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Military Applications of Wearable Computers and Augmented Reality*

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INTRODUCTION

Computers have evolved from huge mainframes to bulky workstations and desktops to slim notebooks and now to highly portable handheld or wearable computers. Wearable and handheld computers have great potential for military use, and there is currently great interest in what these highly portable devices can do. This chapter focuses on highly portable computing devices, those that are wearable (belt, wrist, and head-mounted) and handheld, and the term wearable computers (WCs) will often be used when

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referring to all these devices. The chapter briefly discusses input/output devices since the need for their miniaturization is one of the primary motivations for using WCs. It then summarizes the areas of military application of these devices: communications, position determination and map functions, report preparation and calculation, repair and maintenance, medical support, and the digitized battlefield. It also discusses the wearable computing equipment being developed for US. Army infantry units, a prototype of which was recently tested in a recent Advanced War-fighter Exercise.*

BACKGROUND: INPUT/OUTPUT DEVICES

Although miniaturization has allowed computers to become significantly smaller, the size of conventional input and output devices is now one of the main factors (other factors include thermal dissipation and power supply/battery size) limiting further miniaturization. Therefore, alternatives to the traditional keyboard and monitor input/output devices are being developed by the military and commercial companies and are competitively evolving in the civilian marketplace. These alternatives primarily concern pen computing, speech, and head-mounted displays.

Tablet digitizers (electronic tablets), available since the late 1950s, allow the capture of handwriting and drawing by accurately recording the x-y coordinate data of pen-tip movement. Pen computing arrived when transparent digitizers were combined with flat displays in the 1980s. This brought input and output into the same surface, providing immediate electronic *ink* feedback of the digitized writing and mimicking the familiar pen and paper paradigm to provide a "paperlike" interface. With a pen computer (or a pen-enabled computer), users can not only use the pen (writing stylus) as a mouse but also write or draw as they do with a pen on paper. There is no longer a need for a bulky keyboard since keyboard entry can be mimicked by touching sequences of buttons on a "soft" keyboard displayed on the screen or, alternatively, handdrawn characters can be automatically converted to ASCII code by handwriting recognition software. Available handwriting recognition products are highly accurate on careful handprinting and some products are available that recognize cursive script with accuracy dependent on the writing style and the

*The reader should be aware, however, that this field is changing so rapidly that there will be significant changes even within publishing cycles.

regularity and clarity of the writing (Tapper-t et al., 1990; Tapper-t & Ward, 1992).

Also in contrast to standard forms of input (i.e., keyboard and mouse), input based on speech recognition requires less operational work area and allows "hands-free" operation, eliminating the need for a keyboard. For speech input there are isolated-word and continuous-speech recognition systems. The simplest and most accurate systems operate only on words spoken in isolation (one at a time) and are text-dependent with a limited vocabulary. Since many military applications require only a small number of isolated commands or controls, these systems are relatively easy to create. Continuous speech systems are more complex and less accurate because they must handle the smearing of sounds across word boundaries (Padilla, 1997; Parsons, 1987).

Speech recognition systems currently available commercially include: Dragon Dictate Single, Kurzweil Voice Pad Pro, and IBM Voice Type—Simply Speaking. The first two handle vocabularies of 10,000 words, and the IBM system handles 22,000 words. These systems recognize connected speech, but they do require brief pauses between words. Recent work at Microsoft in audio recognition on a voice application program interface has demonstrated that continuous speech recognition is feasible on 200 Mhz + Pentium desktop systems (Microsoft, 1999.)

To be useful in battlefield applications, speech recognition hardware and software must provide acceptable performance under less than ideal conditions, such as speakers under stress, high levels of background noise, and all weather environments. In such situations, a large vocabulary system may, in fact, not be appropriate. More appropriate for the battlefield environment are small vocabulary, isolated-word (or short phrase) systems using noise canceling and helmet-mountable microphones, and a 100% failsafe system for critical commands (such as "FIRE!") would be imperative.

Speech output devices are also effective in WCs applications because they allow the user to listen, rather than divert visual attention to a monitor. Speech output can be created either synthetically or from recorded natural speech and such systems are readily available.

Another alternative to the traditional monitor is a Head-Mounted Display (HMD). The HMD mounts on the head like eyeglasses or goggles, provides the user with a large virtual display visible in one or both eyes, and is small and portable. Basically, it is a better trade-off of display size and quality versus equipment size than other display technologies, making it ideal for use with WCs. Many applications, including most of interest to the military, use see-through HMDs in which the display is either superimposed or, more usually, projected onto only a portion of the eyepiece so that the user's real-world vision is augmented by the ability to see the displays. One such product currently available is *Virtual I-glasses! VPC* from Virtual i-0. HMDs used for virtual reality, on the other hand. attempt to totally immerse the user in the virtual environment, and they therefore completely block the user's normal vision.

