Parameterized Pole-wire System Structural resilience analysis With Image Processing

Jintao Zhang[1], Xiaolong Ma[1], Dongping Zhu[1], Wei Zhang[2], Amvrossios Bagtzoglou[3] , Jason Parent[4]

[1] Graduate Student, Department of Civil and Environmental Engineering, University of Connecticut, Storrs, CT 06269
[2] Assistant Professor, Department of Civil and Environmental Engineering, University of Connecticut, Storrs, CT 06269
[3] Professor, Department of Civil and Environmental Engineering, University of Connecticut, Storrs, CT 06269
[2] Assistant Professor, Department of Natural Resources and the Environment, University of Connecticut, Storrs, CT 06269

INTRODUCTION

Power distribution system, including poles and wires, are vulnerable to various natural hazards, such as hurricane or winter storm related extreme weather events. In addition to the strong gusty winds, other natural environmental conditions, such as temperature, precipitation conditions, soil conditions, etc., could also affect the safety and reliability of the power distribution system. Failure of the structural components could lead to the failure of the pole-wire system in the community and cause possible cascading effects leading to large area blackouts. Therefore, the structural integrity analysis (SIA) is needed to perform in the structural level as well as in the system level to evaluate the performance of the pole-wire system under various extreme weather conditions and perform efficient hardening decision-making.

The updated pole-wire system model includes the following parameters of the pole: 1) Material; 2) Geometric parameters; 3) Amount and geometry of the existing guyed wire. The failure analysis is to identify the typical failure mode and key parameters.

MOTIVATION

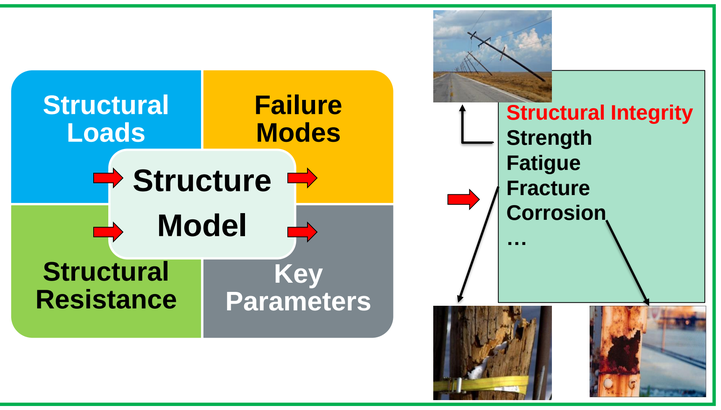


Figure 1.Generalization of SIA

METHODOLOGY

The parameterized pole-wire system model is composed of four parts as follows: First, construct the solid model of the system structure based on existing data such as point cloud data, etc. Second, with the use of model reduction, the structural parameters are extracted from the solid model. Afterwards, the finite element model could be built based on structural parameters. Finally, the risk analysis is performed.

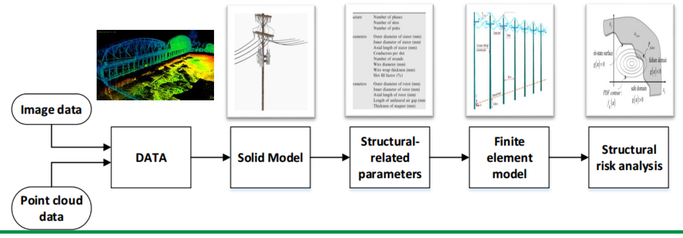


Figure 2.Flowchart of the methodology

IMAGE PROCESSING BASED MODELING

The structural parameters used to be kept in the engineering design records to meet the requirement to model the structure in finite element model which costs a lot of the manual work and wastes a lot of time to make measurements.

Using image processing and machine learning techniques, we automatically identify structural parameters in much faster speed and smart way. Image processing in our research could be divided in to photo processing and point cloud processing.

ContextCapture is employed to build the model from photos taken in different directions. Currently, the model is combined by several surfaces. In the next step, the model surface will be smoothed with the surface smoothing filter and such model will be extended to a 3D solid model.

