Cover Page and Abstract (1 page maximum)

Contestant:	FactualVR, Inc.
Application Title:	MR-LAW: Mixed Reality User Interface for Law Enforcement – Hostage Situation
Point of Contact:	Eduardo Neeter eneeter@factualvr.com

FactualVR is a company dedicated to researching, developing and commercializing groundbreaking virtual reality-based technologies that improve law enforcement investigation and prosecution capabilities. FactualVR was founded in 2016 and has established partnership with several Law Enforcement agencies in the North East and the Mid-West. We have significant experience developing for room-size VR using HTC Vive and work with both Unreal and Unity engines.

HUD interfaces traditionally consist of super imposing semi-transparent images in a transparent display. User input is mostly constrained to adjusting his/her position and/or orientation relative to a scene. There is a need to adopt interfaces with rich input capabilities (e.g gestures, voice command, etc.) and that can incorporate future sensors and display technologies.

We assume the HUD interface would be part of an overall HMD device. The main difference to highlight between HUD (as an interface) and HMD (as a device) is that the HMD device will have – in addition to the display itself – other internal and external cameras and sensors to enable additional capability that we envision will be commercially available in a not so distant future.

The HUD Interface will be a Mixed Reality (MR) interface. It will consist of a fully immersive VR HMD. Instead of displaying the computer-generated objects superimposed on the real world by using a transparent display, the proposed interface will completely replace the user's field of view with a real time stereoscopic video and data feed sourced from cameras and sensors embedded in the user's HMD.

Our approach provides a new layer of persistence for arranging and interacting with UI elements. In addition to allowing UI elements to persist relatively to the user's head (widgets attached to the HMD), we introduce a "UI space" where UI elements can also persist around the user's body, particularly around the chest and waist (widgets attached to the vest and belt). This "virtual UI vest and belt" – which will mostly be interacted with through hand gestures and voice commands – will allow users to move UI widgets (like floorplans, video feeds, etc.) between each of these areas (i.e. persistent relative to head vs chest/waist).

As a deliverable, we will develop a prototype that can be transferred and tested in the provided VR environment. As primary objectives, the prototype will support the user in the following areas:

- Presenting data elements for facilitating decision-making
- Presenting data elements for facilitating navigation
- Providing input mechanism to toggle navigational options
- Providing input mechanism to toggle navigational objectives
- Providing menu mechanism to adjust functional settings

We will also develop a Route Planner/Evaluator engine and an Object Perimeter Identification engine. These modules will provide functionality to: 1) determine possible paths from one point to another, as well as evaluating the cost of each path based on multiple attributes and the relative weight of the attributes (weighted pathfinding); and 2) functionality to identify the visual perimeter of an object presented within the user's field of vision, to register and customize visual information around objects of interests.

Project Description (required) - 4 pages maximum

The project description is structured in the following sections: 1) Knowledge, Skills and Capabilities, 2) Current State of the Art, 3) Competitive Advantage, and 4) Performance Metrics.

1) Knowledge, Skills and Capabilities:

FactualVR is a company dedicated to researching, developing and commercializing groundbreaking virtual reality-based technologies that improve law enforcement investigation and prosecution capabilities. FactualVR was founded in 2016 and has established partnership with several Law Enforcement agencies in the North East and the Mid-West, who are collaborating in the definition and direction of product features. Our software platform integrates the data obtained by sensors (e.g. 3D laser scanners, cameras, etc.) used to capture the facts around crime or accident scenes, and accurately replicate the scene in a shared collaborative immersive virtual reality environment. We have significant experience developing for room-size VR using HTC Vive and work with both Unreal and Unity engines.

Eduardo Neeter is the Founder of FactualVR. He earned his MBA in Management of Technology from the Georgia Institute of Technology, where he also enrolled in the Computer Science/Human-Computer Interactions graduate program. He also has a bachelor's in Systems Engineering. Mr. Neeter has more than 20+ years of experience with VR, starting in 1996 while working for ATR Media Integration and Communications Research Lab in Japan, and then during his tenure as graduate student at Georgia Tech. His professional experience ranges from early-stage tech startup to global financial services corporations.

