Research and Development Opportunities in Video and Image Analytics

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Executive Summary

Every day, more human activities are assisted by computer vision, a form of artificial intelligence (AI) that enables an automated understanding of the visual world. Computer vision research drives new applications in the public safety domain for both government and industry. The Networking and Information Technology Research and Development (NITRD) Program's Video and Image Analytics (VIA) Team was formed to collaborate and engage in this rapidly developing research area. VIA, which includes researchers from 30 government organizations spanning nearly all Federal agencies, developed these research and development (R&D) opportunities to foster a robust multisector ecosystem that supports the Nation's requirements in video and image analytics. The team identified key R&D gaps and focused on six strategic goals and objectives:

- Support R&D in fundamental data science, applications, infrastructure, visualization, and multi-source information analysis.
- Develop effective approaches to R&D funding and acquisition.
- Create a common lexicon to effectively share and leverage R&D products, knowledge, and resources.
- Improve knowledge sharing and public-private partnerships across government, academia, and the private sector.
- Develop and sustain the expert workforce and research community to address the emerging technical and operational challenges.
- Develop standards and best practices that support integration across government systems and social and economic needs.

Achieving these goals depends on building initiatives that bridge operational gaps and keep pace with evolving threats and security challenges including terrorism and cybersecurity. This document is intended to provide guidance and foster collaboration in future Federal R&D efforts and reflects responses to a January 19, 2019 Request for Information placed by NITRD in the *Federal Register.*[1]

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[1] https://www.federalregister.gov/documents/2019/07/18/2019-15315/request-for-information-on-via-task-force-report-randd-opportunities-in-video-and-image-analytics

Introduction

Unlike any other form of data, video and still images convey detailed information about people, their environment, and their interactions. However, managing the large volumes of video available today is challenging. Manual analysis will always be important; however, in order to support real-time operations and alerts with actionable information, technologies must automate and streamline laborious tasks such as data capture, communication, triage, analysis, and management. A rapidly escalating demand for usable video data requires next-generation technologies that accelerate the automation and integration of systems and workflows.

Since the 1960s, Federal research in video and image analytics (VIA) has resulted in innovative and effective agency-specific capabilities. These investments, along with technology advancements and cost reductions, have given rise to an abundance of technologies for both government and commercial markets. More importantly, these investments across government and industry have provided foundational expertise in computer vision and machine learning and dramatically increased research in video analytics. Fifty years later, the government continues to drive innovation. Thirty Federal organizations came together under the auspices of the Networking and Information Technology Research and Development (NITRD) Program's Video and Image Analytics (VIA) Team to identify gaps in research investment and provide guidance for future Federal R&D efforts and collaborations. The research proposed in this document, while critical for Federal agencies, is unlikely to receive enough investment by industry.

Background

Breakthroughs in scientific disciplines such as computer vision, machine learning, data science, distributed computing, and high-speed networking are enabling significant advances in video and image analytic processing. Likewise, video analytics plays an essential role across a variety of systems that span different government agencies, jurisdictions, and sectors and will be increasingly important across the entire workflow of future data capture, analysis, and management systems (see Figure 1).

Figure 1. Video analytics will play a role in every component of future workflows.

The large scale, variable quality, and unstructured nature of video data has made it a difficult Big Data challenge. However, recent improvements in data processing and storage have combined with neuroscience and brain-inspired modeling to enable a new generation of automated learning technologies. When this process is applied to larger, more heterogeneous datasets, these technologies reveal a fundamental language of vision that can be applied to a variety of real-world applications. New high-speed infrastructure and low-cost sensors expand access to video and image data and creates the potential for an ecosystem that drives the right data, to the right technology, at the right time, and in the right context. As a result, decision makers can act rapidly, ethically, and effectively.

A variety of emerging markets (e.g., drones, citizen media, data analytics, and data applications) can be leveraged by the government and commercial sectors to more effectively provide services to American citizens. Smart cities of the future will be built upon a fabric of video analytics to support commerce, public safety, and security through an ecosystem of sensors, smart devices, and the Internet of Things.

