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MULTIMEDIA PROCESSING/EDITING AND MANIPULATION

UNIVERSITY OF COLORADO DENVER

NOVEMBER 2020

FINAL TECHNICAL REPORT

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14. ABSTRACT

Under this contract, the University of Colorado Denver created a corpus of manipulated multimedia assets used for testing and development for the MediFor System, performers under contract, and the broad scientific community. This included manipulation and editing of 6,882 images, 807 videos with audio, and 132 videos and images with the insertion of computer generated imagery. All procedures and processing used to create manipulated/edited assets were logged for evaluation reference including spatial and temporal information as well as filter settings and software used. In addition, purpose driven methods were developed and delivered as executable scripts to assist in the processing of multimedia.

15. SUBJECT TERMS

Phylogeny, Visual Media Forensics, Visual Media Integrity, Visual Media Manipulation

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1.0 EXECUTIVE SUMMARY

Goals for the University of Colorado Denver under the Defense Advanced Research Project Agency (DARPA) Media Forensics (MediFor) Program were to provide manipulated multimedia to be used in system training and programmatic evaluations, develop multimedia processing capability to help facilitate program goals as well as increase challenge to performers in other technical areas, and provide a two-day training course in multimedia authentication.

Goal #1: Multimedia Manipulation
Delivered multimedia, exceeded contracted goals in all categories:

- 6,882 manipulated still image assets
- 757 manipulated video/audio
- 50 green screen video/image assets
- 132 CGI video/image assets

Goal #2: Multimedia Processing
Delivered software:

- Image, video, and audio processing routines to emulate social media compression
- Batch image processing tools to automatically upload and download images and videos

Goal #3: Training course in Multimedia Authentication Analysis

- Provided 2-day training course to MediFor program performers and stakeholders on June 16 and 17, 2016

2.0 INTRODUCTION

This project was executed by the Air Force Research Laboratory under the DARPA Media Forensics Broad Agency Announcement (BAA) DARPA-BAA-15-58. The overall program goal for MediFor was to develop technologies for the automated assessment of the integrity of an image or video and integrating these in an end-to-end media forensics platform. The MediFor program was split into three Technology Areas. This contract supported Technical Area 3 (TA3), "Corpora Creation, Manipulation and Annotations". Under this contract, the University of Colorado Denver (CU Denver) had three overall goals: create a corpus of manipulated multimedia assets, develop software capability as needed to facilitate the creation of manipulated multimedia corpora, and to provide a training course at the MediFor PI Kickoff meeting. All three goals were met and hard numbers for delivery of multimedia assets were exceeded.

The overall program goal for MediFor was to develop technologies for the automated assessment of the integrity of an image or video and integrating these in an end-to-end media forensics platform. Crucial to this goal was the evaluation of developed technologies in an unbiased way that was informative of algorithm performance and the performance of the platform so that accuracy and confidence could reach an acceptable level. The National Center for Media Forensics (NCMF) team, led by PI Jeff M. Smith, worked closely with TA3 (PAR Government and NIST - National Institute for Standards and Technology) along with insight from AFRL and DARPA, to develop sets of manipulated multimedia data in response to performer needs, stakeholder expectations, and evolving technologies that developed over the course of the 4-year program. This included manipulation and editing of 6,882 images, 685 videos with audio, 132 videos and images with the insertion of computer-generated imagery (CGI), and 122 DeepFake videos. In order to accurately assess detection algorithm performance developed under MediFor Technical Area 1 (TA1), "Integrity Analytics Research and Development", all procedures and processing the CU Denver and the rest of TA3 used to create each manipulated/edited asset were logged for evaluation reference. This included all aspects of the manipulation including challenging but necessary information such as spatial and temporal location of edits in addition to filter settings and all software used to execute manipulations.

