１）橋梁点検 UAV（自律飛行技術）、損傷動検出に関する
２）点検結果の 3次元モデリング技術に関する情報

Carnegie Mellon University

Carnegie Mellon University：概要

国土交通省

『**ARIA Project**』(**A**erial **R**obotic **I**nfrastructure **A**nalyst)

同大学のRobotics Institute および Civil and Environmental Engineering departmentsと、Northeastern Universityの連携による研究開発。橋梁を対象に、**「①UAV点検技術」**、**「②3次元モデリング技術」**、**「③分析・データ管理技術」**のトータルプロジェクト。

氏名、役職、所属

Burcu Akinci
Paul Christiano Professor of Civil & Environmental Engineering,
Associate Dean for Research, College of Engineering
Co-Director, Smart Infrastructure Institute

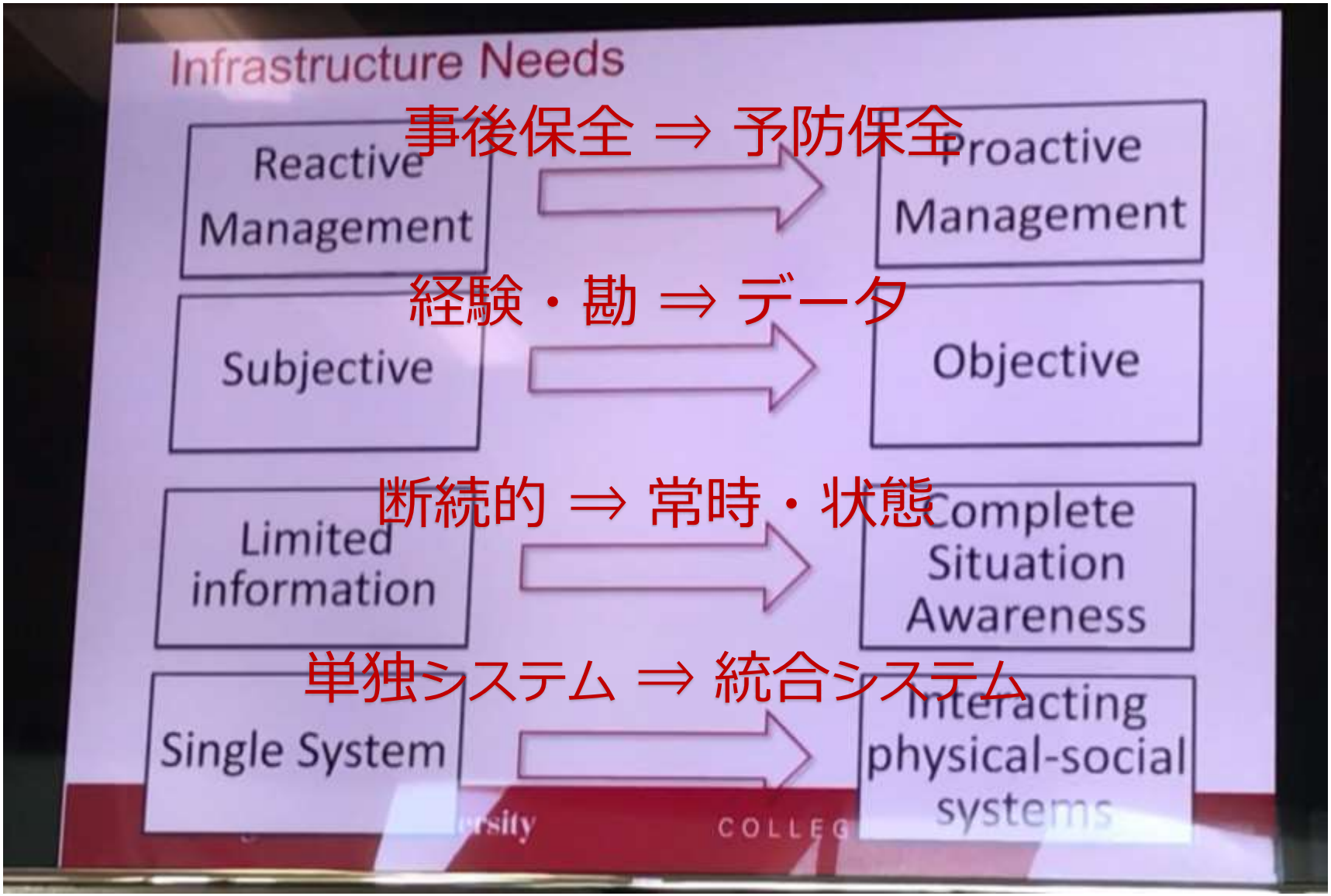
Sebastian Scherer　※欠席
Systems Scientist
Robotics Institute