Vision

The overarching vision is to foster strategic R&D activities across Federal agencies related to VIA technologies that support the health, safety, prosperity, resiliency, and security of the Nation. To achieve this vision, standards and best practices are needed that promote broad access to these technologies including: advanced automation to support the development and scaling of applications and infrastructure; agile programs for effective and efficient Federal engagement; foundational support for an ecosystem of applications, domains, and markets; a large and diverse expert workforce; and a public that is educated in their use and utility.

Evolutionary and Disruptive Trends

The landscape for video is rapidly expanding; soon over 80 percent of Internet traffic will be video.[2]

The public's use of mobile phones and social media creates an unprecedented volume of video and images. Livestreaming video is now an important source of situational awareness for public safety, border protection, and many other government domains. Innovative uses are quickly emerging in commercial markets from home decorating to online shopping.

This massive expansion in the use of video analytics is due to new sources and processing capabilities combined with advances in computing power, networking, data storage, and wireless communications. As a result, scalable computer vision applications now exist that can be deployed at virtually any location.

VIA researchers also leverage recent advances in AI that allow behavioral analysis from camera data such as: for traffic safety, to understand driver distractions and help develop countermeasures; for agriculture, to understand how crops grow and help farmers increase their yield; for wildlife management, to track endangered species; in transportation, for traffic management; and for healthcare, to remotely diagnose and treat patients.

Current Federal Landscape

More than 30 Federal agencies and organizations are engaged in VIA R&D. While each is focused on the agency mission, these efforts are coordinated through the NITRD VIA Team. Table 1 provides a snapshot of research areas and priorities at 10 of these organizations.

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[2] https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html

Table 1. Summary of Federal Engagement in Video and Image Analytics R&D

Department	Organization	R&D Engagement
DHS	S&T	DHS S&T is responsible for leading R&D, developing, testing and implementing video analytics capabilities to support public safety, protect our borders, and defend the Nation from a broad spectrum of homeland security threats.
DOC	NIST	NIST fosters measurement-focused research and broad stakeholder engagement to accelerate technological progress and standards in VIA technologies and applications spanning a variety of national priority domains.
DOD	ARL, NRL, and AFRL	ARL, NRL, and AFRL develop image processing, video analytics, and 3D visualization algorithms to effectively extract and display actionable information from images, videos, and point clouds.
DOJ	NIJ and FBI	NIJ seeks to originate and accelerate the development of image and video technologies that are key to investigate crimes, obtain forensic evidence, and ensure public safety. The FBI seeks to develop and deploy image and video analytics technologies to assist its intelligence, national security, and law enforcement operations.
DOT	FHWA	FHWA focuses on increasing the automation of video image analysis in highway transportation to enhance the safety, security, reliability, and long-term resilience of U.S. transportation networks.
HHS	NIH/NIBIB	NIH/NIBIB seeks to understand how humans view the world and supports the development of technologies to assist those with visual impairments.
IC	Multiple Agencies	Video analytics offers the IC an opportunity to gain intelligence advantage over our adversaries by exploiting video data more quickly and effectively in support of the intelligence mission.
USDA	NIFA	NIFA seeks video image analysis for precision crop management and access to visual-assistive technologies for farmers and ranchers.

Goals and Objectives

The following R&D goals have been identified along with short (3-5 years) and long-term (5-10 years) objectives.

Invest in foundational research that applies to multiple domains

Additional foundational research is required in the areas of infrastructure, visualization, interoperability, and multidata source information correlation and knowledge development. Many state-of-the-art applications only work in limited and controlled conditions, with significant effort required to adapt them to different uses and domains. Investment in foundational research that applies to multiple domains will lead to new applications and help automate the production of fast and accurate information regardless of the domain. Automation will increase efficiency, streamline the process, and decrease the cost through a reduction in person-hours required to get a similar result.

