, the need for humanitarian support is rising rapidly [2]. When hospitals are destroyed, the patients are forced to live in refugee camps where no medical specialists are present.

According to U.S Census Bureau 2014 National Population Projections [3], the United States will experience considerable growth of population aged 65 years and above, at 56.4 million by 2020. With aging, the ability to remain independent gets complicated, poor vision, hearing loss, and memory loss become predominant, hence with these health conditions a regular treatment is necessary. With all the aging complications, medication self-management is becoming a challenge for older adults, which is leading to additional health issues. Hiring an on-site nurse can be expensive and their association with the elderly throughout a day is not practical.

The concept of remote services is an apt solution for all the issues mentioned above. Government and humanitarian organizations like the American Red Cross can use the proposed devices to train experts and have them guide the other aid workers and volunteers on the rescue missions and humanitarian aid projects. Even in day-to-day life, these devices can be used to take care of the elderly and to treat patients remotely at any time of the day.

Using Cyber-Nurse, a remote nurse can help the patients and the elderly in managing their medication. The helper can move the device around and fetch the medicine information. Also, the remote nurse can verify the ingredients and the expiry date of the medicine before the patient or the elderly consumes it. Visually inspecting a medicine to fetch the data may be hard as the text is a fine print. We included a barcode reader application on Cyber-Nurse to read barcodes on the medicine, to obtain all the required information and to display on the remote nurse's dashboard.

Figure 4: Remote nurse reading 2D DataMatrix barcode on the medicine bottles; Medicine information is shown in bottom half of the controlboard

There are two types of barcodes, one and two dimensional. The one-dimensional barcode holds a serial number and is usually the same for the same batch of a product. The medicine information has to be fetched from a database using the serial number. The two-dimensional data matrix barcodes can carry significantly more information, which includes batch or lot number, production date and expiry date [28].

Recording the time and frequency of consumption of medicines plays a crucial role in tracking the health of an older adult and in their treatment. With the Cyber-Nurse, the remote helper can log time and name of the medicine consumed. By providing cumulative data to a physician, the client can diagnose health problems and plan for further treatment.

VI. Cyber-Handyman for Home Repair

There will usually be a high demand for handymen after a disaster. Utilizing the services of a Cyber-Handyman can prevent huge wait times and high prices. We experimented with one of the common home repairs, a leaky faucet, to understand the efficiency of the proposed system. Figure 5 shows a view of the worker's environment.

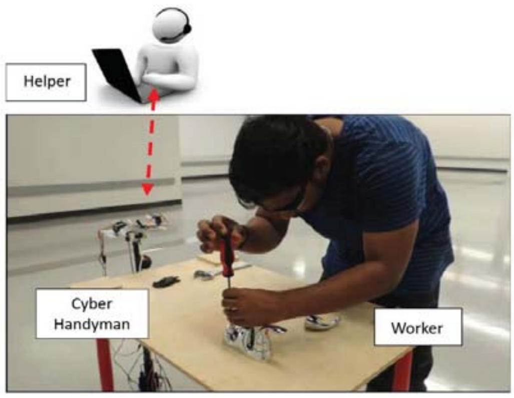

Figure 5: View of the worker's environment. The woker is unscrewing a screw using a screw driver with instructions from the remote helper.

We performed the faucet repair protocol experiment with 30 participants and estimated the complexity using the proposed Protocol Complexity Theory. Only 6 participants had prior knowledge of faucet repair, yet, all the subjects were able to successfully repair a leaky faucet with the assistance from a remote helper. We obtained the complexity value ranging between 171.97 and 466.35 bits and time ranging between 404 and 865 seconds. Figure 5 shows the relationship between the protocol complexity and the time, and it shows that the time taken for the protocol, increases linearly with its complexity. To find the strength of the relation between PCI in bits and time in seconds, we performed regression analysis and obtained a regression equation with P-value of 0.0002379 and a standard error of 105.66 seconds. The P-value indicates a strong relationship between time (T) and Protocol Complexity Index (PCI). This proves that the protocol complexity equation can be used for calculating protocol complexity of a faucet repair protocol.

Moreover, the post-task survey for comparison between the Cyber-Handyman and a YouTube indicates a strong satisfaction of the workers with the remote-helper guiding them than a prerecorded video. The results strengthen the hypothesis that a remote helper will be able to successfully guide the workers in performing a physical task with minimum difficulty.

$$Time = 1.4111 * PCI + 247.4351$$

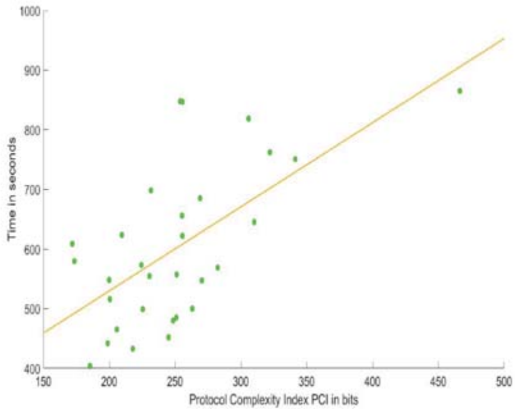

Figure 6: Relationship between Protocol Complexity Index PCI and Time consumed by the protocol

VII. Conclusion and Future Work

After a disaster, the actual presence of rescuers and volunteers are needed at the location to analyze, troubleshoot and fix the problem or even to provide simple directions to execute a recovery task. A deficiency in the skilled workforce and the increased demand for experts for rebuilding the disaster-hit areas result in long waiting even for the simple mechanical, handyman and nursing services. Performing a task with the guidance of remote experts from any geographical location provides an apt solution to the demand for required skills in recovery and restoration. We introduced novel collaboration systems Cyber-Handyman and Cyber-Nurse, using which a remote helper can assist the victims. The victims of the disaster-hit areas, aid workers, older adults and any individual who need remote guidance to perform a physical task can benefit from our invention. We believe the government bodies such as Department of Homeland Security, humanitarian aid organizations such as International Federation of Red Cross and Red Crescent Societies (IFRC), and World Food Programme (WFP) [29] can provide better services by using our remote collaboration system. Building refugee camps, inspect and repair food and water supply trucks, troubleshooting medical equipment, reconstruction of damaged houses are only a few of them.

It is vital that the proposed remote collaboration system be effective and less complex to the consumers. We introduced a novel methodology 'Protocol Complexity Theory', to measure the complexity of a human-human collaboration protocol. We conducted a series of experiments on a home repair protocol, and all the participant were able to complete the task successfully. We obtained the complexity value ranging between 171.97 and 466.35 bits and time ranging between 404 and 865 seconds to accomplish the provided task. We observed that almost all the participants are confident and happy to work with a remote helper.

We would like to extend this work using a Drone-Companion, which can be flown to disaster-hit areas for rescue missions and humanitarian aid programs. With the help of advanced technologies in modern drones, the remote helper can obtain additional visual information than a regular camera and provide more control to the remote expert to gather the necessary information to guide the aid worker. For instance, the Drone-Companion can help the aid workers and the government officials to find victims in disasters such as flooding. It can also be used to locate bombs and guide the bomb disposal unit to neutralize it. It is better to have an aerial view which provides a good line of sight or viewing angles for searching survivors in flooding areas and rescuing the victims after a massive earthquake. Moreover, by obtaining a top view, front view and side view of the site, the helper can make an orthographic projection of the surrounding objects, which will provide more information to the remote helper to help the victims.

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