Sensor, Signal and Information Processing (SenSIP) I/UCRC

Video analysis and restoration for long-range imaging through turbulence

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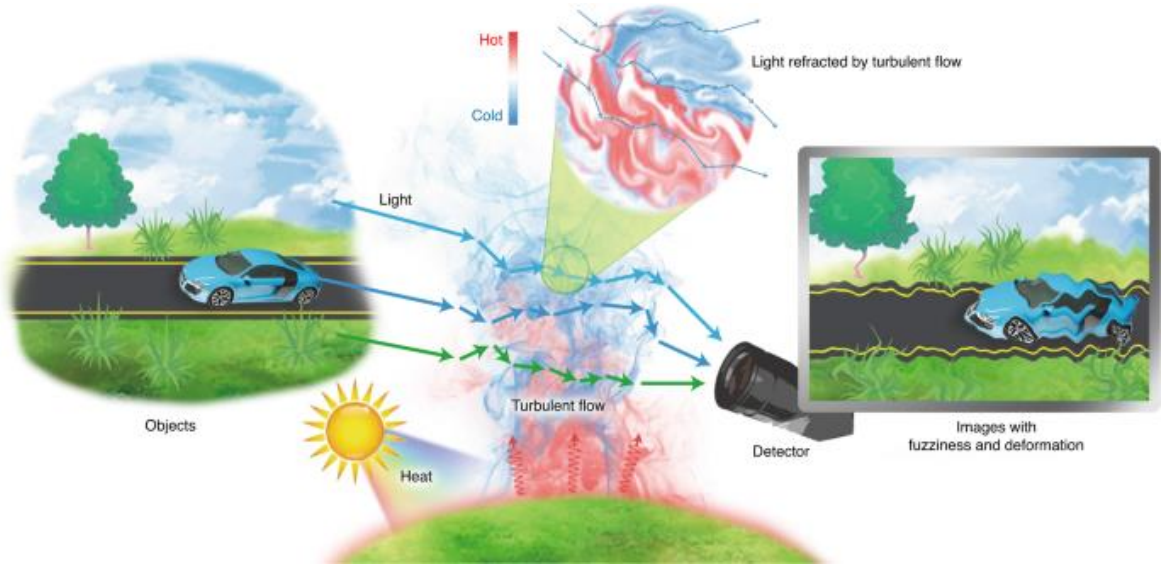
Problem Statement

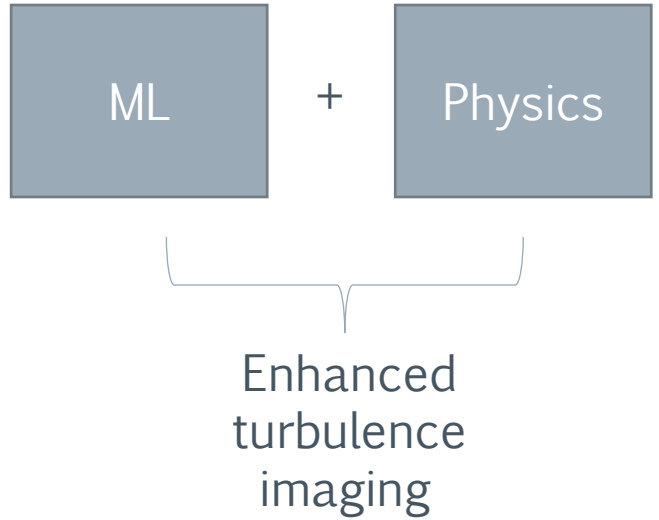
- **Why is this research needed?**
- Analyzing long-range imaging is difficult due to turbulence-induced distortion and blur
- Need robust computer vision algorithms that can assist with analyzing scene content robust to such turbulence degradations
- **What is the specific problem to be solved?**
- Turbulence strength estimation using long-range imaging and physics-based computer vision
- Enhanced video restoration for improved quality