In 1992, the Defense Advanced Research Projects Agency (DARPA) established the HMD Program with the goal of creating small, flat-panel, high-resolution displays that can be mounted in novel ways to present visual information to personnel on the battlefield. The emphasis of the HMD program is to provide information where ordinary displays are inappropriate or impractical: those requiring hands-free operations. where total immersion is important, and those involving unique viewing requirements. such as 3-D images, mapping graphical images onto real images. and night vision. The

FIG. 20. I HMD for the U.S. Army Soldier Systems Command's Land Warrior.

FIG. 20.2. U.S. Army Soldier Systems Command's Land Warrior.

1 l-ounce Combat Vehicle Crew (CVC) goggle, already developed under this program, incorporates a 1280 x 1024 active-matrix electroluminescent display into a standard U.S. Army sun, wind, and dust goggle. The first application of the CVC goggles will be for M 1 A2 tank commanders, while later plans include the Land Warrior (see Figures 20.1 and 20.2) and the Force XXI Soldier.

MILITARY APPLICATION AREAS

There are several aspects of WCs that relate to their use in the military. They must be rugged, and applicable military standards exist (e.g., MIL-STD-8 1 OE, Environmental Test Methods and Engineering Guidelines) to control tests and testing methods for rugged equipment (Hunter, 1996). They may have docking stations. cradles or holsters for recharging, uploading/downloading information, providing communication, or for securing the device and preventing damage. Battery life and other power related considerations are critical. Weight and cost are important. Finally, other features that arise from their mobility requirements include wireless communication and knowledge of current location.

With today's rapid technological advances, particularly in the area of small mobile computing devices, equipment designed and developed by the usual Department of Defense (DoD) method of "full military specification" is often obsolete before it is delivered. An alternative to the "old" method, and now a DoD initiative, is to purchase commercial off-the-shelf (COTS) equipment whenever possible and, only when necessary, modify it for military use (Herskovitz, 1994; McAuliffe, 1996). Sometimes COTS technology can be the starting point for military computers that are modified, for example, by making them more rugged (Fisher, 1996; Herskovitz, 1995). Because many current applications, such as those in the transportation industry, require rugged computing devices, additional ruggedization for military purposes may not always be necessary. Although the COTS initiative is causing changes in many organizations with, for example, NASA making extensive use of COTS subsystems (Rhea, 1996), some are saying that the initiative may be moving too fast and not giving proper consideration to unique military requirements (Wilson, 1996).

Commercially, although only about a half million wearable/handheld computers were sold in 1995 compared to 3.5 million notebook computers (Blodgett, 1996), their use and sale are growing rapidly and this growth is expected to continue. Pen computers, personal data assistants (PDAs), and other small computers are used extensively in industries such as transportation, healthcare, finance, construction, insurance, and police. Usually an organization begins to use these highly portable computers to gain an edge over their competitors.

As in the civilian sector, there are many military applications of PDAs/WCs. Among these are special operations, maintenance, communications, language translation, position determination, map functions, report preparation and calculations, training, security, medical support, logistics support, distance learning, imagery gathering, law enforcement, and reconnaissance. Several of these aspects are discussed in more detail below. It should be noted that many of the advantages cited in individual sections apply throughout.

Land Warrior

As indicated previously, a WC can be worn like a belt, vest, or bandoleer, or shaped to fit into small spaces. Such a device can be used in battle dress or with other uniforms. With WCs there is no need to shuttle between computer workstation and operational site for information processing. These devices can also reduce the need for bulky paper documents.

The Land Warrior (see Figure 20.2) is an integrated fighting system for dismounted soldiers. Its purpose is to enhance the individual soldier's ability to survive in adverse conditions, acquire and engage targets, and become fully integrated in the digitized battlefield. It consists of four physical subsystems and a software subsystem (Aninger, 1996). The integrated helmet assembly subsystem consists of a helmet-mounted computer and sensor display by which the soldier can view digitized maps, intelligence information, and imagery from a thermal sight on his/her weapon. The equipment and protective clothing subsystem consist of a backpack frame that bends with the soldier's natural body movements and body armor that offers improved ballistic protection at a reduced weight. The weapon subsystem includes a thermal sight, video camera, and laser rangefinder/digital compass, which can be coupled with the Global Positioning System (GPS, described later) to provide extremely accurate positional and targeting information. The computer/radio subsystem, built into the backpack frame and integrated with GPS modules, consists of two radios (one for communicating with other soldiers within the squad, the other for communicating outside the squad) and a menu driven computer interface, controlled by a pointing device located on the chest strap. In sum, the Land Warrior program will enhance the soldier's battlefield capabilities through the development and integration of these subsystems, merging the soldier and technology into a cohesive, combat-effective system (Army, 1996).

Communications

One of the commander's main requirements is communications. That is, he must advise subordinates of changes in mission, support, and threat; also, he must inform superiors of changes in threat or timelines. The WC can simplify this procedure. Consider a company conducting a reconnaissance mission to note concentration, activity, and location of enemy defenders, washed out bridges, and/or battle damage. If the commander immediately reports the information by combat net radio, his emission alerts the enemy as to his presence; if he waits until returning to headquarters, his information will likely be stale. A remedy is to input the information into a WC, and at the first safe opportunity, use it to update the database on which such information resides. Communication can be facilitated by antenna arrays sewn into clothing associated with the WC.

