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14. ABSTRACT

In this project, we incorporated motion capture devices, 3D vision sensors, and EMG sensors to cross validate multimodality data acquisition, and address fundamental research problems of representation and invariant description of
3D data, human motion modeling and applications of human activity analysis, and computational optimization of large-scale 3D data. The support for the acquisition of such research instrumentation have significantly facilitated

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Report Title

Final Report: 3D Data Acquisition Platform for Human Activity Understanding

ABSTRACT

In this project, we incorporated motion capture devices, 3D vision sensors, and EMG sensors to cross validate multimodality data acquisition, and address fundamental research problems of representation and invariant description of
3D data, human motion modeling and applications of human activity analysis, and computational optimization of large-scale 3D data. The support for the acquisition of such research instrumentation have significantly facilitated
our current and future research and educate scientists and engineers in areas important to national defense and the DoD's mission.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

<u>Received</u>   <u>Paper</u>

TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

<u>Received</u>   <u>Paper</u>

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

<u>Received</u>   <u>Paper</u>

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

<u>Received</u>   <u>Paper</u>

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

<u>Received</u>   <u>Paper</u>

TOTAL:

Number of Manuscripts:

Books

Received	Book

03/02/2016 1.00 Yun Fu   . Human Activity Recognition and Prediction, Switzerland: Springer International Publishing, (01 2016)

      TOTAL: **1**

Received	Book Chapter

      TOTAL:

Patents Submitted

Patents Awarded

Awards

Dr. Fu was elected as a member of Global Young Academy.

Dr. Fu was recognized by the IEEE Computational Intelligence Society (CIS) as the awardee of 2016 IEEE CIS Outstanding Early Career Award, for contributions to neural computing, manifold learning, and visual intelligence.

Dr. Fu was selected as one of the 2015 National Academy of Engineering US Frontiers of Engineering by NAE.

Dr. Fu was elected to be Senior Member of ACM.

Dr. Fu received 2016 Adobe Faculty Research Awards.

Dr. Fu was promoted to the rank of Associate Professor with Tenure.

Former Ph.D. student Li, Kang's dissertation entitled "Video event recognition and prediction based on temporal structure analysis" has been featured by IEEE Signal Processing society eNews in the year 2015 at http://www. signalprocessingsociety.org/newsletter/category/ph-d-theses/page/11/.

Students Shuyang Wang, Shuhui Jiang, Ming Shao, Zhengming Ding, Handong Zhao and Hongfu Liu received the AAAI Student Travel Award for AAAI 2016

Student Sheng Li, receives the 2015 Chi-nese Gov-ern-ment Award for Out-standing Self-??Financed Stu-dents Abroad.

Student Sheng Li received the 2015 NEU Outstanding Graduate Student Award (Topmost student award in NEU)

Student Sheng Li received the ACM SIGIR Travel Award for CIKM 15.

Students Handong Zhao and Hongfu Liu received the ICDM Student Travel Award for ICDM 2015

Graduate Students

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
Yu Kong	0.00
FTE Equivalent:	**0.00**
Total Number:	**1**

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Yun Fu	0.00	
FTE Equivalent:	**0.00**	
Total Number:	**1**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Student Metrics
This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields: 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields: 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale): 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering: 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields: 0.00

Names of Personnel receiving masters degrees

NAME

Total Number:

Names of personnel receiving PHDs

NAME
Kang Li

Total Number: 1

Names of other research staff

NAME   PERCENT_SUPPORTED

FTE Equivalent:
Total Number:

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

We have used this DURIP award to facilitate our 3D Data Acquisition Platform. We have acquired major instruments such as Vicon MX-T40S camera system, 192 cores of HPC computational equipment, and Trigno Wireless EMG system with 16 Trigno EMG+XYZ sensors from Delsys. Current platform is sufficient to incorporate both motion capture devices and 3D vision sensors to cross validate multimodality data acquisition, and address fundamental research problems of representation and invariant description of 3D data, human motion modeling and applications of human activity analysis, and computational optimization of large-scale 3D data. The support for the acquisition of such equipment has significantly facilitated our current research and educate scientists and engineers in areas important to national defense. We are using this platform to collecting a unique database which could be used for multimodality sensor fusion for human motion analysis, action recognition, and behavior understanding. The impact of this award will last long as the new facility is transforming our current research scope and in the meanwhile help our current and future technology transfer.