To attract academic and industry research on government-related VIA technologies, Federal agencies could pose challenge problems to the public and provide the infrastructure to support the R&D, such as multimodal computing and telecommunication systems.

Short-Term Objectives

- Evolve the foundational science underlying VIA, including research in machine learning, learning algorithms, semantics, visualization, and augmented reality.
- Develop application-oriented technologies that are robust, reusable, scalable, customizable to both specific and unconstrained application areas (e.g., tracking and geolocation, biometrics, scene characterization).
- Establish data sources to support fundamental research, applications, data sharing, and evaluations.
- Create best practices and tools for creating, labeling, analyzing, searching, curating, and leveraging data to support research.

Long-Term Objectives

- Increase the level of automation of expert systems to enable users to perform more efficiently and effectively.
- Establish robust machine learning methods that are finely tuned for visual cognition.
- Develop core hardware and software technologies to support government vision research and applications where there is a lack of broader commercial benefits.

Develop new, agile, and effective R&D methodologies

The development of innovative research methodologies that can access a shared repository of tools, resources, and infrastructure to support agile extensible R&D within and across agencies is required. Evolving these approaches will enable Federal researchers to leverage community resources, accelerate development, standardize architectures and interfaces, and ultimately facilitate technology transfer and improve the overall efficacy of VIA-related R&D investments.

Short-Term Objectives

- Create agile approaches for initiating and conducting intermural and extramural research and technology development.
- Improve government methods and identify incentives for transitioning successful research results into practice and programs.
- Leverage flexibility in the acquisition process to include technology transfer as an integral part of R&D practices.

Improve communication and coordination across government agencies

The underlying technology and infrastructure for VIA are often similar across agencies, but because of their unique mission focus, agencies also engage in R&D projects in isolation. Concrete efforts are needed to create agile R&D collaboration mechanisms that can produce tangible, measurable, and shareable results. After the 2013 Boston Marathon bombing investigation, it became apparent that for Federal, state, and local agencies to maximize the use of VIA they needed to "speak the same language." Developing a common lexicon is a critical first step, as is developing other tools such as an interagency project inventory that is accessible, searchable, and includes incentives and success stories.

Short-Term Objectives

- Create an index of R&D efforts, common vocabulary, shared portals, products, and data across agencies to promote communication and collaboration.
- Create interagency opportunities to engage on emerging needs.
- Develop and share testbeds to compare information, methods, and technologies in the context of integrated systems.
- Expand NITRD VIA efforts to increase participation from all relevant agencies.

Long-Term Objective

- Create a resource guide for VIA R&D project information based on a common framework that includes a repository of government resources such as best practices, access-controlled development frameworks, data, and data modeling tools.

Improve outreach and knowledge sharing between the public and private sectors

A coordinated stakeholder outreach approach is needed for VIA R&D to mature and transition into a robust VIA ecosystem. Educating the public about current and future analytic capabilities will build a deeper understanding of the value of these technologies and how they impact our society.

Short-Term Objectives

- Improve knowledge gathering and dissemination from industry, national laboratories, academia, and the public sector through periodic targeted workshops and other activities.
- Facilitate public forums to introduce benefits, considerations, and uses of new technologies.
- Advocate and incentivize government participation in professional societies and other fora that engage the community.
- Develop relationships between government, industry, and academia to support innovation, education, infrastructure, and roadmaps to foster entrepreneurship.

Long-Term Objective

- Develop and sustain public-private partnerships to leverage investments across stakeholders.

Develop and sustain an effective and diverse technical workforce and a robust research community

There is intense competition for video and image analysis experts. Given the rate of growth in this area, there is a compelling case for more training and formal education programs, and incentives, to build expertise in this area. For Federal agencies with VIA operations there is a need to offer advanced training for their existing staff, bring in new expertise, and leverage external expertise.