Silvio Maeta
Senior Research Programmer
Robotics Institute

Weikun Zhen
PhD Student
Robotics Institute

Colleen McCabe Mantini
Program Manager
College of Engineering

研究の背景


Infrastructure Needs
事後保全 ⇒ 予防保全
Reactive Management
Proactive Management
経験・勘 ⇒ データ
Subjective
Objective
断続的 ⇒ 常時・状態
Limited information
Complete Situation Awareness
単独システム ⇒ 統合システム
Single System
Interacting physical-social systems

Carnegie Mellon University：ARIA Project

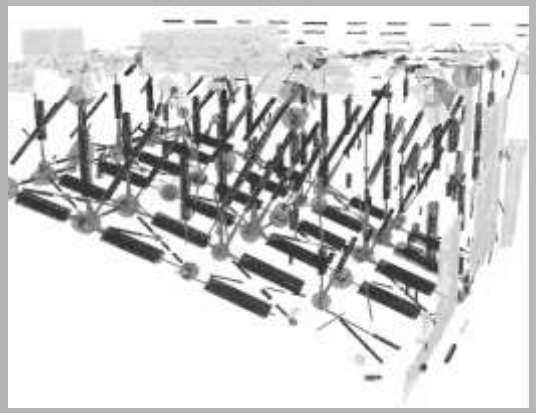
国土交通省

ARIA Project Objectives

Robotic sensing system

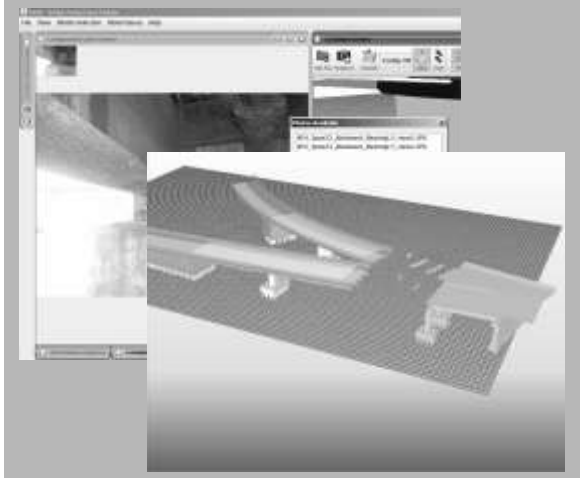
The robot acts as an inspector's tool, accomplishing inspection tasks with various levels of autonomy.

Rapid infrastructure modeling and analysis



Algorithms transform 3D and imagery from accurate low-level point cloud captured by the MAV, into a high-level semantic model, and finally a finite element model.