A secondary goal for CU Denver was to develop purpose driven algorithms as executable scripts to assist in the processing of multimedia. This included CU Denver's ImageLaundering software developed in C++ and later integrated into the PAR's Journal Tool with Python bindings. The ImageLaundering plug-in facilitated fast image recompression, resizing, and file-writing to emulate popular social media sites Facebook and Instagram. Similarly, FacebookVideo is a shell script application which processes videos in batch similar to how Facebook would process them. Other CU Denver software applications, YouTube-UpDown and Twitter-UpDown, used APIs provided by these popular social media sites to write Python programs to upload and subsequently download multimedia material in batch through the internet.

Another goal for CU Denver to help DARPA and performers meet the goals of the MediFor program, was to provide a 2-day training course in forensic techniques for multimedia authentication. Leveraging the NCMF's recognized leadership in the forensic community for multimedia authentication techniques and application, MediFor performers and stakeholders were exposed to the common baseline for state-of-the-art media forensics at the 2016 program start date.

3.0 METHODS, ASSUMPTIONS, AND PROCEDURES

3.1 Multimedia Manipulation

The overall program goal for MediFor was to develop technologies for the automated assessment of the integrity of an image or video and integrating these in an end-to-end media forensics platform. Crucial to this goal was the evaluation of developed technologies in an unbiased way that was informative of algorithm performance and the performance of the platform so that accuracy and confidence could reach an acceptable level. The NCMF team, led by PI Jeff M. Smith, worked closely with other TA3 performers (PAR Government and NIST), along with guidance from AFRL and DARPA, to develop sets of manipulated multimedia data in response to performer needs, stakeholder expectations, and evolving technologies that developed over the course of the 4-year program.

To execute believable and seamless manipulations using a variety of techniques and tools common to manipulators in the wild, various teams were assembled at CU Denver. These teams covered the following areas: Image Manipulation primarily using Photoshop, Video/Audio Manipulation primarily using After Effects, Green Screen Production and Replacement using After Effects, and CGI Manipulation primarily using Nuke and Maya. These teams were comprised of CU Denver faculty, graduate, and undergraduate students from programs in media forensics, digital design, digital animation, and video production.

3.1.1 Image Manipulation.

The Image Manipulation team used only camera-original (high provenance) images to create believable fabrications changing semantics dealing with person, place, time, etc. Innovative techniques in the removal, duplication, and splicing of imagery between images relied on clean blending and consistent lighting/shading. Some projects were carried out by the manipulator independent of guidance on topic or content, some were carried out as a team working on a particular task or manipulation type. Many projects were carried out in collaboration with other manipulators in what we termed “Shared Provenance” – one image was given to a group of manipulators and they each independently carried out manipulations on that image.

Each manipulator was trained in the process of logging manipulation procedures and settings so that they could accurately journal their manipulations using PAR’s Journal Tool.

Overall, this team delivered 6,882 manipulated images over the program. This exceeded the contracted goal of 6,720 by 162 images.

Figure 1 below shows a typical image manipulation using Photoshop where a car from a donor image has been added to another image to change its meaning.

Figure 1: Photoshop image manipulation with Original Image (top), Donor Image (right), and Manipulated Image (bottom)

3.1.2 Video/Audio Manipulation

The Video/Audio Manipulation team produced many videos from scratch for purpose driven manipulations using high quality production equipment supported by the program. These high provenance videos were then fabricated to remove, duplicate, or splice spatial information across frames using video stabilization techniques. This was primarily carried out in Adobe After Effects where motion tracking across video frames allow for the insertion or duplication of material while content-aware removal techniques available in this software made removal of imagery seamless and readily executable. Figure 2 below shows a person taken from a donor video and added to a different video. Additionally, temporal information was manipulated to remove or add information, thereby changing video duration.

Audio expertise was used to change audio tracks associated with videos. Using Pro Tools, Adobe Audition, and some other tools voice information and ambient sounds were changed and, in some cases, replaced with new, original recordings in order to modify the semantic meaning of videos and alter persons and places involved.