Short-Term Objectives

- Promote academic programs and curricula to increase the number of video analytics researchers that understand the needs of government.
- Develop Federal expertise in emerging areas via degree programs, continuous training, internships, and interagency details.
- Identify and disseminate best practices in Federal agency training programs and promote standardization of knowledge, training, and experience across agencies.
- Support graduates in critical technology areas and incentivize government service.

Long-Term Objectives

- Support the inclusion of VIA technologies as part of the STEAM (Science, Technology, Engineering, Art, and Math) programs at all grade levels.
- Ensure a Federal Government career path that includes job titles and positions specific to VIA.

Develop and promulgate standards and best practices that support integration of R&D

Best practices and standards need to be fostered and developed for VIA research, testing, development, and operations to facilitate consistent, repeatable, and reliable implementation. The lack of standards and best practices are impeding innovation, commerce, and utilization in critical application areas.

An integrative approach to standards is needed that is driven by a broad community of experts and results in formal Federal, national, and international standards and best practices. Clear governance of these activities is necessary that support the public interest, foster commerce, are measurable, and are based on sound scientific principles.

Short-Term Objectives

- Establish communities of practice to collaborate on the development of best practices.
- Increase Federal involvement in industry and government standards development to meet mission needs and foster practices that enable integration of disparate systems.
- Promote science-based research efforts, including reference implementations, data, and performance testing methodologies to contribute to best practices and standards development.

Long-Term Objectives

- Identify government needs for and coordinate agencies' implementation of long-term archive processes.
- Facilitate public-private partnerships on standards for new VIA technologies.

Conclusion

It is imperative that the U.S. Government produce and apply video and image analytics more efficiently and effectively than their adversaries and competitors. There are vast opportunities for using these technologies to benefit society, but rapid growth is overwhelming traditional government research and acquisition cycles. The coordination across government agencies that this document advocates demonstrates the agency's motivation and willingness to invest in and drive research into practice. The goals and objectives outlined here will make government R&D more efficient and agile, develop a future-focused workforce, and create the necessary research ecosystem to support them.

Abbreviations

AFRL	Air Force Research Laboratory		**NIBIB**	National Institute of Biomedical Imaging and Bioengineering
AI	Artificial Intelligence		**NIFA**	National Institute of Food and Agriculture
ARL	U.S. Army Research Laboratory			
DHS S&T	Department of Homeland Security, Science and Technology Directorate		**NIH**	National Institutes of Health
			NIJ	National Institute of Justice
DOC	Department of Commerce		**NIST**	National Institute of Standards and Technology
DOD	Department of Defense			
DOJ	Department of Justice		**NITRD**	Networking and Information Technology Research and Development Program
DOT	Department of Transportation			
FBI	Federal Bureau of Investigation		**NRL**	Naval Research Laboratory
			NSF	National Science Foundation
FHWA	Federal Highway Administration		**R&D**	Research and Development
HHS	Health and Human Services		**RFI**	Request for Information
IC	Intelligence Community		**USDA**	U.S. Department of Agriculture
			VIA	Video and Image Analytics

About the Authors

The NITRD Program is the Nation's primary source of federally funded work on pioneering information technologies (IT) in computing, networking, and software. The NITRD Subcommittee of the National Science and Technology Council's Committee on Science and Technology Enterprise guides the multiagency NITRD Program in its work to provide the R&D foundations for ensuring continued U.S. technological leadership and meeting the needs of the Nation for advanced IT. The National Coordination Office (NCO) supports the NITRD Subcommittee and the Interagency Working Groups (IWGs) and Teams that report to it. The NITRD Subcommittee's Co-Chairs are Kamie Roberts, NCO Director, and Margaret Martonosi, Assistant Director of the NSF Directorate for Computer and Information Science and Engineering. More information about NITRD is available online at http://www.nitrd.gov/.

The VIA Team provides for information sharing among Federal agencies with interests and responsibility for visible world video and image analysis technology R&D strategy development, collaboration, and resource sharing. The VIA Team reports to NITRD's Artificial Intelligence IWG. More information is available online at https://www.nitrd.gov/nitrdgroups/index.php?title=VIA.

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