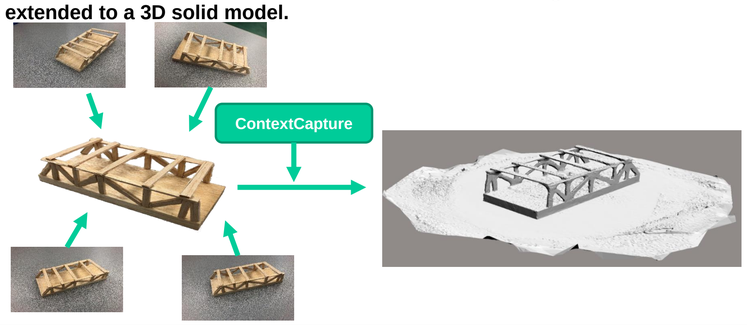


Figure 3. Exhibition of the mechanism of PHOTOSHOT PROCESSING

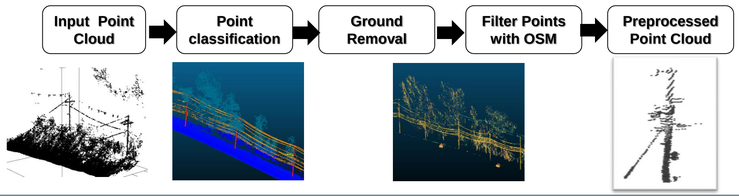


Figure 4. Exhibition of the mechanism of POINT CLOUD PROCESSING

PARAMETERS OF THE POLE AND WIRE IN THE MODEL

Crossarm
Amount, length, cross section, material, rotation around the pole, position of the linking wire

Wire
Wire ID, cross section, material, upstream pole ID, downstream pole ID

Pole
Pole ID, Height, cross section, material, lean, position of the crossarm, position of the linking wire, number and position of the guyed wire

Support
Support condition (fixed/soil spring), soil layer information, stiffness of the soil spring at each layer

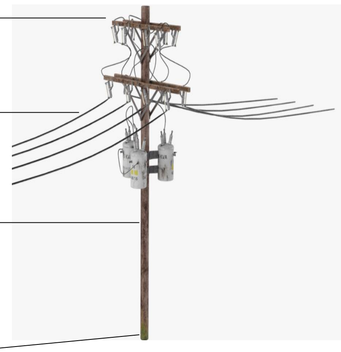
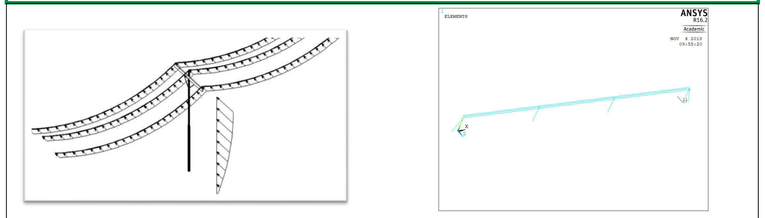


Figure 5. Demonstration of Parameters of the pole and wire considered in the model

POLE-WIRE MODEL AND ANALYSIS

Pole-Wire model mainly experiences the wind load and tree branch load ,etc. The load distribution under wind load and physics-based model are displayed in the following figures. Effect of soil-structure-interaction is also considered.

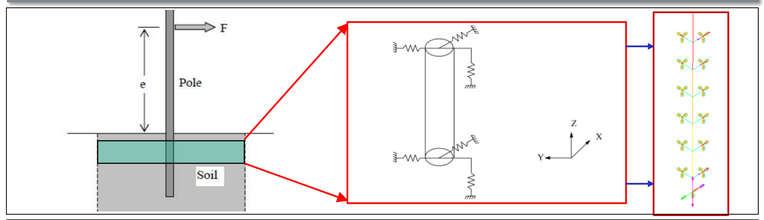
One way to evaluate the severity of the damage under these loads is to perform structural reliability analysis. It's processed as the use of functional relationships between the conditional probability of failure pole-wire mode land the parameter(s) of the hazard loading The fragility curve is generated to link the structural reliability and the environmental parameters.



a. Pole-Wire wind load distribution

b. Three Span Pole-Wire Model

Figure 6. Structural Models using ANSYS



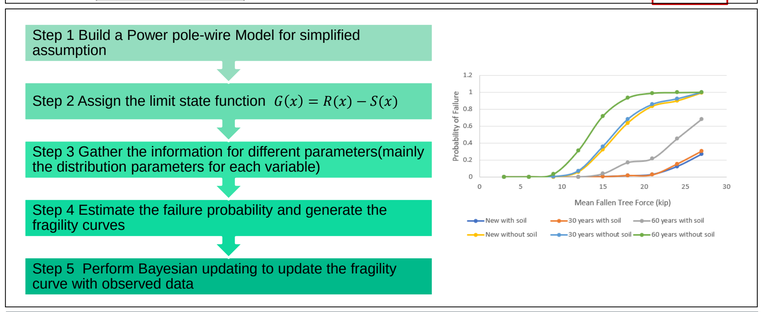


Figure 7. Flowchart of the Fragility curve and Demonstration of the fragility curve under tree branch load

ACKNOWLEDGEMENTS & REFERENCES

- Eversource Energy; EverSource Energy Center; CEE Department, SwRI
- Bruce Milardo, Osvaldo Pensado, Dave Wanik, Hao Yuan, etc.
- Yuan, H., Zhang, W., Zhu, J., Bagtzoglou, A. (2018) "Resilience Assessment of Overhead Power Distribution System under Strong Winds for Hardening Prioritization". *ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems*, 4(4). https://doi.org/10.1061/AJRUA6.0000988.

UCONN Eversource Energy Center EVERSOURCE