Additionally, under this category, a new type of video manipulation emerged during the program. Face manipulation using deep learning technology, coined "DeepFakes" in 2017, became a focus for TA1 and TA3 performers alike. CU Denver stepped up to the challenge of researching and understanding this new threat and carrying manipulations in ways that started surfacing in the public space. Important factors affecting the creation and detection of DeepFakes CU Denver learned through research and practice was presented at the American Academy of Forensic Sciences. (Smith & Grigoras, 2019)

All video/audio manipulations were journaled succinctly for all projects across the program.

Overall, 757 video/audio manipulations were delivered to the program exceeding the contracted goal of 186 by 571. These delivered numbers include 122 high-quality DeepFake videos depicting 40 different persons.

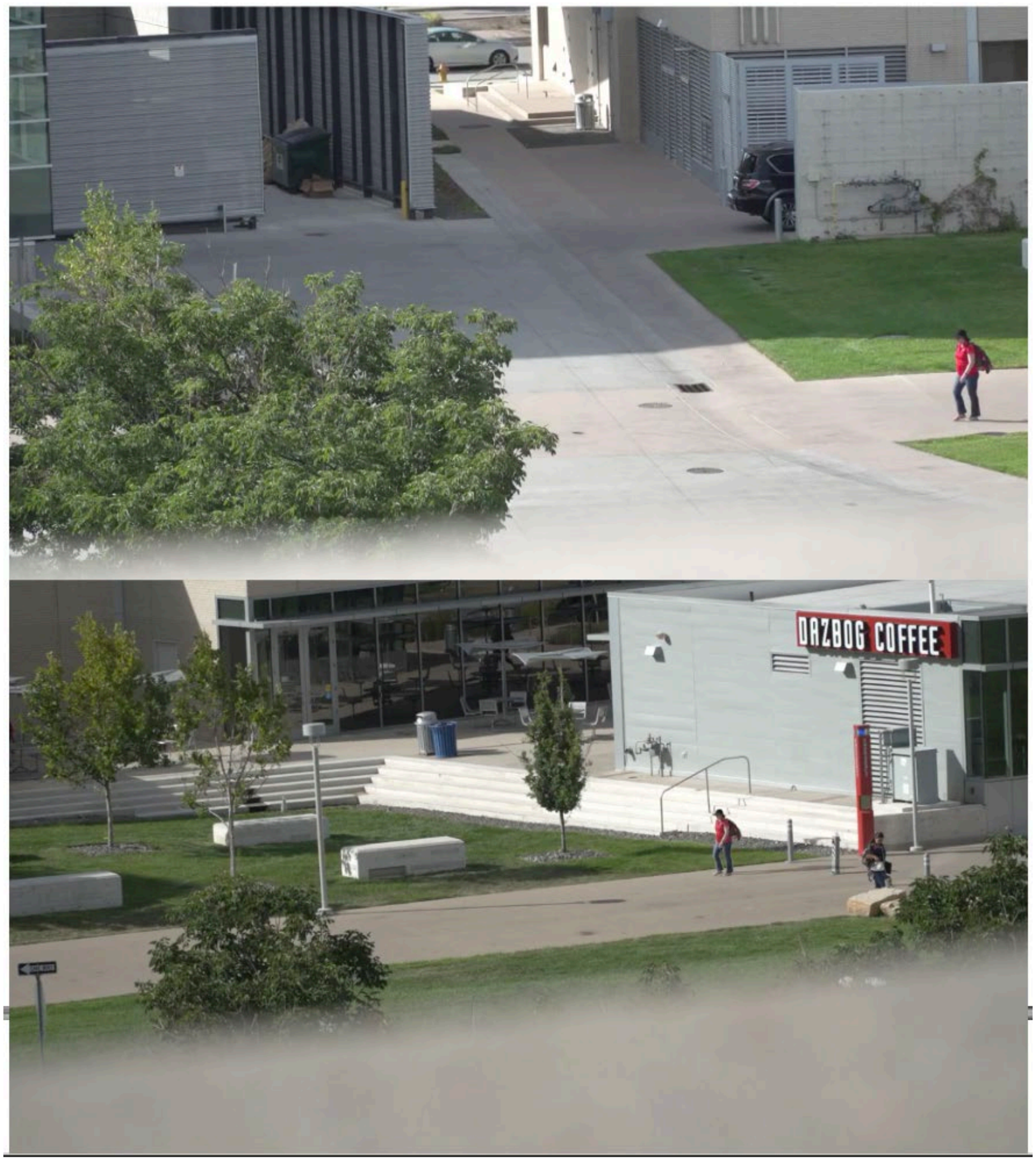

Figure 2: Video manipulation using After Effects, the subject in the top video has been duplicated manually, frame-by-frame, to the bottom video

3.1.3 Green Screen Production and Replacement

The Video/Audio Manipulation team produced many videos from scratch for purpose driven Green Screen manipulations using high quality production equipment supported by the program. With this technology, objects/persons filmed in front of a green screen are inserted into a chosen location. This primarily gives the manipulator freedom to place a person or thing anywhere in the world they want. Figure 3 below shows the before and after result of this process. CU Denver teams collaborated on some green screen projects such as placing persons within 3D computer generated spaces, to place 3D animated persons into real videos, to change the ambient audio or speaking persons, etc. There were 50 projects of this type delivered, meeting the contracted goal.

Figure 3: Green screen replacement of background using chroma-key removal can be used to place a person/object filmed in front of green screen (top) into another video (bottom)

3.1.4 CGI Manipulation.

