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EVOLUTION OF 360 DEGREE LOCAL SITUATIONAL AWARENESS (LSA) TO AID THE WARFIGHTER

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ABSTRACT

Northrop Grumman has developed a software and hardware solution to provide enhanced 360 degree local situational awareness (LSA) to enable the warfighter with an overmatch capability on today's modern battlefield. The architecture exploits technological gains in cameras, video processing, and video compression. The approach allows rapid comprehension of local and remote situational views presented with operational relevance for a ground combat platform or tactical wheeled platform crew. The 360 Degree LSA approach provides direct visualization of relative positioning of targets, threats, and lines of fire; and additionally offers common situational understanding / operational picture from the dismounted soldier to higher echelon commands. The approach provides prioritized information through LSA software to provide an enhanced view to the warfighter whereas the squad leader becomes an integral part of the crew with a view of the common operating picture (mounted) and additional sensors on tablet or handheld device (dismounted via wireless). The approach uses a platform agnostic form factor with components that can be selected and applied to legacy or new platforms based on their size, weight, power, and mission constraints.

INTRODUCTION

Imagine yourself a modern day mounted soldier, spending downtime connected to the rest of the world through modern electronics. The weather, news, contact with friends and family are all in the palm of your hand. That same soldier, while in training and in combat, is given a mission brief standing around a paper map with grease pencil graphics, closed up in the back of a vehicle that they cannot see or hear out of, dropped off in an unfamiliar environment (potentially under hostile enemy fire) and is expected to adapt, fight and overmatch an uncertain and changing threat. Given the amount of technological aids and information potentially available to this soldier, this is a recipe for failure.

Now imagine that same soldier, during mission planning, with the capability to see a three-dimensional (3D) model of his/her area of operations populated with video overlays taken the day prior or even more recently. That soldier, while tethered to the vehicle platform has access to perform virtual rehearsals with fellow squad members. That soldier receives current weather and threat ("be on the lookout - BOLO") situation information. That soldier is able to share any video or weapons sight view to enable closer coordination with the vehicle crew. That soldier is able to see through the vehicle armor using external networked multispectral cameras integrated in the Indirect Vision System (IVS), understand the situation and terrain, and know exactly where the mission objectives are relative to the current vehicle position. This soldier now has leveraged the modern tactical advantages gained through the use of integrated LSA technology and has the confidence necessary to overmatch and dominate an enemy threat. This alternative scenario provides a greater likelihood of success.

Vehicle crewmembers currently have access to basic Situational Awareness (SA) data through the benefit of the Tactical Internet (TI). The next logical step in providing enhanced 360 degree LSA capability to the warfighter is by implementing 360 degree / Three-Dimensional Situational Awareness (360 3D SA) and making it available to all crewmembers and squad soldiers. This capability will use inter-vehicle sensors and communications to provide a ground level view of the mission Area of Operations (AO) represented as a 3 dimensional map painted with the actual environmental textures and colors. Friendly and threat data is integrated into the 3D map and periodically refreshed. This technology provides actionable intelligence simultaneously at multiple levels and better prepares a squad for operations.

BENEFITS TO THE WARFIGHTER

When Force Battle Command Brigade and Below (FBCB2) was first introduced, it was hesitantly embraced by commanders and soldiers alike. Concerns surrounded the reliability of the electronics and currency of the shared battlefield information. Through continued training and practical application, the value in the analog to digital transition was transformational for the Army at the tactical and strategic levels. The sharing of information across the battlefield helps commanders to understand the placement of units and enemy, obstacles to mission success and aids decision making to overcome those obstacles. Enhanced 360 LSA brings similar advantages down to the lowest level of combat operations, the vehicle platform and squad level (small unit).

Small Unit Commanders

Small Unit Commanders will be able to visualize the area of operations in a more intimate and detailed way both pre-, during and post- mission using information gathered and compiled from many different data sources, being scalable to accept data from present and future sensors.