Project Description

- **How will this project approach the problem?**
  - We propose developing methods for assessing the strength of turbulence in video as well as video restoration
  - Key insight: use state-of-the-art physics-based neural network methods
  - Goal: Algorithms that can work for videos in the wild (unstabilized, drone-based platforms)

- **Preliminary results from this or previous projects:**
  - Existing method for turbulence strength estimation
  - Video-based turbulence enhancement



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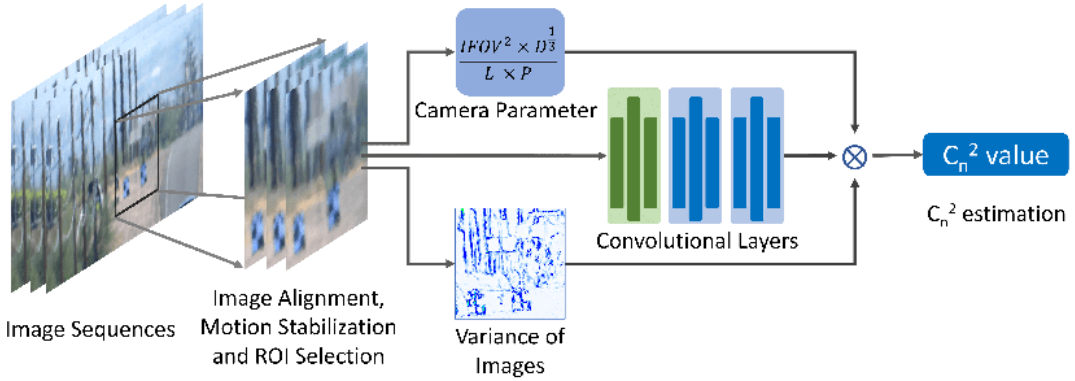
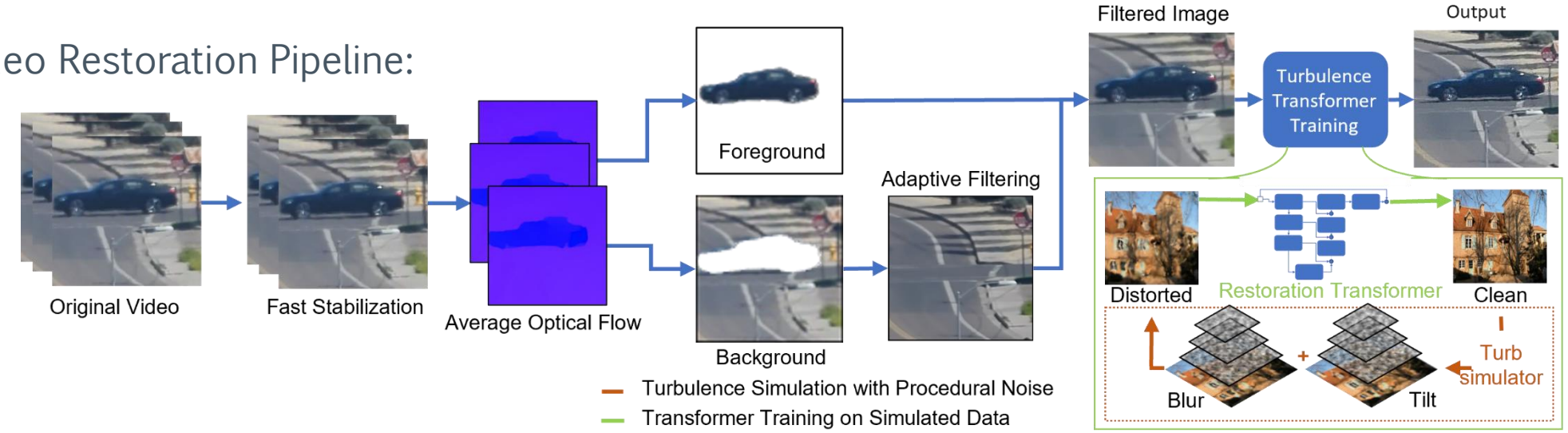
Turbulence Strength Estimation:

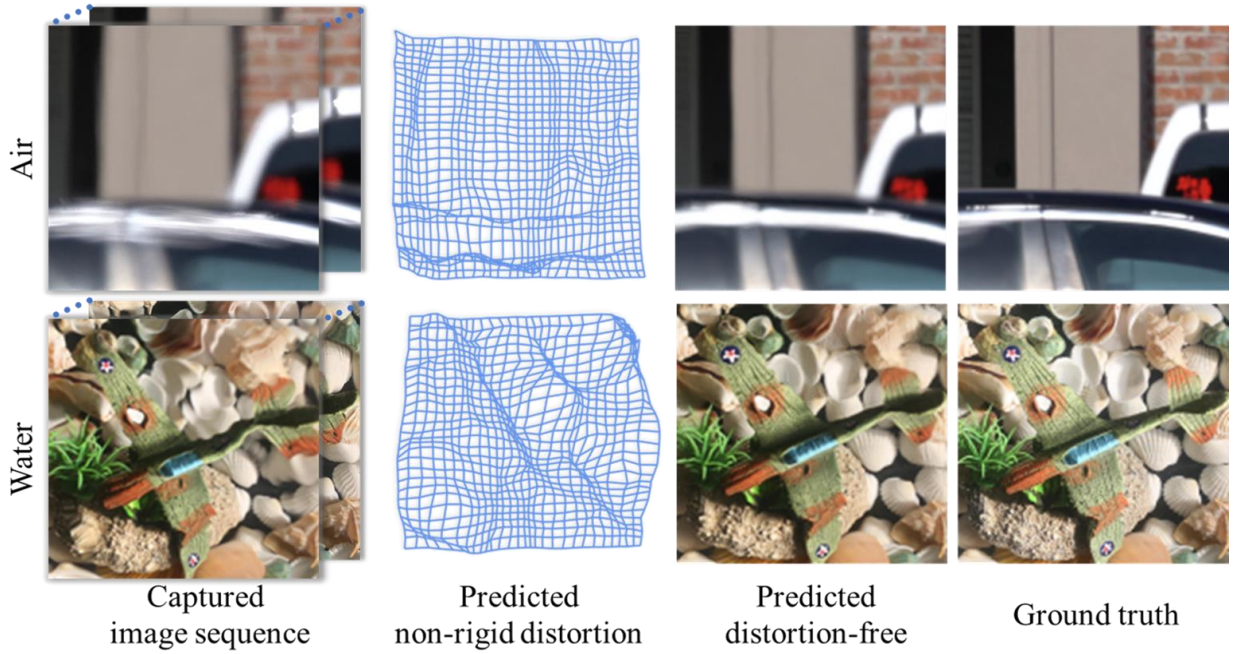


Video Restoration Pipeline:



Preliminary Results

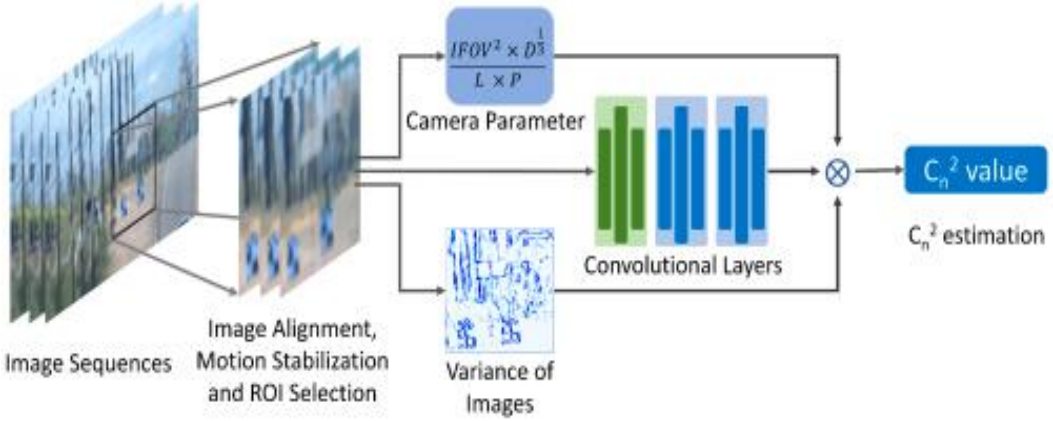
- Our lab has worked on unsupervised learning methods to correct image distortions for turbulent images
- Method leveraged neural fields or implicit neural representations for estimating underlying distortions
- Paper published in ICCV 2021