Philippos Mordohai (Stevens Institute of Technology) is an Associate Professor of Computer Science at Stevens Institute of Technology, which he joined in 2008. Prior to that, Dr. Mordohai earned his Ph.D. in Electrical Engineering from the University of Southern California and held postdoctoral researcher positions at the University of North Carolina, Chapel Hill, and the University of Pennsylvania. His expertise encompasses several aspects of 3D computer vision, including image and video-based 3D reconstruction; structure from motion; 3D shape representation, and perception for robotics. Real-time algorithms for these tasks are an important aspect of Dr. Mordohai's work, since he serves as PI for two ongoing research projects on robotics funded by the National Science Foundation and the National Institutes of Health.

2) Current State of the Art:

There are multiple implementations of HUD interfaces that can be considered as State of the Art for diverse domains, but no single instance can be identified as the State of the Art HUD Interface for Situational Awareness for Law Enforcement in a Hostage Situation,

The closest example we are considering as benchmark are the systems used by soldiers in combat situation, like the Army's: Tactical Augmented Reality (TAR) and BAE Q-Warrior system.

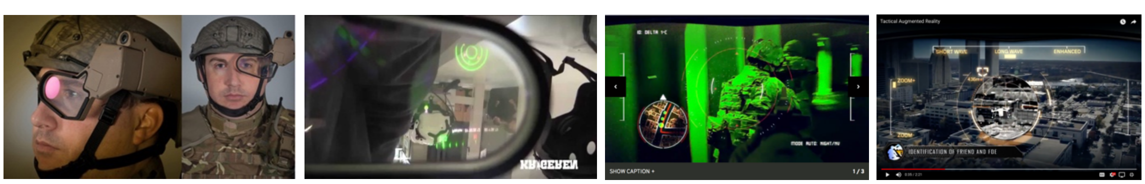


Fig 1 - Examples of Military HUDs for soldiers.

In addition, there are currently two strong use-cases for HUDs supporting users in the task of navigating from point A to point B. We grouped these navigation systems in two main categories, based on the environment in which they are used. The two categories are vehicular navigation and indoor navigation.

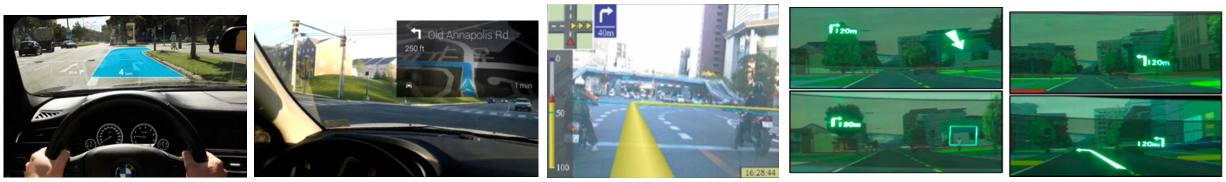


Fig 2 - Examples of Vehicular Navigation showing AR imagery on HMD and vehicle windshield

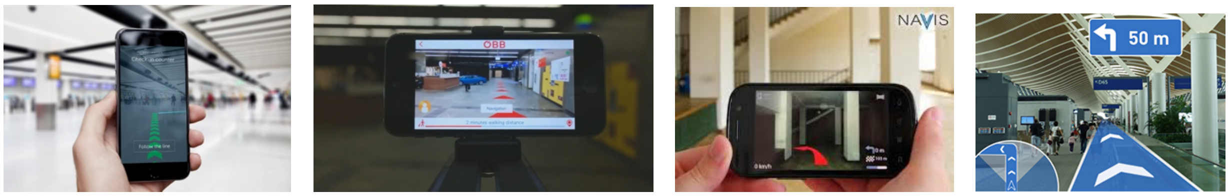


Fig 3 - Examples of Indoor Navigation showing AR imagery on hand held devices

2.a) Key shortcomings, limitations, costs, and challenges

- Limited to super imposing semi-transparent images in a transparent display
- Limited user interaction - the items displayed in the HUD are not easy to interact with.
- User input is mostly constrained to adjusting his/her position and/or orientation relative to scene.
- Most applications of personal HUD interfaces are suitable for wide areas, not quite for indoor use.
- Indoor apps are mostly concentrated in mobile/hand-held devices that occupy the users' hands.
- Need to adopt interfaces with rich input capabilities (e.g gestures, voice comand, eye-track, etc.)
- Need to design interfaces that will incorporate future sensors and display technologies as they become affordable (e.g. wearable cameras, 3D scanning, night vision, etc)