Small Unit leaders will be enabled to follow through on the old adage, "trust, but verify". Through video and photo sharing targets and scenarios are better described. What may now be reported as a mob of 100 people congregating in the village square, through a simple picture, could be revealed as nothing more than a hotly contested community soccer game. In this example, "a picture can be worth a thousand words", with the capability potentially saving lives.

Enhancements in 360 LSA can enable leaders to share their commander's vision through detailed mission walkthroughs using 3-D digital sand-tables, compiled from intelligence gathered from manned scout missions, other squads and Unmanned Aerial Vehicles.

Vehicle Commanders and Crews

A 360 LSA supports better inter-vehicle communication and collaboration, as well as more effective operations with the dismounted soldiers. Enhanced 360 LSA supports target handover and cueing inter- and intra-platform. Video and still photos can be shared between weapon sights and the Indirect Vision Systems (IVS) users on the platform. Three dimensional environmental models and route planning applications help crews determine safe routes that provide both vehicle cover and concealment. This type of toolset will also help vehicle crew effectiveness in missions like: support by fire, squad link-ups and extractions during the "fog or war".

Dismount Squads and Teams

Enhanced 360 LSA allows dismounted squads and fire teams to perform detailed planning and execution at a lower level. At a drop-off location, the squad may know their general position and orientation, but in combat it is critically important to know how to get from the vehicle to the first covered position when the ramp drops and the squad disembarks from the platform.

The squad is capable of receiving situational updates and mission change information effectively on the move. It is not a question of "if", but more a question of "when" things change. While the soldiers have limited resources to replan, the squad will, in the future, be provided the resources to understand and visualize the changes, disseminate new plans and conduct effective virtual rehearsals.

One of the key characteristics of the U.S. Army that has been critical to its success is the adaptability of small unit leaders to complete the mission without significant oversight and direction. Enhanced 360 LSA provides information and tools to the individual soldier, increasing each soldier's capacity and likelihood to contribute positively to the effort.

<u>The following represent the operational relevance of Enhanced LSA</u>:

- Rapid comprehension of local and remote situation
- Direct visualization of relative positioning of targets, threats, and lines of fire
- Common situational understanding / operational picture from dismounted soldier to higher echelon commands
- Graphical representation of LSA that is immediately available to support dismounted planning and dismounted operations.
- Collaboration of squad leader and fire team using the common operating picture (COP) for mission planning
- Mission scenarios simulated within a virtual environment

CHALLENGES

While the desire to provide more information to the warfighter has been strong, there are technological hurdles that limit the productization of enhanced 360 LSA initiatives. Most of these limitations fall into a few key areas.

Resolving, Defining and Managing User Needs

User needs drive system requirements, which in turn drive technical requirements which affect product design. The robustness of commonly available commercial communications systems (smartphones, tablets, WIFI etc.) coupled with mainstream media science fiction has led to certain expectations within the customer domain. Speed of service, quality, reliability and cost of the capability set must be balanced appropriately for the situational needs.

Defense and commercial applications share some of the same requirements. Speed of service and reduction of data latency, whether for position reporting between platforms, near-real time camera data, or system startup times, are highly desired and push the limits of COTS computing solutions, which is forcing innovation in systems and component design.

Defense applications also have domain unique issues. Required DRI (Detection, Recognition, and Identification) ranges in various environment using passive methods are more achievable based on availability of evolving digital cameras and optics design. As better cameras become available, visual acuity for camera and sight systems has become more accessible for Local Situational Awareness and targeting solutions.

Secure infrastructure data communications bandwidth is far more limited in most military applications. Scaling expected performance based on the compromises required to perform within the available bandwidth is a challenge. Defining the proper data standards for a 360 LSA system has also become increasingly difficult as new standards emerge and evolve along with the resources required for new camera resolution advances, as systems architectures built around low bandwidth cannot easily scale with exponential changes in data throughput.