Technology Transfer

Project Summary Sheets (PSS)

Title: 3D Data Acquisition Platform for Human Activity Understanding
Grant No: DURIP under W911NF-14-1-0516
PI: **Yun Raymond Fu**, Associate Professor, Northeastern University, Boston

1. Objective

Reliable online recognition and prediction of human actions and activities in temporal sequences has many potential applications in a wide range of Army-relevant fields, ranging from video surveillance, warfighter assistance, human computer interface, intelligent humanoid robots, unmanned and autonomous vehicles, to diagnosis, assessment and treatment of musculoskeletal disorders, etc. a computational approach for action prediction can extend our findings to machines and also promote further research in human prediction and intention sensing. Apparently, a practical prediction system must output a rapid response for partial observations. This brings up a new challenge to the computational models and motivates machine learning researchers to make more progresses. Moreover, action prediction will need to model temporal structures and may raise an important advance for action recognition. The underlying basic goal of the proposal is to enhance the DoD's capabilities of visual intelligence for leveraging automatic human activity understanding using 3D data acquisition platforms.

2. Scientific Barriers

Using 2D visual information captured by single or multiple cameras for human activity recognition has been extensively studied and applied to real-world systems in the past decade. However, a remaining open problem is how to generalize existing models and frameworks to robust and viewpoint independent recognition and even prediction of diverse human actions and activities in a real environment. Recent advances in 3D motion capture technology, 3D depth cameras using structured light or time-of-flight sensors, and 3D information recovery from 2D images/videos have provided commercially viable approaches and hardware platforms to capture 3D data in real-time, and have been nurturing a potential breakthrough solution to such problem by using 3D data.

A computational approach for action prediction can extend their findings to machines and also promote further research in human prediction and intention sensing. Apparently, a practical prediction system must output a rapid response for partial observations. This brings up a new challenge to the computational models and motivates machine learning researchers to make more progresses. Moreover, action prediction will need to model temporal structures and may raise an important advance for action recognition.

3. Approach

Our 3D human data acquisition platform consists of a set of 3D motion capture sensors (e.g. Vicon) and a set of 3D cameras (e.g. Kinect) that are synchronized and integrated to cross validate data acquisition, as shown in Figure 1. As illustrated in the computing (right) module, new methodologies of 3D motion reconstruction and 3D visual modeling will be developed to fill in the gap between vision and motion data and form the computational component to drive interactions. The gap between the middle level and low level data flow is filled by parametric and composable low-dimensional manifold representations. Such integrated data acquisition and methodologies will link the visual representations to quantitative biomechanical assessment of the human movements in the form of

immersive activities, which aid the development of human models and assist in the progressive parametric refinement of modeling.
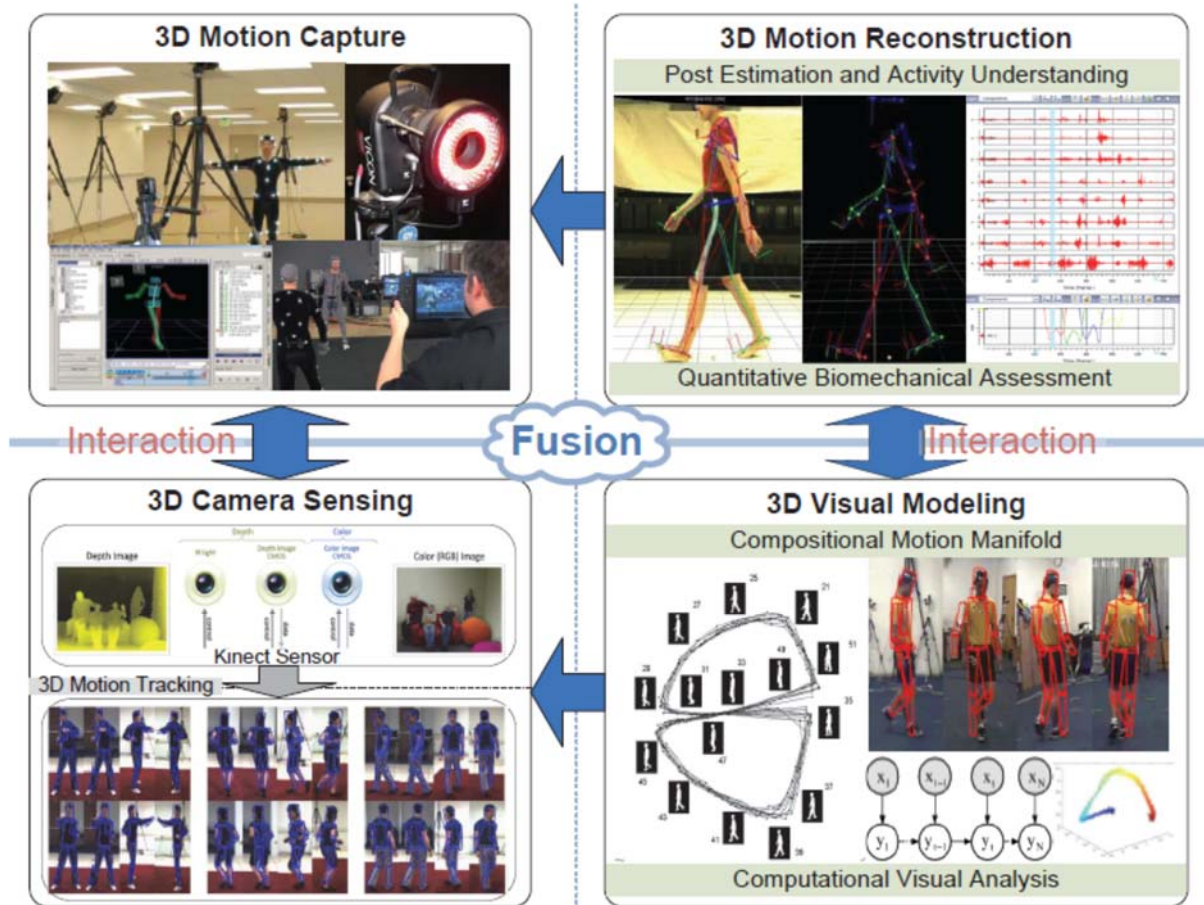