The Army's Communications Electronics Command (CECOM) at Fort Monmouth predicts that by 1999 every soldier will be issued a small computer. They are currently experimenting with a rugged handheld computer called "The Grunt" that fits into the thigh pocket of the battle dress uniform (BDU). It communicates with satellites, runs complex software, and operates by fingertip on a touch-sensitive screen to eliminate the need for a keyboard (Matthews, 1994b). Such mobile computing devices in the hands of individual soldiers may be tomorrow's combat "force multipliers" (Glasser, 1997).

With the current trend toward multinational missions, communicating with automatic language translation becomes extremely important. Even when forces of various countries are separate, translation is vital in coordinating operations, both at headquarters, where such coordination is routinely performed, and also at the fighting level, where functions such as unit boundary development and field of fire coordination are addressed. There are several software options that can provide support in this area. For example, the Psion Series 3 PDA with Berlitz Interpreter permits translation of 28,000 words among five European languages (Psion, 1998).

Position Determination and Map Functions

In many operations it is necessary to know one's location accurately. For example, only when the location of a field artillery battery is properly surveyed and stored can gun orders be calculated. Moreover, one certainly would not want to call for artillery fire without accurately knowing one's own location! The Global Positioning System (GPS) was designed for and is operated by the U.S. Military. Twenty-four satellites orbit the earth in 12-hour orbits to provide the user with five to eight satellites visible from any point on earth. They send ephemeris data to GPS receivers over radio signals. GPS receivers require input from at least four satellites and convert the radio signals into x–y–z position and time. The primary function of GPS is navigation in three dimensions (latitude, longitude, and altitude). Velocity and acceleration are also easily computed.

Precise Positioning System (PPS) data can only be received by government-authorized users with cryptographic equipment and special receivers (20 meter accuracy). Standard Positioning System (SPS) signals, intentionally degraded by the DoD, provide decreased (100 meter) accuracy to civilian users that can be captured by most receivers without charge or restrictions. Differential GPS techniques can be used to correct bias errors at one location with measured bias errors at a known position, thereby increasing the accuracy of the data (differential SPS, for example, can obtain 1-10 meter accuracy).

As for the receiver, the Army is in the process of fielding the Precision Lightweight GPS Receiver (PLGR, AN/PSN-11). The PLGR is a small, handheld, GPS receiver featuring selective availability/anti-spoofing (SA/A-S) and anti-jam capability (see Figure 20.3). It provides precise

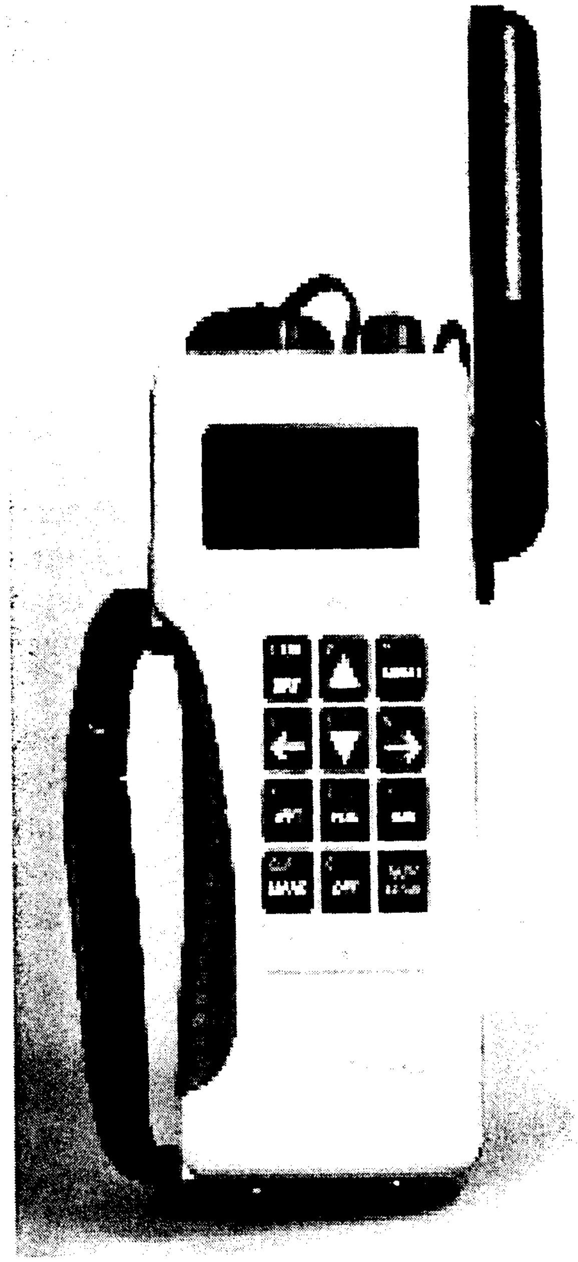

FIG. 20.3. Precision Lightweight GPS Receiver (PLGR).

positioning and timing solutions based upon signals received from the GPS satellite constellation. It is a five-channel receiver, capable of Precision Code (P Code) and Y Code (encrypted P Code) reception. Positioning solutions can be displayed in latitude, longitude, military grid reference system, Universal Transverse Mercator, British National Grid, and Irish Transverse Mercator Grid coordinates. It contains 49 map datums, can be programmed to support navigation, and has a built-in test feature.