Balancing Technical Performance

For large ground vehicles, ensuring reliable 360 degree visibility (at a reasonable unit cost) typically requires a combination of multiple multispectral cameras, significant computing resources, large aperture separation and wide Field of View (FOV) lenses. There are secondary effects of these characteristics of design that must be considered: system cost, data latency, parallax, and optical quality.

Typically the greatest cost of a multispectral 360 degree camera system on a platform is in the cameras. In LSA systems design there is a desire to use as few as possible. In a fixed aperture architecture, this leads to large FOV optics dispersed around a platform. In order to support DRI ranges across a large FOV, more pixels and less noise must be produced by the cameras, driving both video data bandwidth and camera/lens quality. For distributed data collection devices (LIDAR, cameras) parallax created by the need to distribute sensors to maximize coverage over a large vehicle is something that needs to be addressed, as the visual artifacts may be misleading to system users (i.e. blind spots, duplication).

There are costs and technical complexities associated with capability reliability. Soldiers find ways to use and leverage reliable capabilities, while ignoring unreliable capabilities that become a distraction from mission accomplishment. Soldier and equipment safety must be considered in every new capability provided. The limitations of the system should not be easily overlooked or taken for granted. Both electronic redundancy and non-electrical manual backup capabilities should be considered in the soldier use cases and design. A reliable network and computing infrastructure needs to be provided for reliable performance. Reliability of each component needs to contribute to the total subsystem requirements.

The delay from photons into a camera to the time in which the user perceives change in the visual environment is often used to characterize a video system. The need to more precisely time synchronize data and optimize a full motion video experience requires data synchronization through the sensor suite, which limits the use of common, cheap, non-deterministic subsystem components and software. To achieve ultra low data latency in a high bandwidth environment requires specialized data handling hardware, deterministic data processing, optimized video processing components, and data synchronization. Depending on the data rate of the system, out of phase processing can cause significant delay between perceived and real environmental change. This desynchronization most commonly leads to a negative user experience due to mental fatigue and motion sickness.

To perform effective data collection, correlation and processing, significant computing and processing power is required. To reduce network loads, data compression is often necessary. Each compression technique contributes to overall data accuracy and resolution. Data storage is both a capability and a burden. While valuable for after action reviews and intelligence gathering, the amount of raw data captured must be well managed. What to record, how long to keep it, how to offload and secure the data must all be addressed in a complete solution. Computing resources and data storage strategy are key drivers of system Size, Weight and Power (SWAP), which is a key set of attributes by which a capability is currently measured. High SWAP is undesirable as it increases physical and power loads on personnel and platforms alike.

Creating a User Experience

The user experience must be positive or the soldiers will discount the capability, no matter how technically good it is. Managing motion sickness and soldier cognitive workload are key drivers in developing a positive user experience.

Motion sickness is a common and complex 360 LSA problem that is not easily measured or addressed. The degree to which motion sickness is felt is a combination of personal physiological factors (innate sensitivity, age, level of hydration, food consumption, shape of inner ear) and the external environment (i.e. temperature, smells, stimulus, frequency of motion, disparity between motion and expectation of motion). It is easier to think of each person on a sliding scale between two opposites: unaffected and incapacitated. Each person starts somewhere on the scale based on the internal factors, and the external factors start to push either way. The goal in 360 LSA system design is to significantly consider the controllable factors in user interface (UI) design to minimize negative external factors.

With the increased availability of sensor data, it becomes increasingly important to acknowledge potential additions to soldier cognitive workload. Overwhelming a soldier with data can be as incapacitating as not giving a soldier any data at all to make decisions. Local Situational Awareness raw data integrated in a cohesive and simple fashion is key to utility, and its importance is often overlooked.

Difficulties of System Evaluation

Assessment of the effectiveness of a 360 LSA systems performance is difficult. While modeling provides a repeatable way to assess system performance, not all real world variables can be accounted for. The reliability of the model is highly dependent on the strength of the assumptions, algorithms and relevance of the data variables.