Nianyi Li, Simron Thapa, Cameron Whyte, Albert Reed, Suren Jayasuriya, Jinwei Ye, Unsupervised Non-Rigid Image Distortion Removal via Grid Deformation, IEEE International Conference on Computer Vision (ICCV) 2021

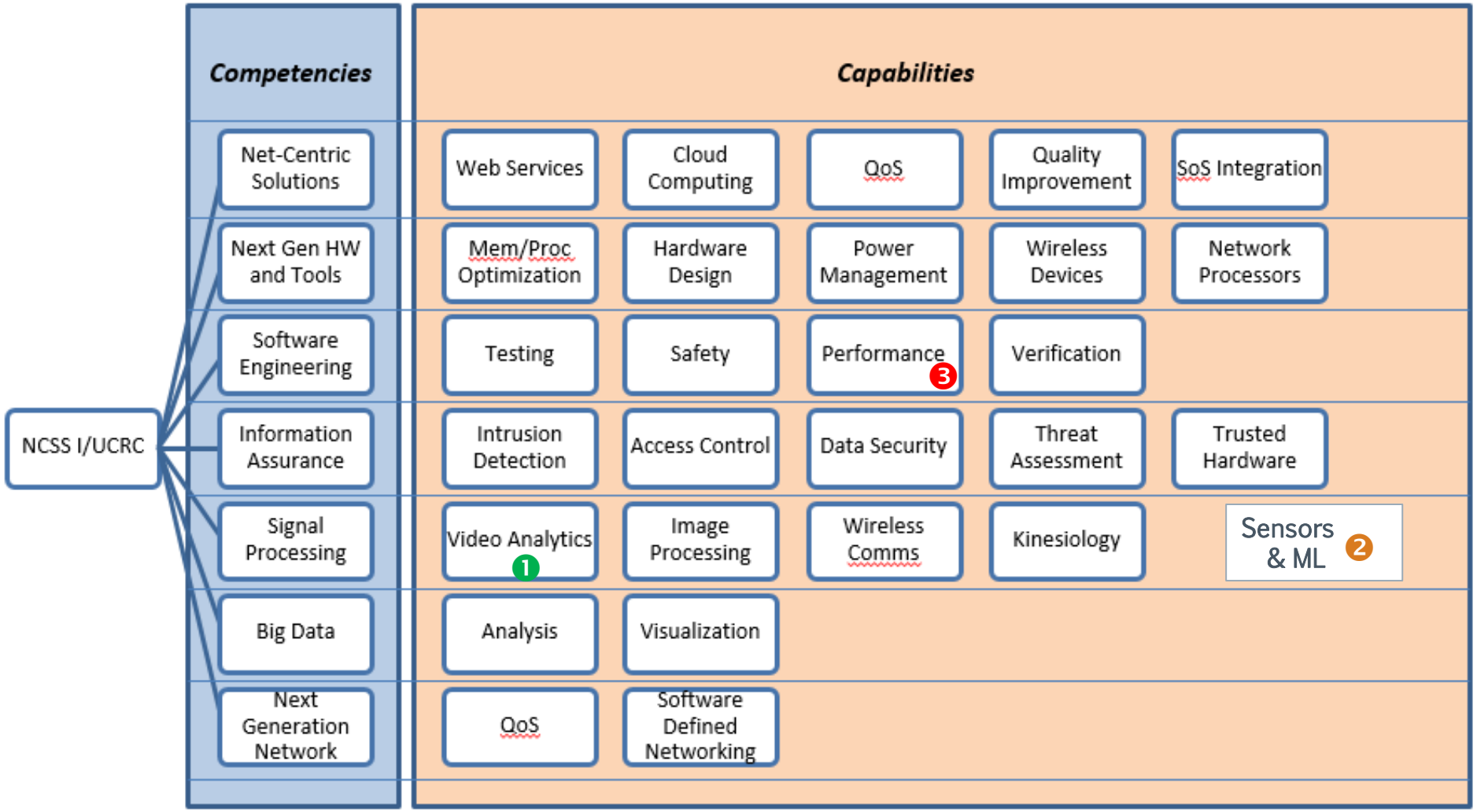
Preliminary Results

- Collected ground truth measurements of turbulence strength with scintillometer and RGB camera for Army Phase II SBIR program
- Performed comparative analysis of classical vs. deep learning methods
- Developed physics-based network architecture that combines learned convolutional layers with a differentiable image gradient method
- Paper published in Optics Express 2022



Ripon Saha, Esen Salcin, Jihoo Kim, Joseph Smith, Suren Jayasuriya, Turbulence Strength Cn2 Estimation from Video using Physics-based Deep Learning, Optics Express 2022

Connection to NCSS Competencies/Capabilities



1=Primary, 2=Secondary, 3=Tertiary

Statement of Work

Work to be performed, timeline for 4 most significant tasks.

Months 1-6:
Task 1 = Develop pipeline for video enhancement.

Months 7-12:
Task 2 – Improve existing method for turbulence strength estimation, investigate the use of infrared imagery

Months 13-18:
Task 3 – Test pipeline for video enhancement on real data

Months 19-24:
Task 4 – Create a software package and benchmarking to deploy algorithms developed in this project

Project Differentiators

- What results does this project seek that are different (better) than others?
  - Combined use of physics + machine learning algorithms to enable synergistic benefits
  - Evaluating algorithms on real camera data;
  - What specific innovations or insights are sought by this research that distinguish it from related work?
  - Use of novel machine learning architectures (transformer-based restoration methods)

Potential Member Company Benefits