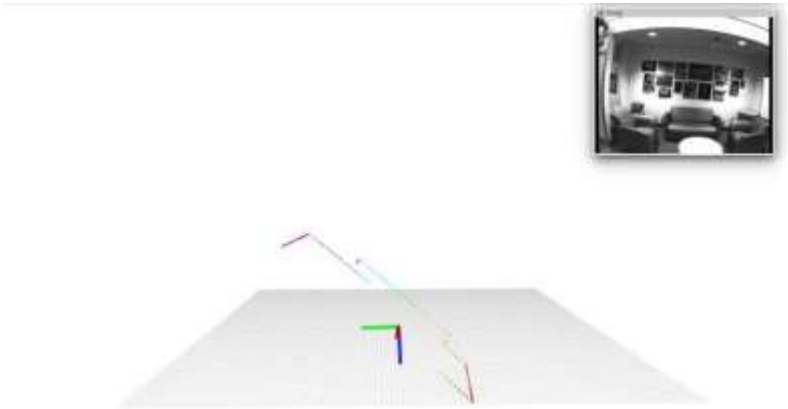
Immersive inspection and assessment



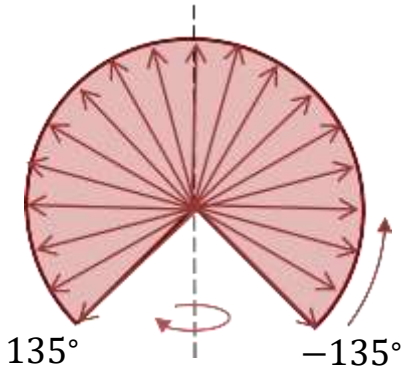
A visualization environment provides an immersive virtual infrastructure representation to aid in inspection and assessment tasks.

橋梁点検UAV技術（＋損傷自動検出技術）

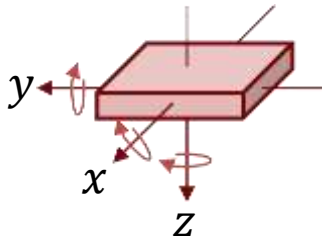
Robot (MAV)



- **Rotating 2D Laser Range Finder (LiDAR)**
  - Scan in a 2D fan from $-135°$ to $135°$
  - Return ~1000 points/sec
  - Collect 40 scans/sec
  - Rotate $180°$/sec



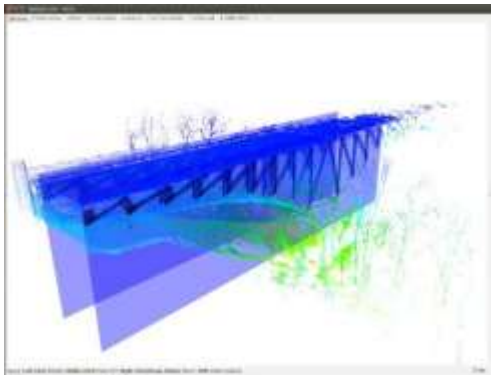
- **Inertial Measurement Unit (IMU)**
  - 3-axis linear acceleration
  - 3-axis angular velocity
  - Data streamed at 100Hz



Plane Segmentation, Coverage Planning and UI

Plane Segmentation

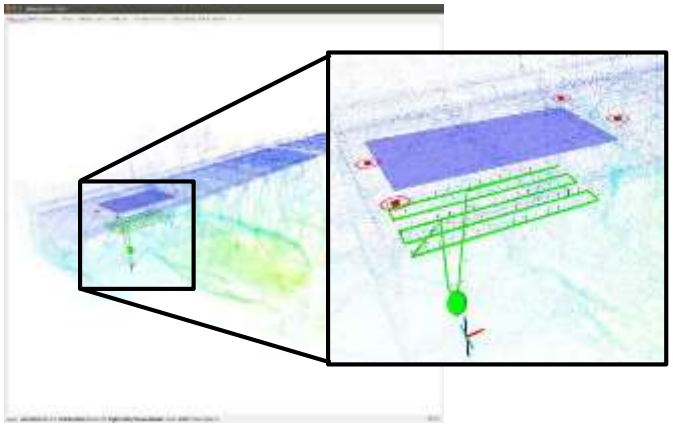
- Extract major planes from acquired point cloud map
- Works well for relatively simple structures
- Need manual adjustment for a specific bridge to capture critical structures



Extracted planes from Charles Anderson Bridge

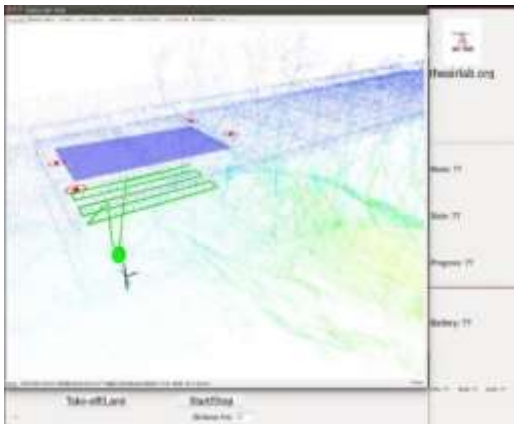
Coverage Path

- Generated from waypoints set that guarantees safety and coverage



UI

- Select and adjust plane
- Check path safety
- Auto take-off and landing
- Monitor task and robot status