Some commercial GPS products are stand-alone units used primarily for air, sea, and land navigation that receive the *x–y–z* location and time data and perhaps display the location on a chart or map. Some car rental agencies, for example, are beginning to add this equipment in their vehicles. Other GPS products are sold as add-on equipment for handheld and notebook computers.

Because the display of the PLGR is alpha-numeric only, the soldier must read the display and correlate it to his or her map. Alternatively, this can also be performed quickly and conveniently with FieldWorker software. Acting as a bridge between the GPS and a computer's operating system, it provides rapid flexible data collection, along with equipment linkage testing and GPS averaging (Apple, 1997). Along that same line, cadets at the United States Military Academy (USMA) recently participated in a project that involved taking data in real time from a PLGR and displaying the PLGR's location on a moving map displayed on a laptop computer screen. A map of West Point was digitized and a moving map software program that used Visual Basic was developed to display the user's location on the map. As the unit moved, the map was redrawn to indicate the movement, maintaining the cursor in a centralized position on the map.

Moving from one location to another is an integral part of operations such as attack and force consolidation. The manner and route of such movements should be determined in advance to avoid increased vulnerability to enemy fire and delays created by terrain, congestion, and excessively long routes. Route planning can be facilitated through WC capabilities that have been used in civilian applications. One software package, Microsoft's Automap Road Atlas, has 400,000 miles of North American highway data. On entering start and destination, Automap responds in seconds with the fastest, shortest, or preferred route; provides step-by-step instructions; and plots a customized map (Microsoft, 1998). Some research and development effort would be required to convert the commercial version, utilizing a network of distance and speed data, to military route planning. For example, a military version would have to store factors associated with a two-dimensional space, vehicle and surface types, weather conditions, etc.

Report Preparation and Calculations

A commander must routinely send reports throughout the chain of command with respect to various items such as target sightings, troop movement plans, ammunition availability, casualties, incoming fire, and maintenance requirements. A WC could help the commander by allowing him to compose such reports (or insert the date in formatted templates) in moments when his presence is not immediately required in battle management activities. The use of a WC also has the advantage of not constraining him to the location of his main battlefield computer/communication systems. A system such as the MessagePad, with compatible software, could easily be used for report preparation.

At some point, every commander finds some of his time expended by simple mathematical calculation. He must frequently perform tasks like determining north alignment for gun emplacements, estimating the time when his fuel will be expended, determining magnitudes of disparities between his operations orders and current status, estimating when he will be required to move his position, etc. These functions can be performed with a handheld calculator, but the WC would help the commander by facilitating the input and output.

Repair and Maintenance

See-through HMDs are currently being used for vehicle and other repair tasks. The Navy, for instance, is using a belt-mounted computer and HMD unit for helicopter maintenance, and the Army is putting 147 Ml tank maintenance manuals onto CD-ROMs for use in WCs. The user reads instructions and sees diagrams concerning the necessary repair in a display projected onto a small portion of his eyepiece and can work on the repair without shifting his focus of attention. Other uses of this equipment might allow a soldier coming up a hill to see in his eyepiece images transmitted from an unmanned aircraft of what lies on the other side of the hill (Matthews, 1994a). NASA has been using mobile computing since the first space shuttle flights. They currently use wireless units and pen computers to help with navigation and to help the crew monitor experiments and operations (MacNeill, 1996).

Medical Support

To an extent, the PDA has replaced reference books and patient index cards. Its main capability has been automation of ancillary tasks, giving the physician more time to practice medicine. The medically oriented **PDA** is now a specialized tool for managing large amounts of information. Educational Research Laboratories, Inc., has released a number of texts and handbooks in electronic format that can utilize the Newton's built-in search functions, thereby making it easy to cross-reference information. In the realm of patient management, PocketDoc by Physik, Inc., helps automate clinical experiences by allowing information to be handwritten directly into the database and handed off conveniently. There are other PDA options, including: Med-Notes, allowing quick point-of-care collection of patient information; Medicine Series, accessing the complete contents of references for medical residents; and PocketDoc Practitioner, a mobile record system designed to mimic the workflow of physicians (Mansell & Cogle, 1996).

On the battlefield, the first hour after a soldier is wounded is the most critical for patient care. Today's soldier can expect rapid transport from the battlefield to a hospital via aircraft; however, he or she must still wait for a medic to arrive, assess the situation, provide initial treatment, and have an aircraft dispatched. To expedite this process, one alternative is to bring the higher technology to the soldier.