2.b) How to overcome:

- HUD vs HMD: We assume the HUD interface would be part of an overall HMD device. The main difference we want to highlight between HUD (as an interface) and HMD (as a device) is that the HMD device will have – in addition to the display itself – other internal and external cameras and sensors to enable additional capability that we envision will be commercially available in a not so distant future.

- The HUD Interface will be a Mixed Reality (MR) interface. It will consist of a fully immersive VR HMD (not a traditional AR-like interface). Instead of displaying the computer-generated objects superimposed on the real world by using a transparent display, the proposed interface will completely replace the user's field of view with a real time stereoscopic video and data feed sourced from cameras and sensors embedded in the user's HMD.

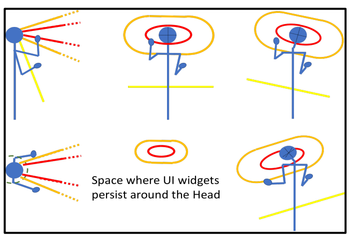
- The HUD interface will assume that the HMD has depth sensors (infrared, laser, etc.) and will allow the registration of computer generated 3D objects to the external/real environment visible to the user. We assume the 3D geometry of the scene is known and would be available for the system and the interface.

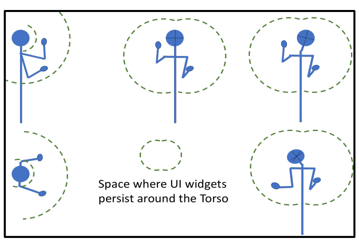
- The HUD interface will also incorporate multimodal user input and output, even if such capability is not currently affordable given the cost, size and performance requirements. Among these input and output elements we can list audio communication, voice commands, hand gestures, eye tracking, haptics, wearable devices, etc. The combination of these input and output extensions to the HUD interface would enable a richer and wider interaction area, accessible space between the user and the interface

3) Competitive Advantage

Our approach provides a new layer of persistence for arranging and interacting with UI elements. In addition to allowing UI elements to persist relatively to the user's head (widgets attached to the HMD), we introduce a "UI space" where UI elements can also persist around the user's body, particularly around the chest and waist (widgets attached to the vest and belt). This "virtual UI vest and belt" – which will mostly be interacted with through hand gestures and voice commands – will allow users to move UI widgets (like floorplans, video feeds, etc.) between each of these areas (i.e. persistent relative to head vs chest/waist).

In addition, we design the interface for a fully immersive AR/MR/VR experience. By this we mean we will design the HUD interface assuming the user wears a fully stereoscopic immersive head mounted device, with capabilities like seeing through objects to completely occluded environments, hand tracking, voice controls, etc.





UI element persistence relative to User's Head	The subset of graphical elements that are modeled and displayed as if floating within the user's field of view:	The subset of graphical elements that are displayed and modeled as floating around the user's body, irrelevant to where the user points their head.
UI element persistence relative to User's Torso	Images and UI elements are placed in space as if they were attached to the user's head. The UI elements persist in space relative to the user's head position and orientation.	Images and UI elements are placed in space as if they were attached to the user's body. The UI elements persist in space relative to the user's torso position and orientation.