In a fiscally constrained environment, it takes innovation and compromise to define, procure and integrate a solution that provides value to the soldier. An incomplete solution is a liability.

SOLUTIONS

Technical Solutions

Consumer and commercial applications are continued drivers of innovation and advanced design which feed into military LSA applications.

Advancements yielded from security and personal photography continues to stimulate innovation in camera and optics design. Consumer color cameras built for use in outdoor and extreme sports has created a commercial market for low-cost, rugged, high frame rate, high resolution, and compact cameras which are also a great fit for the military market. Low cost cameras for enthusiasts of all types have helped to create a pool of developers of video and imagery applications from image quality improvement and optimization to 360 video stitching.

Smart cameras are comprised of not only light sensing/measuring elements and lenses, but now have embedded processing capabilities that allow image enhancements before becoming output from the camera. If data bandwidth comes at a premium price, then each pixel that leaves the camera should be optimized.

In the specialty camera market, trends indicate a reduction in pricing of cooled detectors and SWIR technologies which make these effective tools more affordable.

As the data to be distributed has grown exponentially with higher resolution cameras and greater amount of available sensor data, it has outpaced cost effective data routing infrastructures, so low-loss/lossless data compression has become an area of increased study and innovation.

Data communications, transport mechanisms and interface standards are evolving to keep pace with the increased data flows. GigEVision 2.0, USB 3.0, and the use of fiber optics (single mode and multi-mode) are examples of supporting technologies oriented on data routing for higher total bandwidth and faster throughput rates. With the increased capability in video distribution and handling, taking video footage for “sharing” has become a part of human culture as evidenced by the number of videos hosted on internet sites like Youtube.

The video gaming industry has created a market for Graphics Processing and GPU advancement. Compute Unified Device Architecture (CUDA) processing on General Purpose Graphics Processing Units (GPGPUs) and Direct Memory Access (DMA) transfer efficiencies are advanced features that will likely be leveraged by designers of LSA systems to lower SWAP and support low latency designs through more efficient data transfers.

UI Solutions

Work yielded from the commercial market supports the development of a more intuitive UI and positive user experience. The commercial market represents a rapidly expanding testbed which iterates quickly with a large sample size. By using an established baseline from the consumer electronics UI design, through iterative modeling and user trials an effective soldier UI can be designed, tested and evolved into something useful to soldiers and requires minimal training.

Automotive designers face similar challenges to the military environment and have solved issues in some very savvy ways. One of the key tenets is only show the user what they must know, not what they might need to know. Backup cameras, pedestrian detection and obstacle avoidance warnings, laser adaptive cruise control are no longer only found on flagship vehicles, but have migrated down as technology packages available to most vehicles.

In order to make the data accessible to users, display technologies must be integrated in soldier space. Rugged, low power, high resolution displays are commonly available in various platform sizes ranging from tablet size (8 inch) to full platform crew station size (17 inches and greater). With advancements in Projected Capacitive Touchscreens (PCAP), multi-touch gestures can now be recognized and used for common functions, such as zoom.

Evaluation Solutions

In addition to Army standardized camera modeling tools, evaluation of Modulation Transfer Function (MTF) helps to assess both nominal and off-axis, sub-nominal performance as a characteristic indicator of performance.

Experimenting and assessment of 360 LSA in real world is a great way to progress beyond modeling and simulation. It is not expensive to craft a low cost non-rugged capability. Modeling, followed by exercise (structured and unstructured) of prototypes in relevant environments involving soldiers provides a cost effective path to evolving a useful LSA system.

EMERGING LSA RELEVANT TRENDS AND TECHNOLOGIES

As we look forward to providing advanced 360 LSA to each individual soldier, there are trends that provide indicators of upcoming and relevant technologies.