A team of Digital Animation students and faculty created dozens of manipulations where fabricated 3D objects and persons were inserted into real scenes primarily using Nuke and Maya software. This included fabricated explosions, weapons, moving and stationary vehicles and aircraft, and everyday objects such as a stapler. Figure 4 below shows a video before and after the splice of a three-dimensional atmospheric explosion. The process to produce this manipulation involves designing explosion parameters for physical generation of the model, rendering a video of the explosion over an alpha channel, motion tracking the original video, and lastly placing the 3D explosion in the estimated 3D environment.

Furthermore, complete three-dimensional models of scenes were created by hand with enough detail to be photorealistic. These scenes can be animated with camera movement, lighting/shading, atmospheric properties (wind, humidity, etc.), and moving objects to create realistic videos at various times of day and with various circumstances and activity. Figure 5 below shows a completely fabricated scene of an abandoned room in a bunker filmed and lit by a handheld smartphone.

Overall, 101 videos and 41 still image manipulations were delivered using 3D animation and 4 complete CGI scenes were created.

Figure 4: Video before (top) and after (bottom) the splice of a three-dimensional atmospheric explosion

Figure 5: Example of complete 3D scene fabrication with lighting, texture, and atmospheric choices made during creation

3.1.5 Manipulation Journaling.

CU Denver worked closely with PAR and NIST to develop a method of logging manipulation procedures and filter settings. This aspect was crucial for the evaluation of algorithms developed by TA1 for the program. Techniques and technologies for journaling the media on a mass scale were published during the program. (Robertson, et al., 2019) (Guan, et al., 2019)

3.2 Multimedia Processing

CU Denver developed software for batch processing multimedia material in a meaningful way. Nowadays, the vast majority of material is shared using internet social media. This means investigators in Law Enforcement and Intelligence are analyzing probative material collected from the internet more and more each year. Social media creates an additional layer of manipulation obfuscation in multimedia because material will be recompressed in order to be stored in servers and delivered to internet clients. As it impacted the MediFor program, this meant that understanding how social media compression effects multimedia material and the detection of manipulations was tantamount to increasing technological capability.