4) Performance Metrics

4.a) What will be produced

Main Deliverables:	Description:	Supported Objectives:
HUD Interface	A prototype user interface that can be transferred and tested in the provided Virtual Reality environment. As primary objectives, the prototype user interface will support the user in the following areas:	• Presenting data elements for facilitating decision-making • Presenting data elements for facilitating navigation • Providing input mechanism to toggle navigational options • Providing input mechanism to toggle navigational objectives • Providing menu mechanism to adjust functional settings
Route Planner and Evaluator:	Functionality to determine possible paths from one point to another, as well as evaluating the cost of each path based on multiple attributes and the relative weight of the attributes (weighted pathfinding).	• Functionality support module

Object Perimeter identification:	Functionality to identify the visual perimeter of an object presented within the user's field of vision, to register and customize visual information around objects of interests	• Functionality support module

4.b) When it will be produced

Phase	Due Date	Milestones
Stage 1	1/26/18	This concept paper
Stage 2	3/9/18	1st HUD interface prototype running on Unreal environment
Stage 3	5/11/18	2nd HUD interface prototype and 1st Route Planner and Evaluator prototype running on PSCR environment
Stage 4	6/9/18	3rd HUD interface prototype and 2nd Route Planner and 1st Object Identifier prototype running on PSCR environment

4.c) How it will be verified

1) The development of the HUD interface will follow an iterative process. Specific design elements and UI widgets will be designed and produced using rapid prototyping techniques. Multiple design alternatives will be compared and evaluated to make the appropriate trade-offs and arrive to the final user interface design for each stage.

2) The development of the route planner and evaluator engine will leverage open source software and ongoing research at Stevens. If the size of the map is small, both stochastic and deterministic techniques will be used to generate routes, and a Support Vector Machine will be trained to rank route options for a given scenario according to static and dynamic elements in the scene. Training data will be collected through simulation. Re-planning will be performed periodically and immediately after major events.

3) The development of the object perimeter identification engine will follow and will be tightly integrated with the 3D object detection engine. Static scene geometry, available from maps and floorplans, will be used to detect hostages, partners and threats, while hazards will be pointed out by team members. The success of this engine will be measured by its effectiveness in placing virtual annotation on the perimeter of objects without obscuring the objects or cluttering the scene.

4) The required deliverable for each Phase will be provided as a downloadable executable file that can be run independently in order to verify the functionality. Appropriate documentation will be provided with each software drop.

Resume Information for Key Team Members (required - 3-5 pages)

Eduardo J. Neeter

20 Second Street #2202 • Jersey City, NJ, 07302 • eneeter15@gsb.columbia.edu • (201) 942-5112

FactualVR, Inc – Jersey City, NJ 05/2015 - present

Founder, CEO

Started a new technology venture to develop a Virtual Reality (VR) platform to help Law Enforcement and Prosecutors to accurately replicate and communicate the facts around a crime scene. ***Key Achievements:***

- Completed a Technology Accelerator program focused on idea-stage technology startups. Formulated idea and identified market, defined product offering and business model, filed patent and drove fundraising.
- Developed proof of concept to demonstrate basic capabilities to potential users, investors and stakeholders.

CIBC TECHNOLOGY AND OPERATIONS – Toronto, ON 12/2013-04/2015

Senior Director, Strategy

Managed the strategic planning process, including scenario analysis, communication process, and reporting for interactions of the T&O Head with the CEO, Board of Directors and Regulatory Agencies.
Key Achievements:

- Defined the Risk Appetite Statement for Technology and Operations, converged on the subset of Key Risk Indicators used to drive alignment and communicate periodically with Board of Directors and Regulators.
- Established a new Scenario Analysis function to prepare strategic responses to potential scenarios identified by T&O Senior Management Team as areas of interest. Equipped executives with proactive action plans.
- Developed and sustained strong relationships with front and back office executives. Managed stakeholders' expectations and promoted transparency of issues and decisions among participants to reach resolution.

CIBC DISTRIBUTION TECHNOLOGY AND CHANNEL STRATEGY – Toronto, ON 11/2010-11/2013

Senior Director, Strategy

Aligned the technology portfolio and roadmap with "Leadership in Client Experience" corporate goal. Realized mandate to integrate across Retail Branch, Call Center, Internet and Mobile Banking channels.
Key Achievements:

- Forrester and Gartner often cited CIBC Omni-Channel achievements as leadership among peers.
- Produced a 5-year Technology Roadmap for more than $400MM in investments that directly aligned with and enabled the Channel Strategy, setting priorities for multi-channel initiatives and common capabilities.
- Reengineered internal PMO processes, established metrics and dashboards to track initiative progress, issues and risks. Improved intake and estimation processes to enable enhanced investment governance.