In addition to answering the dismal question of whether a soldier is still alive, analysis of a soldier's vital signs, specifically heart rate and breath rate, serve as indicators of a soldier's immediate general health (e.g., current level of fatigue, stress, anxiety, etc.). If this analysis were done on a continuous basis and monitored remotely, it could assist superiors in assigning the best qualified personnel to a given mission. The Acoustic Sensor Division of the Army Research Labs (ARL) is developing a medical monitoring device that has a liquid filled acoustic sensor pad to detect these physiological sounds (Siuru, 1997).

The sensor pad has close to the same density of the human body and the surface material is close to that of human skin. Thus, when placed in contact with the human body, the pad provides good acoustic coupling between the person and the hydrophones embedded in the pad. The hydrophones produce a low amplitude analog signal that is amplified and passed through an analog-to-digital converter to create a digital representation of the physiological sounds. This signal is processed in the WC by digitally filtering to allow only the low-level heart and breath sounds to remain and performing Fourier analysis to separate heart and breathing signals for display if necessary.

Each soldier will be equipped with such a medical status monitor that constantly reads blood pressure, pulse, respiration, and blood oxygen level. A built-in expert system will determine when the soldier's condition warrants attention and automatically transmits an alarm, including GPS location and possibly injury severity.

Since there is a limit to the complex equipment a medic can carry, ARL and the Medical Advanced Technology Management Office are developing the Mobile Medical Mentoring Vehicle (M3V) (Balakirsky, 1996). Inside the M3V a physician's assistant and dispatcher are in charge of medical operations. The dispatcher alerts a medic in close proximity to the casualty over the Medic-cam (discussed below), notifying him of the location of the wounded, the conditions, and best route. In addition, actual coordinates are downloaded into the medic's WC. By integrating GPS with this route, the medic is given direction and distance indications to the wounded. The medic's video signal is compressed by his WC using a lossless scheme to avoid losing detail important for the physician. The medic's feed is controlled by a voice-activated interface and displayed on a monitor in the M3V. The assistant can retrieve an electronic inventory of what the medic is carrying and choose the most appropriate medication. The medic scans the barcode on the medication package, with the information automatically transmitted to the M3V, where it is incorporated into the treatment record.

Expertise from the M3V or even more distant medical centers will be observable through the use of the Medic-cam. The medical expert will remotely see and hear the patient and observe the output from the medical monitors. The Medic-cam comprises mainly a pencil video camera on glasses worn by the medic and electronics located on his load-bearing equipment. His voice is picked up by a flexible boom mike; audio reaches him through small earphones. A view screen positioned under the medic's eye allows him to see the image being transmitted. A WC, tactical communication links, and long-life batteries are currently under investigation for this system.

On a much larger scale, the Telemedicine Acquisition Initiative provides the Army Medical Department (AMEDD) with the latest communication capability to support field medicine from the forward edge of the battlefield to the continental United States. From reading diagnostic images to visually inspecting patient conditions with direct consultation links, AMEDD experts can participate in treating patients anywhere in the world.

Distributed Data Fusion

The military intelligence process concerns the collection, analysis, and interpretation of information to answer a request for specific intelligence concerning an area of interest. There are three corresponding information-processing tasks: data fusion, situation analysis, and countermeasure planning. Data fusion is the process of assembling a model of the domain of interest from disparate data sources and has three main characteristics: multi-sensor data fusion, uncertainty, and continuous process (Keene & Perre, 1990).

Data fusion represents the consolidation of data that are received from sensors. The data are consolidated, typically using some probabilistic model, to form a view of the area in question. One method of data fusion establishes a tree-structure hierarchy that identifies which levels perform which type of data reduction. Measures of effectiveness (MOEs) for data fusion concern the underlying probabilistic models being employed in the various fusion processes (Broman & Pack, 1994).

It is possible to use a "standardized template" based on the predicted data. These templates are based on previous studies of how forces typically deploy, such as predicting force structure entering your geographic area based on the sensor data (Mikulin & Elsaesser, 1994).

As described, data fusion is a one-way process; that is, data from sensors are taken in raw form and sent to the next level in the hierarchy. Each subsequent level continues to process these data. However, each level brings with it a degree of uncertainty. The top level, within the Army's All Source Information Center (ASIC), is the first time an assessment is made. This hierarchy is clearly delineated in Figure 20.4(a) (Keene & Perre, 1990).