Carnegie Mellon University：UAV点検デモ

国土交通省

Interactive Detailed Inspection

Autonomous MAV Inspection Test
at Charles Anderson Bridge

air lab

Carnegie Mellon University

Carnegie Mellon University：ARIA Project

国土交通省

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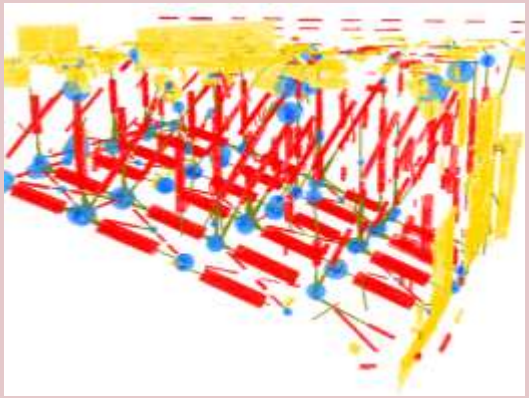

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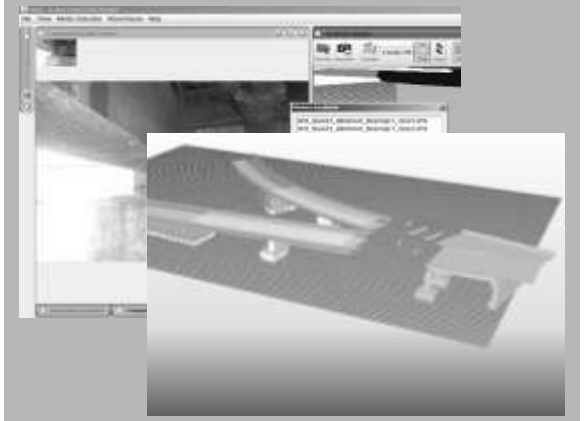


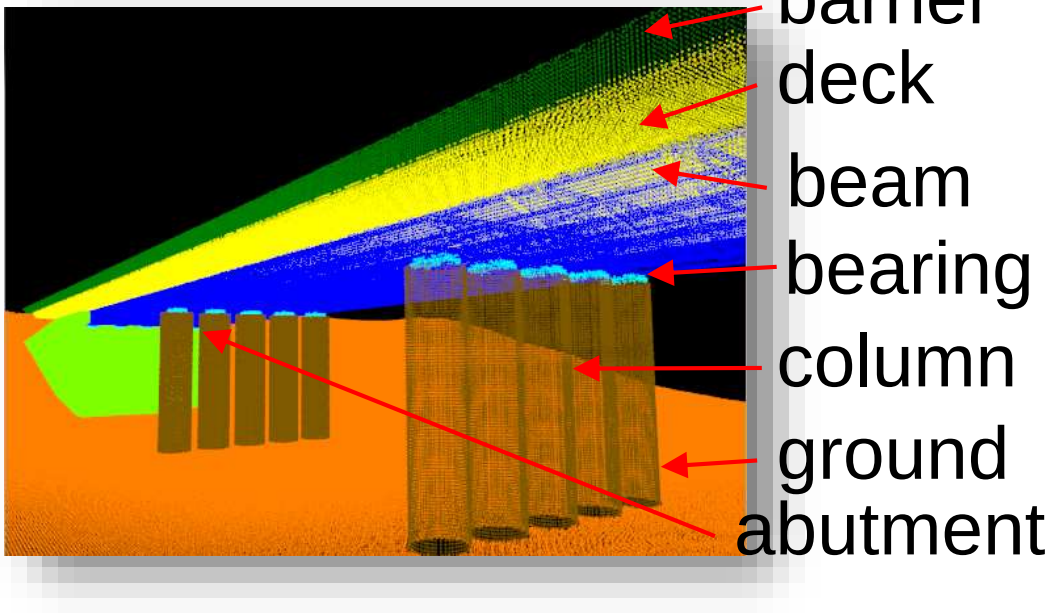
A visualization environment provides an immersive virtual infrastructure representation to aid in inspection and assessment tasks.

