SmartCam3D Provides New Levels of Situation Awareness

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SmartCam3D (SC3D) is a hybrid synthetic vision system that combines live sensor information with data from a synthetic vision system to create a virtual cockpit window. This combination of technologies allows the system to circumvent some of the limitations from each approach. SC3D is supporting various Department of Defense, NASA, and commercial industry endeavors related to the operation of tele-operated and windowless cockpit designed vehicles.

The pertinent information related to the environment and operational envelope of a vehicle is commonly referred to as situation awareness (SA). A lack of SA is responsible for numerous aircraft accidents that claim hundreds of fatalities per year. Additionally, the monetary cost associated with poor SA is in the billions of dollars due to lost aircraft, increased training time, decreased capabilities, and operational inefficiencies. The Department of Defense (DoD), NASA, and the general aviation industry have all lost important assets because an operator did not have adequate SA.

The development of a visualization system that would greatly improve a pilot's SA would prove very valuable to both government and commercial organizations. SmartCam3D (SC3D) was developed to serve this function and has provided SA to pilots at levels not previously possible.

Development of SC3D principles and technology components began in 1996 as parallel efforts by Rapid Imaging Software (RIS) and NASA. RIS was developing a commercial product that would allow for the visualization of terrain. At the same time, NASA's Johnson Space Center was developing visualization technologies that would be used on the X-38 program. The X-38 program was a technology development program that was building a series of flight-test vehicles to determine what would be required to develop a fully functional crew return vehicle for the International Space Station. In 1997 both organizations developed a collaborative partnership to develop an advanced visualization system that would greatly enhance a pilot's SA.

A hybrid synthetic vision system (HSVS) combines live sensor data with information from a synthetic vision system (SVS) to create real-time, information-rich visuals. An SVS provides a computer representation of the operational environment and is typically created using digital elevation data, imagery, maps, charts, vehicle models, etc.

SVS visuals are typically full of information and can be used during day, night, or low-visibility conditions. An SVS by itself can suffer from *data freshness* problems. These problems can occur because the SVS visuals are created from data typically collected by a satellite or aircraft flying overhead, meaning the data could have been collected days, weeks, months, or years ago. In a dynamic environment, the information could be outdated and provide obsolete or inaccurate scene information.

A live sensor system can provide up-to-the-second information for the region of interest, but by itself is not very useful when visibility conditions are hampered by rain, snow, sand, fog, and smoke, which are frequently encountered by vehicles.

HSVS visuals allow the user to circumvent some of the limitations from each separate approach by providing real-time information-rich visuals. SC3D has become the government's premier HSVS system. The SC3D system, with its innovative concepts and one-of-a-kind software technology, blurs the traditional distinction between visual and instrumented flights/operations.

Strategies and Methodologies

The team organization played an important factor in the overall success of the SC3D. This team included experts with hands-on experience in software development, human factors, visualization, configuration management, avionics, and aviation piloting. Other major factors that played a significant role in the success of the SC3D system were the processes that were followed and the design decisions made during the planning phase.

The system was developed using a spiral development approach implementing agile programming practices, object-oriented design (OOD), and object-oriented programming (OOP). The team also followed a rigorous quality assurance program throughout the entire development, implementation, and deployment life cycle. Spiral development has allowed users to see an increasingly more functional system throughout the development of the SC3D system. It also allowed for an iterative approach to requirements development by providing successive spiral cycles that contained the lessons learned from previous spiral cycles. Agile programming permitted the developer to incorporate user feedback into the software within each spiral cycle. The OOD and OOP principles simplified maintenance, reuse, and capability augmentation of the core technologies.

Any problems encountered could be quickly isolated to individual components making problem identification and resolution much easier. As new capabilities were needed, the various components were easily created/modified. Although the SC3D system has more features than any visualization system currently available and supports real-time visualization of very complex environments, reliability has always been the most important factor. An intense quality assurance process was utilized that allowed for the development of a product that users could trust to work. New algorithms were verified theoretically and experimentally before being added to the source code. Beta test versions of the algorithms were extensively tested by various organizations composed of users from NASA, the DoD, and industry. Bug reporting, tracking, and resolutions were included in the software quality assurance process.