Evaluations of the assessment are based on how well the assessment matches the reality. Yet, there is a substantial opportunity for the situation to change between the sensors acquiring data and the ASIC producing information. This is why the fusion process must be considered a continuous process. However, in order to stabilize the situation to allow a template to be utilized, a decision must be made to more or less freeze the input. At this point, the template may be employed as described by Mikulin and Elsaesser (1994). However, when model verification takes place, an inherent factor not mentioned in the referenced documents (Mikulin & Elsaesser, 1994) is establishing this "freeze" point. In other words, if a template matched the situation, did the template match because it accurately reflected the situation, or did the model match because the situation had not been allowed

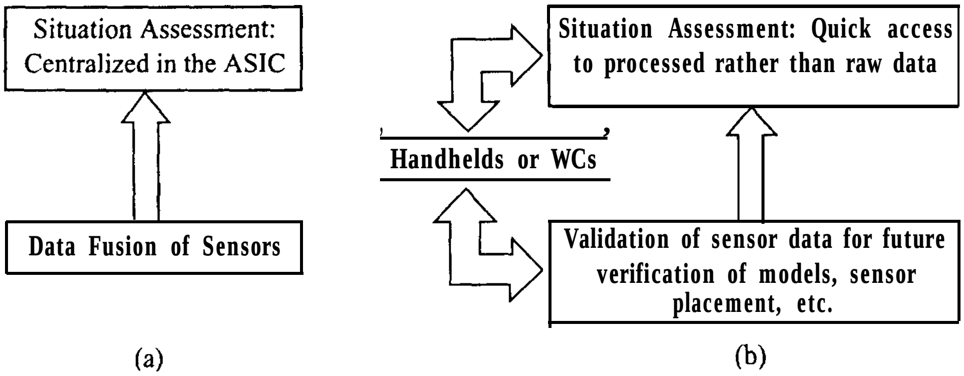

FIG. 20.4. Proposed modification to data fusion model: (a) the current hierarchy of one-way flow between hierarchy regions, and (b) utilizing handheld devices or WCs in a two-way linkage of hierarchy regions.

to develop to a point where a different template would have been more appropriate?

One reason there is an acceptance of the one-way nature of data fusion is the problem of integrating all forms of data. Human Intelligence (HUMINT), Communications Intelligence (COMINT), and Electronics Intelligence (ELINT) are fundamentally different types of sensors. Thus, the centralized assimilation in the ASIC seems the natural approach. Unfortunately, such a natural approach lends itself to having decisions made far removed from where data have their most reliable reading. Obviously, it is not possible to place a person at every sensor location. Yet the advent of WCs may allow for the insertion of decision makers at different points in the hierarchy, such as a two-way link within the hierarchy as depicted in Figure 20.4(b).

Figure 20.4(a) shows the traditional flow of data from the sensors to the ASIC. This is a one-way flow. After the ASIC makes an assessment, overall verification takes place outside the model. By using WCs, several possibilities identified in Figure 20.4(b) become evident. First, a decision can be made earlier in the process. For example, the information previously available only at the ASIC level can be transmitted to a handheld or WC operating in the “sensor” level of the hierarchy. Assimilated data from the ASIC can be based on data coming from the sensor at the fusion level of the handheld or WC. If the data are consistent, the ASIC can continue processing along its current models. However, if the data coming from the sensor show a significant difference, then the ASIC can immediately be told to recalculate for more suitable models based on current data. In this scheme, the handheld is bypassing some of the higher levels of the sensor region of the hierarchy. Thus, data from the lower portion of the hierarchy are weighed more heavily in this instance.

Such a weighing, though, is not represented by any of the measures identified in Broman and Pack (1994). Under the current MOEs, any data point is assumed to have the same value to the overall fusion process as any other data point. Obviously, then, the MOEs need to be adaptable to the potential of some data points being more "important" than others. Hence, the insertion of handhelds or WCs into the hierarchy influences the overall fusion process in terms of MOEs. How such MOEs would be modified, however, remains to be determined.

Related to weighing various sensor inputs is the coupling of confidence factors to possible template models. As described in Mikulin and Elsaesser (1994), a template is selected based on the results of computing several confidence factors. These confidence factors are algorithmically determined based on matches between the sensor-driven establishment of unit locations against a database-driven location of where a unit should be, based on the doctrinal template. The doctrinal template is established based on the correlation of the template to actual circumstances. This implies, then, that the doctrinal template is the end result of all the times that template has been selected. Thus, if a template is selected, and it does not match the reality of the situation, there are two negative effects. The first is that the wrong actions may be taken at the tactical level. For example, preparing for a unit of Type-A when it is actually a unit of Type-B. The second negative effect is that the template may be adversely adjusted due to an outlier data entry, that is, the wrong application.

Using WCs within the hierarchy can help eliminate such adverse effects. The WC can receive potential templates from the ASIC. Utilizing fuzzy-logic techniques, the WC can perhaps be used to backward engineer the data required for a template to have a high confidence factor. Again, the WC is used to bring the decision closer to the data-entry point in the fusion process.

Once the theoretical justification is made, an experimental environment would need to be established wherein testing resources (both hardware and software) could actually model the proposed hierarchy. This would be established based on using the WC as proscribed for a given level of the hierarchy. It would be best to assume the WC is not at the sensor level. If it were, one would have in effect substituted a person for the sensor, thus discounting the need for sensor fusion. By the same token, the WC would not be used within the ASIC, since other more powerful equipment is already at work on the assimilation of the data. Hence, the WC insertion into the hierarchy would have to be tested at some intermediate level (or levels).