Fig. 2. 3D human data acquisition platform.

4. Scientific Significance

Visual intelligence is now ubiquitous; yet, understanding of high-level semantic dynamics is still not comprehensively addressed as what we do here. We propose an end-to-end solution to the video analysis problem that integrates "best-in-class" ideas and innovates where the state-of-the-art is lacking. The success of this research has revealed new understanding about interactions and intentions of human centered environment, fill in the semantic gap between visual signals and contextual reasoning. The proposed research transforms the field of visual understanding by enabling the information rich video media to be intelligently utilized. Research on imminent activity prediction with unconventional approaches may undertake directions that challenge assumptions and have the potential to radically change established practice. Such progresses will significantly advance the visual intelligence field and contribute to the accomplishment of DoD's mission. The project also impacts engineering and science education at various levels through collaborative research project involvement by students from various backgrounds, especially K-12 and undergraduate students. The inspirational aspects has attracted young scholars to careers in science and engineering, while promoting scientific values and progress to the broader community.

5. Scientific Accomplishments

We have used this DURIP award to facilitate our 3D Data Acquisition Platform. We have acquired major instruments such as Vicon MX-T40S camera system, 192 cores of HPC computational equipment, and Trigno Wireless EMG system with 16 Trigno EMG+XYZ sensors from Delsys. Current platform is sufficient to incorporate both motion capture devices and 3D vision sensors to cross validate multimodality data acquisition, and address fundamental research problems of representation and invariant description of 3D data, human motion modeling and applications of human activity analysis, and computational optimization of large-scale 3D data. The support for the acquisition of such equipment has significantly facilitated our current research and educate scientists and engineers in areas important to national defense. We are using this platform to collecting a unique database which could be used for multimodality sensor fusion for human motion analysis, action recognition, and behavior understanding. The impact of this award will last long as the new facility is transforming our current research scope and in the meanwhile help our current and future technology transfer.

In summary, in the past period of research under this award, the PI's group has published a book solely edited by the PI, and research outcomes have started been citing/using by other researchers internationally for transitions.

- [Book]Yun Fu, Human Activity Recognition and Prediction, Springer, 2016. doi: 10.1007/978-3-319-27004-3

In particular the PI and his team have received many international recognition, awards and honors listed as follows:

- Dr. Fu was elected as a member of Global Young Academy.
- Dr. Fu was recognized by the IEEE Computational Intelligence Society (CIS) as the awardee of 2016 IEEE CIS Outstanding Early Career Award, for contributions to neural computing, manifold learning, and visual intelligence.
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- Student Sheng Li received the ACM SIGIR Travel Award for CIKM 15.
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6. Collaborations and Leveraged Funding

Leveraged by this grant, the PI has submitted an ARO regular proposal with a title of "Deep Multi-Factor Learning for Intelligent Human Identification", which is under review and consideration. The PI is collaborating with MIT Lincoln lab for TrecVid evaluation and achieved top ranking. By collaborating with the Natick Solider Center (NSC) and applying new techniques for shape analysis and classification to these 3D data will help designers of clothing and personal protection equipment to understand and fit Army population.

7. Technology Transfer

N/A

8. Anticipated Scientific Accomplishments

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9. Future Research Plans

We propose a series novel deep learning methods for multi-factor human action recognition to address real world negative factors. The technical merits of deep learning is it can well utilize large-scale training data from thousands hours of surveillance videos, and millions of mug shot photos, and can adapt to multi-view human action recognition in low-quality surveillance environments with flexible model structure. This essentially mimics the cognitive process of human being, which processes the visual information layer by layer. The DURIP project facilitates our 3D human modeling which could significant enhance system performance which therefore compensate for different poses, modality, low image quality, occlusions, and noisy labels.

10. Conclusions

The PI has achieved significant research progress and created a strong collaboration with colleagues at MIT LL and ARL. The accomplishments include book publication and several major awards and honors. The funding support leverages the future funding endeavor by the PI.