- Physics-based machine learning algorithms
- Enhanced long-range imaging technology for applications in monitoring, surveillance
- Will release software for reproducible research including exemplar data as well as trained machine learning models

Sponsorship and Collaboration

- Efforts to involve multiple companies in project sponsorship:
  - Alphacore
  - Companies interested in long-range monitoring/surveillance (PSG, Raytheon)

Project Quality Attributes

PI's assessment of extent to which project demonstrates each QA.

Scale: 5=To a LARGE extent, 4=To a MODERATE extent, 3=To SOME extent, 2=To LITTLE extent, 1=Not at All, 0=Unrated

Project Quality Attribute Self-Assessment:		
PI's assessment of the extent to which the proposed project demonstrates each Quality Attribute. Scale: 5=To a LARGE extent, 4=To a MODERATE extent, 3=To SOME extent, 2=To LITTLE extent, 1=NOT AT ALL, 0=Not Rated)		
To what extent does the project demonstrate each Quality Attribute?	Rating	Comments (Required if Rating < 3)
Alignment with Center Competencies	4	Signal Processing
Sponsor-acknowledged Leverage to R&D	3	Project aligned with Alphacore's imaging capabilities
Multi-company Sponsorship	3	Alphacore, Raytheon, PSG
Multi-university Collaboration	5	Algorithms based on previous research conducted in part with Clemson University and George Mason University
Compliance with NSF Operations Requirements	5	
Objective Deliverables	4	Algorithms for turbulence strength estimation and video enhancement
Innovation & Technology Evolution	5	IP in algorithm solutions
Potential for Derivative Services	4	Physics-based ML algorithms can be of use to other members
Commercialization Opportunities	3	It will need additional resources and time.
Past Performance	4	Previous submitted publications on turbulence imaging