SC3D, which is comprised of approximately 64,000 lines of code, has met the required specifications regarding performance, functionality, and reliability. The initial performance requirement called for refresh rates between five hertz and 10 hertz. Testing indicates that the SC3D system provides much better performance than this, with refresh rates between 10 hertz and 30 hertz. The system functionality requirement called for enhanced SA to be provided to operators of remotely piloted vehicles. The successful integration and use by multiple military branches, various NASA programs,

and many other government, commercial, and education organizations is proof that the system can provide windowless cockpit and remote ground station (tele-operation) visualization. The embracement of the SC3D system by many organizations, where lives depend on the reliability of the information, is a testament to its excellence.

Weekly and quarterly reports were used as part of an Earned Value Management process to track schedule, budget, and deliveries. Weekly reports highlighted the technical accomplishment for the week and outlined what would be done the following week. Quarterly reports were comprehensive and included the money allocated for the quarter, percentage of physical work completed to date, and the work that would be performed the upcoming quarter. The average Cost Performance Index and average Schedule Performance Index for the third SC3D spiral development cycle of the project were 0.99 and 1.0 respectively. The SC3D project met or exceeded all scheduled software, hardware, and documentation deliveries.

User Base

A testament to the enormous capabilities, quality, and reliability provided by the SC3D system is the large number and diversity of users that have enjoyed the benefits provided by the SC3D system. SC3D usage consists of individuals from more than 90 different organizations, including the following: DoD, NASA, education institutions, research institutions, European Space Administration, and many industrial organizations.

The SC3D system supports several branches of the military by providing functionality in many major areas that include combat/reconnaissance visualization for unmanned aerial vehicle (UAV) operators, development of new human interface concepts for pilots, training of new and experienced pilots, and supporting troops in combat. SC3D will also play an important role as a recruitment tool such as the following:

- The Advanced Systems and Concepts Office, in the Assistant Deputy Undersecretary of Defense (ADUSD) office, has been investigating many uses of SC3D for the warfighter. Cmdr. Thomas Moore, special assistant in the ADUSD office noted:

  > SmartCam3D is truly a one-of-a-kind breakthrough technology in situation awareness. There is no other software currently available that provides these benefits to the warfighter. [1]

- The Air Force Research Lab (AFRL) is using SC3D technology to develop new interface paradigms for UAV operators. The AFRL Interactive Visual Interface Environment for UAVs program has integrated the SC3D system with a Predator simulator to create an excellent environment to test new human interface concepts related to the tele-operation of Predator UAVs. As Dr. Mark Draper (Human Effectiveness Directorate - AFRL) noted:

  > Within the past year, this effort has been successfully demonstrated and briefed to the commanders of AFMC, AFRL, ASC/RA and ACC/DR UAV SMO among others … The Air Force clearly sees the potential that SmartCam3D technology provides. [2]

- The SC3D system has provided commanders/soldiers with enhanced battle SA. Operators with the 1-14 Cavalry in Iraq noted:

  > Our current mission is Force/Perimeter Protection since our immediate threat is very real and very close. Every OP [Observation Post] that hears or sees something we respond to. Having the SmartCam-3D overlays assisted in our response time. [3]

- The SC3D system will become an extremely important recruiting tool. As a project office representative with the 1st Stryker Brigade Combat Team noted:

  > SmartCam3D is a big hit with the soldiers. SmartCam3D could become the Army's biggest recruiting tool to encourage young video gamers to enlist and re-enlist. [4]

Another major user of SC3D is NASA, which is using the system to support endeavors related to flight/aviation safety, visualization requirements definition for future spacecraft, mission planning, flight safety/operations, and visualization for future Mars and Lunar rovers. SC3D technology, which includes VisualFlight and Landform, is also supporting various endeavors related to basic research, accident investigations, educational outreach, entertainment, and other efforts.

Summary

SC3D is the first real-time HSVS system. Its component-based architecture allows it to be easily incorporated into other software applications. The processes, technologies, and early inclusion of user feedback played a critical role in the highly successful nature of the SC3D system. Its numerous innovations make it easy to use and provide numerous capabilities not offered in any other visualization system currently available. SC3D technology reduces uncertainties, minimizes costs, and improves safety.

Its large user base includes many federal government agencies, various education institutions, the European Space Administration, many commercial companies, and the entertainment industry. This large user base and highly successful flight utilization are a testament to the usability and quality of the software. The improved SA that SC3D provides has proven very valuable to U.S. troops in combat operations, reconnaissance missions, and is helping to neutralize terrorist threats. As a project office representative with the 1st Stryker Brigade Combat Team noted, "This software [SC3D] will save lives."◆

References

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