FLEMINGS TECH – Panama City, PA / Caracas, VE / Atlanta, GA 11/2008-10/2010

Co-Founder, Product Strategist

Established a new business to develop and commercialize a brokerage technology platform for Latin America. Designed/architected the entire solution and managed relationship with outsourced developer. ***Key Achievements:***

- Analyzed market opportunities, defined business plan and obtained initial funding for new venture.
- Established partnership with key initial clients to gain understanding of business processes, regulatory environment, user requirements, and serve as focus group to influence and validate prototype design.
- Identified, selected and negotiated agreements with software development vendors to assure the successful execution of the project plan and aggressive schedule.

CITIGROUP MARKETS AND BANKING TECHNOLOGY – New York, NY 09/2006-10/2008

Vice-President, Strategy and Planning

Managed the Application Portfolio Management Program for over 3000 applications globally, supported executive decision-making leading to a 3-Year Application Roadmap and Investment Governance oversight for over $2.5B of technology programs and projects. ***Key Achievements:***

- Defined and implemented quantitative evaluation framework for portfolio of applications, resulting in Buy/Sell/Hold rating of technology assets, used to support decisions on capital allocation and investment.
- Managed program for applications retirement, 300+ applications retired in first year resulting in instant $16MM and ongoing $42MM savings. Expected results of $72MM net run-rate reduction for 3-year plan.
- Established Business Intelligence Center to perform analysis and reporting of overall portfolio, based on business architecture and taxonomy, cost drivers, technology diversity and geographies, among others.
- Re-engineered internal Technology Provisioning processes based on Six-Sigma best practices, leading to more than 30% lead-time reduction and run-rate saves of over $7MM in one year.

CITIGROUP OPERATIONS & TECHNOLOGY – New York, NY 07/2003-09/2006

Vice-President, Strategic Initiatives

Served as focal escalation point for over 30 global projects; helped define vision, facilitated strategy sessions, and oversaw implementation of initiatives targeted to reduce operations costs by 15% within a $3.5B budget over a five-year period. Remotely project managed presence in New York, London and Singapore. ***Key Achievements:***

- Led environmental, internal, and competitive analysis for internal technology division. Adopted the Balanced Scorecard methodology to create and measure comprehensive strategic implementation plan.
- Championed compliance with Citigroup Records Management policy affecting 110 countries and over 1,500 record types. Lead a global 47-member task force charged with adoption /roll out.
- Successfully adopted Information Technology Infrastructure Library (ITIL) and Control Objectives for Information and Related Technology (CoBIT) best practices to implement process improvement programs.

SEVERAL COMPANIES IN SILICON VALLEY – San Francisco, CA / Palo Alto, CA 09/1998-04/2001

Team Leader / Senior Software Engineer

Managed complete software development lifecycle, led the use of UML methods and CASE tools to produce system designs and architectures, programmed in Java, C++, and other languages. ***Key Achievements:***

- Attained more than 1/3 reduction in development cycle time by incorporating industry best practices within a commercial software development organization, resulting in improved new processes.
- Designed and developed Java user interfaces for the first web-based electronic trading system commissioned to the Stanford Research Institute (SRI Consulting) by the largest European bank.
- Developed proof of concept for new product offering based on intelligent agent technologies, speech recognition, global positioning, and cellular phones. Obtained initial round of funding.