As commonly shown in military exercises, the need to transmit data to the end-user is critical to swift decision making. This results in a two-way problem. The data being fused together results in a consolidation from thousands of points into a single, logical view of the battlefield. This view of the battlefield is then broken out and transmitted back down to units. The effective use of WCs, properly incorporated into the data fusion pyramid, can build the local picture by accessing data on its way up to the highest consolidation level. This will significantly reduce the time from data capture to information distribution.

Tactical Internet Applications

Just as the marketplace has generated new opportunities with respect to WCs for the military, it has also provided new ways to tie these computing elements together to develop new types of networked applications. How the military will actually link different information system components together and use the combined set of systems will be driven to some extent by commercial developments, particularly the Internet.

Presently information systems are constructed on the Internet utilizing a client/server architecture. This is a relatively recent shift in the general architecture of such systems. Beginning in the 1960s, central, time-shared computing systems used terminals (with varying levels of intelligence). This architecture continued into the era of the personal computer. Twenty-five years later, by approximately 1985, the general corporate computing architecture had begun the conversion to a PC/file server architecture. Then, within a short eight years (1985–93), that architecture was replaced by the present client/server architecture. This 25 to 8 ratio of change suggests that not only is more fundamental change coming, but that it is coming faster than ever before. In fact, after just four years, even the client/server architecture is now suggested as giving way to Network-centric application development (Netscape, 1996). The benefits and problems associated with the present architecture impact the way WCs will ultimately be interfaced and the context in which they will be used in corporate America and to some extent in the military.

A number of benefits have emerged from the client/server architecture that impact wearable computing applications and how they are interfaced and integrated into computing environments: *scalability* (there are no “power of computing” limitations that suddenly appear, as a solution is scaled up for use by more simultaneous users), *cross platform compatibility* (the same functionality is available on a wide variety of platforms), *interoperability* is established at a machine family level (i.e., multi platform support is designed in at a low level on a machine-specific basis rather than being added as conversion software or a gateway interface), *reusability, reliability* (with graceful degradation), and *extensible functionality* to new alternative uses.

This new architecture is not without its difficulties, among which are the unpredictability of user computing requirements (particularly when compared to prior architectures) and the need to support multiple protocols on each potential computing platform. To a significant degree, the problems that have been the good-news/bad-news of the commercial marketplace have carried over to the military computing context. Several of these topics are further expanded below.

Certainly, the most important development that will impact the migration of Internet technology to the tactical Internet is XML. In two years (1998–2000) the extensible markup language has become the *lingua franca* of Internet middleware computing (Cover, 2000). All current Army database server software vendors provide support for XML based import and export. The segregation of content data from presentation data is allowing PDA computing to incorporate integrated data sources and display that data in a manner that best uses the limited visual area common in WC's (Moeller, 1997).

Other emerging commercial areas of development with potential impact on military computing applications of WCs include: roaming; off-line use; on-demand access; push technology; digital TV regulatory announcements (digital TV by 2006); intelligent objects; content replication capabilities; dynamic recovery with real-time, expert system driven load reallocation; "Crossware" cross everything applications; "Netcasting" (server side) and recasting; client systems with multiple, cooperating, (possibly) distributed agents acting for the individual or the unit that the individual leads or represents (this is a different orientation of design and interpretation of intentionality than would traditionally be considered in a top-down design!); dynamic collaborative systems; and remote location configuration and site management.

Areas of potential interest that are suggested by military information systems development with respect to Internet and WCs include: dynamic evaluation of the proximate location of required minimal computational functionality (i.e., find the nearest, in time and/or space, system that can support the needed computation or interaction); maximum "thickness" of client software within a particular type of device; flexibility and reliability of Simple Network Management Protocol (SNMP) functions (as SNMP functionality expands, it may prove necessary to proxy some functions to avoid the occurrence of unnecessary or potentially dangerous communication traffic for a combat/military environment); and the need to bring new technologies that are applicable to a military computing environment quickly, and cleanly, in a maximally pervasive manner.

As discussed in the Data Fusion Section, communication delivery and enhancement concerns focused by the nature of military computing necessitate that communication support functions integrate data from a variety of sources such as traditional audio, visual (video in many forms), ground sensory systems, and satellite systems. Such data streams may be used to implement new communication supports: *virtual conversations* (for example, if a particular situation occurs, a prespecified command conversation is available for the soldier who is "on the spot!"); *distributed display* ***of*** *integrated information* from many sources (from real-time sensors on the ground to satellite downlinks, to audio [both real-time analog and digital], to video and artificial intelligence enhanced video, to virtual reality-like situational simulation based on available data and knowledge of enemy doctrine and tactical context); *temporally disjoint communication support* that would allow the review of recent similar communications from temporally indexed digital archives of analog communication); and Situation Report (SITREP) display of the combat zone with communication and status infornation from combat units being accessed in a "point and hear" or a "pomt and see" manner (with the level of "information freshness" also displayed); nontraditional forms of *command transmission* that might include a simulation of the action that is expected to occur and which is used by each level of the command chain to interpret their situation, needed resources, tactical alternatives, etc. This simulated course of battle command might be able to continue its "performance" by integrating real-time information about the actual battle and providing insights into how to respond to initial results even when communication with higher command elements is infeasible, difficult, or even dangerous.