Full motion video from remote sensors

As remote sensors become more prevalent in the military environment, the bandwidth, processing and user interface to the valuable data that these sensors provide must be managed. By providing ways for the user to carefully select the data that they need at any specific time will help to manage the data.

Adaptive Mode/Dependent GUIs

Adaptive/Mode dependent GUIs will be designed to provide the right information for a particular user role during a particular set of conditions. Adaptive UIs are starting to be adopted by many automotive manufacturers. Based on user mode selection, sensing of environmental conditions and driving characteristics, users will see data that is unique to their driving style. A basic example of the application of this philosophy is that a driver’s parallax correction can be speed dependent, while the rest of the crew has a parallax fixed based on operational mission and detection distance requirements.

Head Mounted Displays

Head Mounted Displays with head motion sensing technologies may allow for traditional displays to be removed and a more natural viewing experience of the virtual environment. Two types of HMDs are becoming popular, both with their own advantages and disadvantages: Augmented and Virtual Reality.

Augmented Reality, similar to the capability provide by Google Glass provides information about a particular physical scene, without losing or having to recreate the environment for context. It is more like a Heads-up display that adds indictors, attributes and tags to existing real objects.

Virtual Reality, as provided by hardware similar to the OCULUS Rift, supports an immersive experience, where the user is insulated visually from the external environment. Context is only provided within the virtual reality construct, making the accuracy of the construct very important. If it is not modeled, then it is not perceived by the user and planned for or acted upon.

3D Representation of the Battlefield

3D modeling of the battlefield will serve several key purposes: training, mission planning, rehersals, and situational awareness.

3D Virtual Training will allow users to visualize and prepare for missions. Enhanced LSA products will enable 3D Visualization, essentially a more complete recreation of an area of operations, created through collaboration of active and passive sensing elements and intelligent data assembly. Having access to an accurate 3D model populated with situational awareness data is truly the next step forward in battle command and LSA. With greater resolution of the battlefield conditions, mission preparation can be more detailed and engaging.

CONCLUSION

Providing enhanced LSA provides benefit at all echelons

<u>An Enhanced 360 LSA capability is vehicle agnostic and will bring many of the stated elements together to achieve the following:</u>

- Common, near-real-time, 3D, augmented reality view of terrain, structures, obstacles, vehicles, and personnel
- Multi-vehicle ground level view of the mission Area of Operations
- Actionable intelligence simultaneously at multiple levels
- Free flight and zoom throughout the space, with recall and playback over recorded history
- Networked ISR and mission command data feeds with mounted and dismounted LSA data feeds
- Augmentation of the Common Operational Picture (COP) by transmitting additional wireframe data for other vehicles over data radios
- Prioritized information for the warfighters through maturation of Local Situation Awareness (LSA) software to provide an enhanced view to the warfighter
- View COP on tablet or handheld device (mounted or dismounted via wireless)
- Multiple video feeds from multiple platforms (LSA cameras, sights, UAVs, UGVs) to populate LSA picture
- Applications to pass data from vehicle to a dismounted squad via data radio
- Users can pass sectors of fire based on Target Reference Points (TRPs)
- Electronic range card
- Platform-to-platform still imagery transfer through data radio
- Augmentation of the warfighter’s decision-making capabilities

Local Situational Awareness must be well designed and executed if it is to create value and combat enhancement to soldiers. A system must manage soldier workload, and provide reliable decision aids.

Intelligent implementers will use commercial User Interface context for a natural transition and to minimize training. These UIs will alert soldiers primarily when inputs/actions are required, not just because. Using a signal processing analogy, we want to find the signal in the noise and make that as clear for the user as possible.

Local Situational Awareness allows all soldiers to contribute more. By providing a squad access to platform camera system, you now have many more observers looking for threats to the vehicle and mission. Everyone is clear on mission objectives, terrain, friendly and enemy situation, even when it changes. Informed users can offer better solutions, allowing soldiers at the lowest levels to become greater influencers of mission success.

References: None