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Additional Positions:

Market Research Supervisor, Procter & Gamble, Venezuela

Software Engineer, ATR Media Integration and Communications Research Labs, Japan

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EDUCATION AND CREDENTIALS

Certificate in Business Excellence / Executive Education • Columbia University – New York, NY
Negotiation and Decision-Making Strategies / Persuasion: Influencing Without Authority
Reinventing Innovation / Leading Strategic Growth and Change /
Driving Strategic Impact / Strategic Intuition

Master of Business Administration • Georgia Institute of Technology – Atlanta, GA
Graduate Certificates - Management of Technology, Entrepreneurship
MBA Student of the Year – National Society of Hispanic MBAs (NSHMBA)
Beta Gamma Sigma Honor Society; Georgia Tech Tower Award
Vice-President, Student Government MBA Class of 2003

Bachelor of Science in Systems Engineering • Universidad Metropolitana – Caracas, Venezuela
Governmental Acknowledgement; Thesis Honorific Mention; Dean's List
Founder/President, Computing Research Student Association

Human-Computer Interaction Graduate Courses – Georgia Institute of Technology – Atlanta, GA

PMP – Project Management Body of Knowledge

ITSM – Information Technology Infrastructure Library (ITIL)

Six Sigma – Green Belt Certification

Philippos Mordohai
Associate Professor
Department of Computer Science
Stevens Institute of Technology

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Tel: +1 201 216 5611 Email: Philippos.Mordohai@stevens.edu
URL: http://www.cs.stevens.edu/~mordohai

Professional Preparation

- University of Southern California, Los Angeles, CA, Electrical Engineering, M.S., 2000
- University of Southern California, Los Angeles, CA, Electrical Engineering, Ph.D., 2005
- University of North Carolina, Chapel Hill, NC, Computer Science, Postdoc, 2005-2007
- University of Pennsylvania, Philadelphia, PA, Computer & Information Science, Postdoc, 2007-2008

Appointments

2015 - present	Associate Professor, Department of Computer Science Stevens Institute of Technology
2008 - 2015	Assistant Professor, Department of Computer Science Stevens Institute of Technology

Selected Grants

1. NSF National Robotics Initiative: Autonomous Quadrotors for 3D Modeling and Inspection of Outdoor Infrastructure, PI: P. Mordohai. 09/2016-08/2019.
2. NIH National Robotics Initiative: An Egocentric Computer Vision Based Active Learning Co-Robot Wheelchair, Original PI: Gang Hua, PI since 09/2015: P. Mordohai 09/2014-08/2017.
3. NSF Robust Intelligence: Learning to Eliminate Heuristics in Stereo Vision, PI: P. Mordohai.09/2015-08/2018.
4. NVIDIA: CUDA Research Center, PIs: I. Florescu, R. Chatterjee, N. Ganesan and P. Mordohai, co-PIs: A. Compagnoni, J. He, G. Hua, G. Kamberov, H. Wang, R. Chandramouli, K. P. Subbalakshmi, J. Toland, K. Khashanah, S. Yang, G. Creamer, E. Gousgounis and W. Mason. 4/2013.
5. NSF Robust Intelligence: Uncertainty-driven Dynamic 3D Reconstruction, PI: P. Mordohai. 08/2012-07/2016.
6. DHS Exploratory Research: Development of Volumetric Imaging Methods for Reliable Detection of Nuclear Materials, PI: L. Mihailescu (Lawrence Berkeley National Laboratory), Stevens PI: P.Mordohai. 09/2010-10/2012.
7. Google Research Awards: Object Recognition in Large-Scale Scenes from Video and Point Cloud Streams, PI: P. Mordohai, co-PIs: G. Kamberov and G. Kamberova. 03/2010.

Selected Publications

1. C. Freundlich, Y. Zhang, A. Zhu, P. Mordohai, and M. M. Zavlanos. Controlling a Robotic Stereo Camera under Image Quantization Noise. International Journal of Robotics Research, 2017.
2. Y. Chang, M. Kutbi, N. Agadakos, B. Sun and P. Mordohai. A Shared Autonomy Approach for Wheelchair Navigation based on Learned User Preferences. Fifth International Workshop on Assistive Computer Vision and Robotics, 2017.
3. M. Kutbi, Y. Chang and P. Mordohai. Hands-free Wheelchair Navigation Based on Egocentric Computer Vision: A Usability Study. IROS workshop on Assistance and Service Robotics in a Human Environment, 2017.
4. H. Li, M. Kutbi, X. Lin, C. Cai, P. Mordohai. and Gang Hua. An Egocentric Computer Vision based Co-Robot Wheelchair, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2016.
5. A. Spyropoulos and P. Mordohai. Correctness Prediction, Accuracy Improvement and Generalization of Stereo Matching using Supervised Learning. International Journal of Computer Vision, vol. 118, no. 3, pp. 300-318, 2016.