3次元モデリング技術

Object Detection and Identification

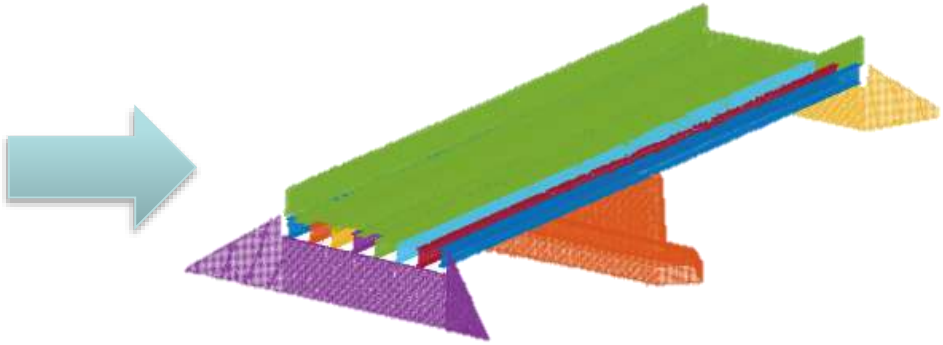
Heuristic Approach for Detecting Structural Members

- Direction Consistency
  - Girder along traffic direction
- Vertical Ordering
  - column < bearing < deck
- Neighbor Likelihood
  - abutment is adjacent to ground and deck

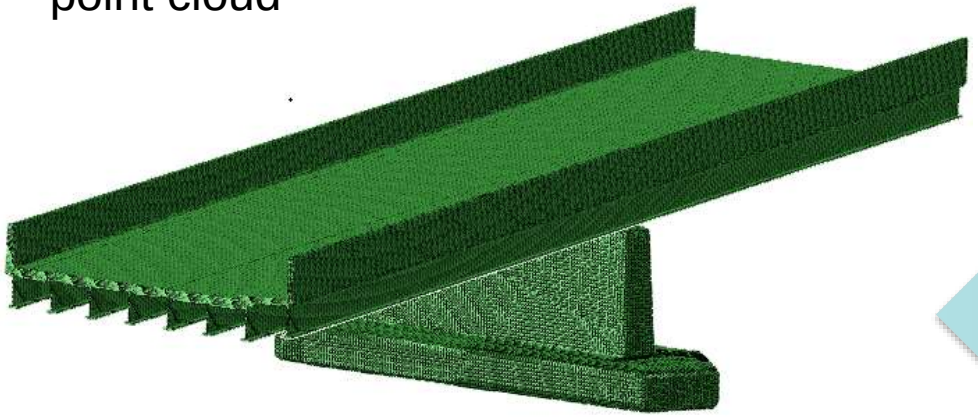


Results on Mill Run Bridge

Texture-mapped laser point cloud



Component classified laser point cloud



Finite Element Model

Summary and Future Work

1. Advantages:

- Can detect more details and planes with very sparse point densities;
- More robust than RANSAC and Region Growing based method (local optimization).

2. Disadvantages:

- Sensitive to penalty factor and time-consuming.

3. Future work:

- Calculate the penalty factor automatically
- Extend the algorithm to multiple types of models cases.

質疑応答の要点

【点検全般】

① 点検個所へのチョーキングは行っているか？
- 米国ではチョーキングしていない。

② ひび割れ検出の精度・要件は？
- 0.1mmは困難。米国でそのレベルは求められない。

【UAV技術】

① UAVで対象物にどこまで接近可能か？
- SLAMに制限はなく機体の性能に依存。
  現状、市販機体を使用しているため、2m程度。

② SLAM点群から自動で面（Plane）抽出が可能か？
- 可能

【3次元モデリング技術】

① 3次元モデリングでは、個々の点群に部材属性を付与するのか？
- その通り

Carnegie Mellon University：考察・所感

- 土木分野とロボット分野の研究者が協力し、メンテナンスサイクル全体を見渡して、各段階で必要なロボット技術の研究開発を網羅的に実施。

- UAV点検技術は現場運用、3次元モデリングは維持管理での活用を見据え、実用アプリケーション開発として取り組まれている。

- 一方、日本の性能要求や幅広い構造種別への対応は課題。
技術の適用可能性について国内技術も組合せて改良・検証の検討が必要。

- そのためには、日本の検査に即した検証データの整備が求められる。