When improvements to network-based applications force system rescaling, two strategies are possible (both may be employed simultaneously). First, assume use of "thin clients." That is, forcing a few servers to grow by a factor reflects the maximum dynamic user demand possible at any instant. Alternatively, assume use of "thick clients;" forcing all client machines to "grow a little," which may result in a "trickle down effect" to end-user systems, which is unacceptable. Interoperability should be achieved by vendors providing direct native support for a particular platform or cross platform support. Relative to the client/server architecture, support for nontraditional, non-PC devices should be done in such a way that new devices are fluidly integrated with those already in use in the military.

Wireless local area networks (LANs) are a new and exciting addition to the realm of networking, particularly with WCs. Wireless LANs offer cheaper installation costs than wired networks, as well as scalability and roaming. However, although they are easy to install and configure, their throughput may be too limiting to offer a suitable substitution to existing wired networks.

CONCLUSION

Much research is still needed, but new modes of human-computer interface will certainly be developed. For example, input may be via the wearer's camera tracking a "finger mouse." A worn computer that is constantly attentive to the wearer and the environment would assist the wearer with perceptual intelligence in daily activities. A sophisticated WC has potential as a "visual memory prosthetic" or perception enhancer, enabling the wearer to see things otherwise missed and to better remember items of note. Visual filters can be incorporated to study the otherwise unseeable; a freeze-frame capability, for example, would enable seeing propellers in motion. The user might transmit a sequence of images to show colleagues where he or she has been, in a kind of shared visual memory. HMDs could also computationally augment visual perception in real time. For example, virtual images could have attached labels for easier processing in a complex field environment. A community of wearers could have a networked "safety net" via the ability to see exactly what others see or by monitoring each other's physiology (Mann, 1997).

Voice recognition as an input alleviates the need for manual interfaces. Hands-free operation generally means less time is required for data entry and retrieval. Heads-up displays permit simultaneous operation of various options without keyboard or mouse. The screen can be variously visible or overlay the real-world scene for textual or graphical processing. Miniaturized into eyeglasses, the unobtrusive apparatus permits interaction both with the computer and other personnel. Many devices include connectors to support PC peripherals such as mice, keyboards, VGA video, serial ports, and audio I/O. Some permit plug-and-play enhancements.

Clothing is a natural way to carry a processing device, and by wearing the device it is always ready for use. Component miniaturization has enabled wearable systems that are almost invisible, so that the user can move and interact freely. A number of military functions could be performed more readily or efficiently with the use of WCs. These devices will continue to gain social acceptance due to improved miniaturization and the proliferation of similar devices, such as cellular phones and pagers.

Future network application system support "improvements" cannot dictate operating system updates that demand more powerful hardware. New functionality must not be achieved at the cost of continued compatibility conflicts with in-place technologies already deployed-and-trained in the active military forces. The more ubiquitous a system is to the military, the more the military will be wary of "improvements" or changes. Concerning the tactical intemet, the importance of network-centric applications is being emphasized at the undergraduate level in many universities, including USMA. Here, for example, all plebes (freshmen students) develop their own home pages and many senior-level systems design projects involve the development of Internet or intranet-based applications and, in the near future, thin-client wearable/handheld computers will be used in many projects.

In March 1997, the Army conducted an Advanced War-fighter Exercise (AWE) at the National Training Center, Fort Irwin, CA (AUSA, 1997a; Time, 1997). The AWE put many of the Army's newest high-tech systems to the test. In particular, the light infantry soldiers were equipped with the dismounted soldier system unit (DSSU), an experimental WC and communications system, using a variety of commercial and government components. While the infantry soldiers reported that the DSSU enhanced their communications capabilities, they also found it heavy, bulky, and fragile (Griggs, 1997). The DSSU, however, is not intended as a fieldable system; instead, it is serving as a prototype for the fully integrated, smaller, and lighter Land Warrior system, which the Army plans to start fielding in the year 2000 (Aninger & Hubner, 1997). The initial outcome of the AWE test indicated a draw (Wilson, 1997), but the Army's leadership and doctrine writers will undoubtedly study this exercise well into the future.

General Hartzog, then Chief of the Army's Training and Doctrine Command, stated that the 2 1 st Century Army must have information dominance on the battlefield (AUSA, 1997b). The AWE is at the heart of determining future requirements, and the Army plans to field a completely digitized division by 2000. That "Experimental Force" will test and measure the impact of information technology on future combat in terms of communications, computer hardware, and software (AUSA, 1997c).

The United States Military Academy has the mission of producing leaders capable of meeting the rapidly changing face of technology in today's Army. West Point student and faculty research can and should focus on the future needs of the Army. By using existing ties between the Academy, ARL, and other research centers, new ideas can be explored by initially developing them, and then turning the results over to the appropriate agencies for further development.

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