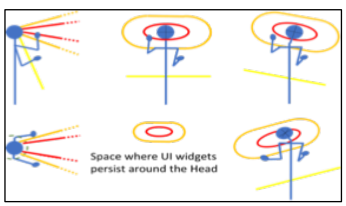
6. A. Spyropoulos and P. Mordohai. Ensemble Classifier for Combining Stereo Matching Algorithms.International Conference on 3D Vision (3DV), 2015.
7. I. Tsekourakis and P. Mordohai. Consistent 3D Background Model Estimation from Multi-Viewpoint Videos. International Conference on 3D Vision (3DV), 2015.
8. C. Freundlich, M. M. Zavlanos and P. Mordohai. Exact Bias Correction and Covariance Estimation for Stereo Vision. IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2015.
9. C. Freundlich, P. Mordohai and M. M. Zavlanos. Optimal Path Planning and Resource Allocation for Active Target Localization. American Control Conference, 2015.
10. L. Teran and P. Mordohai. 3D Interest Point Detection via Discriminative Learning, 13th European Conference on Computer Vision (ECCV), Zurich, Switzerland, 2014.
11. Y. Lin, G. Hua and P. Mordohai. Egocentric Object Recognition leveraging the 3D Shape of the Grasping Hand, Assistive Computer Vision and Robotics workshop, Zurich, Switzerland, 2014.
12. A. Spyropoulos, N. Komodakis, and P. Mordohai. Learning to detect ground control points for improving the accuracy of stereo matching. IEEE Conference on Computer Vision and Pattern Recognition, 2014.
13. 18. C. Freundlich, P. Mordohai and M. M. Zavlanos. Hybrid Control for Mobile Target Localization with Stereo Vision. IEEE International Conference on Decision and Control (CDC), 2013.
14. C. Freundlich, P. Mordohai and M. M. Zavlanos. A Hybrid Control Approach to the Next-Best View Problem using Stereo Vision. IEEE International Conference on Robotics and Automation (ICRA), Karlsruhe, Germany, 2013.
15. X. Hu and P. Mordohai, "A Quantitative Evaluation of Confidence Measures for Stereo Vision", IEEE Transactions on Pattern Analysis and Machine Intelligence, 2012.
16. P. Mordohai and G. Medioni, "Dimensionality Estimation, Manifold Learning and Function Approximation using Tensor Voting", Journal of Machine Learning Research (JMLR), vol. 11, pp. 411-450, 2010.
17. A. Toshev, P. Mordohai and B. Taskar, "Detecting and Parsing Architecture at City Scale from Range Data", IEEE Conference on Computer Vision and Pattern Recognition (CVPR), San Francisco, USA, 2010.
18. P. Mordohai, "The Self-Aware Matching Measure for Stereo", International Conference on Computer Vision (ICCV), Kyoto, Japan, 2009.
19. M. Pollefeys, D. Nistér, J.-M. Frahm, A. Akbarzadeh, P. Mordohai, B. Clipp, C. Engels, D. Gallup, S.-J. Kim, P. Merrell, C. Salmi, S. Sinha, B. Talton, L. Wang, Q. Yang, H. Stewénius, R. Yang, G. Welch, H. Towles, "Detailed Real-Time Urban 3D Reconstruction from Video", International Journal of Computer Vision, vol. 78, no. 2-3, pp. 143-167, 2008.
20. D. Gallup, J.-M. Frahm, P. Mordohai, M. Pollefeys, "Variable Baseline/Resolution Stereo", IEEE Conference on Computer Vision and Pattern Recognition (CVPR), Anchorage, Alaska, USA, 2008.
21. V. Kwatra, P. Mordohai, S. Kumar Penta, R. Narain, M Carlson, M. Pollefeys and M. Lin, "Fluid in Video: Augmenting Real Video with Simulated Fluids", Computer Graphics Forum, vol. 27, no. 2, pp. 487-496, 2008.
22. A. Patterson, P. Mordohai and K. Daniilidis, "Object Detection from Large-Scale 3D Datasets using Bottom-up and Top-down Descriptors", 10th European Conference on Computer Vision (ECCV), Vol. 4, pp. 553-566, Marseille, France, 2008.
23. D. Gallup, J.-M. Frahm, P. Mordohai, Q. Yang and M. Pollefeys, "Real-time Plane-sweeping Stereo with Multiple Sweeping Directions", IEEE Conference on Computer Vision and Pattern Recognition (CVPR), Minneapolis, Minnesota, USA, 2007.
24. E.S. Larsen, P. Mordohai, M. Pollefeys and H. Fuchs, "Temporally Consistent Reconstruction from Multiple Video Streams Using Enhanced Belief Propagation", International Conference on Computer Vision (ICCV), Rio de Janeiro, Brazil, 2007.
25. P. Merrell, A. Akbarzadeh, L. Wang, P. Mordohai, J.-M. Frahm, R. Yang, D. Nistér and M. Pollefeys, "Real-Time Visibility-Based Fusion of Depth Maps", International Conference on Computer Vision (ICCV), Rio de Janeiro, Brazil, 2007.