The problem with obtaining material directly from the internet is that some platforms do not allow mass upload or download. Also, social media processing works like a black box and therefore the accurate logging of multimedia asset processing is broken. Lastly, it is time-consuming and burdensome to manually upload and download content on the scale that was necessary for MediFor corpora. To overcome these challenges and facilitate the need for bulk manipulation of assets featuring this type of obfuscation, CU Denver developed algorithms as executable scripts to assist in the processing of multimedia. Two approaches cover the most prolific platforms: Facebook, Twitter, YouTube, and Instagram.

With the first approach, CU Denver emulated video, audio, and image processing for platforms that do not allow for mass up/download – Facebook and Instagram. CU Denver's

ImageLaundering software Facebook-Video script were integrated into the PAR's Journal Tool with Python bindings. These tools facilitate fast multimedia recompression, resizing, and file-writing to emulate these popular social media sites. In order to understand the behavior of these social media platforms and to facilitate emulation, research projects were undertaken with CU Denver Media Forensics graduate students and published in research theses. (Douglas, 2018) (Wolanin, 2018) (Pippin, 2016)

With a second approach, CU Denver's YouTube-UpDown and Twitter-UpDown, batch process material using platform specific APIs to automatically upload and subsequently download multimedia material in batch through the internet. Research and implementation details were published with CU Denver graduate students as research theses. (Lomboy, 2018) (Whitecotton, 2017)

3.3 Training Course in Multimedia Authentication Analysis

Leveraging the NCMF's recognized leadership in the forensic community for multimedia authentication techniques and application, MediFor performers and stakeholders were exposed to the common baseline for state-of-the-art at the 2016 program start date. On June 16 and 17, 2016, Co-PI Catalin Grigoras led a two-day course on Multimedia Authentication Analysis following the PI Kickoff Meeting hosted at CU Denver.

4.0 RESULTS AND DISCUSSION

The MediFor Program was an opportunity to bring industry, government, and academic researchers together to address the challenge of media manipulation detection with the development of new tools against existing and new challenges. In the ever-changing landscape of information exchange, it is not surprising to find that the anticipated path for our activity as media generators in the program changed as well. There were three primary lessons the NCMF team learned during the MediFor program with generating media. First, it is necessary to be prepared strategically and technically to take on new manipulation techniques. We saw this particularly in the realm of facial synthesis using deep learning (DeepFakes). Secondly, with our research into social media re-compression (see References section for NCMF publications related to this activity) we developed novel methods to research and characterize social media handling and processing of multimedia data which helped inform processing in this program as well as broaden understanding in media forensics. Last, we helped the program gain an understanding of multimedia manipulation techniques and the advantages and limitations that bad actors have with various tools at their disposal. With the realistic, varied, and fully annotated manipulations the NCMF and PAR generated for the MediFor program, the collective understanding of program progress and strengths were realistically calibrated against the threats posed by multimedia manipulation.

5.0 CONCLUSIONS

At program completion, all programmatic goals for CU Denver had been met or exceeded as follows:

- 6,882 out of the contracted number of 6,720 manipulated still image assets
- 757 out of the contracted number of 486 manipulated video/audio

5.0 CONCLUSIONS

At program completion, all programmatic goals for CU Denver had been met or exceeded as follows:

- 50 out of the contracted number of 50 green screen video/image assets
- 132 (101 video + 41 still image) out of the contracted number of 50 CGI video/image assets
- 6,882 out of the contracted number of 6,720 manipulated still image assets
- 757 out of the contracted number of 486 manipulated video/audio

With CU Denver's assistance, the MediFor program met annual goals for deploying Media Forensics Challenges and the MediFor Platform for multimedia analysis was assembled and improved over time. We are thankful for the opportunity to contribute to this important work and will continue to learn, react, and collaborate in future DARPA programs.

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LIST OF ACRONYMS

- NCMF – National Center for Media Forensics
- CU Denver – University of Colorado Denver
- CGI – Computer Generated Imagery
- 3D – Three-dimensional