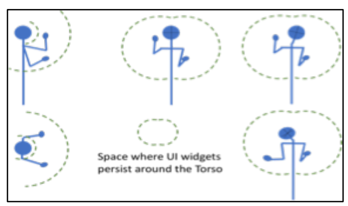
Summary Slide (required) –

MR-LAW: Mixed Reality User Interface for Law Enforcement
FactualVR, Inc.

Project Summary

- The HUD Interface will be a Mixed Reality (MR) interface. Instead of displaying the computer-generated objects superimposed on the real world by using a transparent display, the proposed interface will completely replace the user's field of view with a real time stereoscopic video and data feed sourced from cameras and sensors embedded in the user's HMD. It will also incorporate multimodal user input, even if such capability is not currently affordable. Among these elements we can list audio communication, voice commands, hand gestures, eye tracking, haptics, wearable devices, etc. The combination of these input and output extensions to the HUD interface would enable a richer and wider interaction area, accessible space between the user and the interface, and a significant tool for support of officers in the filed.





UI element persistence relative to User's Head	UI element persistence relative to User's Torso
The subset of graphical elements that are modeled and displayed as if floating within the user's field of view:	The subset of graphical elements that are displayed and modeled as floating around the user's body, irrelevant to where the user points their head.
Images and UI elements are placed in space as if they were attached to the user's head. The UI elements persist in space relative to the user's head position and orientation.	Images and UI elements are placed in space as if they were attached to the user's body. The UI elements persist in space relative to the user's torso position and orientation.

Participant Summary

- Eduardo Neeter is the Founder of FactualVR. He earned his MBA in Management of Technology from the Georgia Institute of Technology, where he also enrolled in the Computer Science/Human-Computer Interactions. Mr. Neeter has more than 20+ years of experience with VR. His professional experience ranges from early-stage tech startup to global financial services corporations.
- Philippos Mordohai is an Associate Professor of Computer Science at Stevens Institute of Technology, which he joined in 2008. Dr. Mordohai earned his Ph.D. in Electrical Engineering from the University of Southern California and held postdoctoral researcher positions at the University of North Carolina, Chapel Hill, and the University of Pennsylvania. His expertise encompasses several aspects of 3D computer vision, including image and video-based 3D reconstruction; structure from motion; 3D shape representation, and perception for robotics.

Technical Outcome

- The proposed approach will result in significant improvement in the usability and practical application of HUD interfaces for Law Enforcement. It leverages a familiar cognitive concept of placing items around the user's vest and belt (e.g. radio, handcuffs, etc.) to enhance the functionality and provide easy access to additional capabilities.
- The resulting HUD interaction design and respective prototype, supported by the Route Planer and Evaluator, as well as the Object Perimeter identifier, will significantly improve the situational awareness of officers in hostage situation, as well as improve their effectiveness by providing critical information for rapid decision-making.