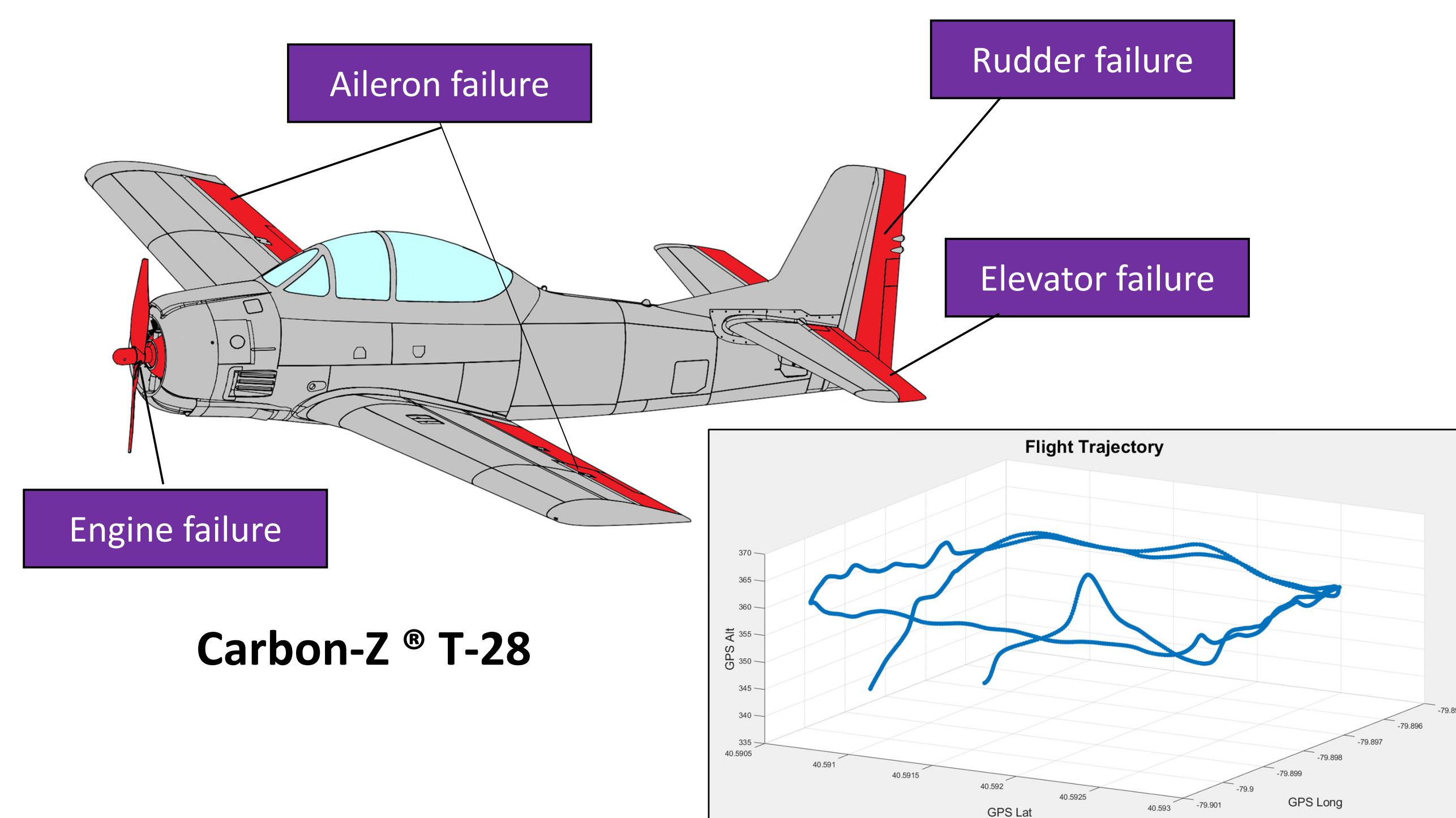# Morphology Of Uninhabited Vehicle Platform Complexity Using Information Theory-based Methods

Uninhabited Vehicle Platform

Aileron failure
Rudder failure
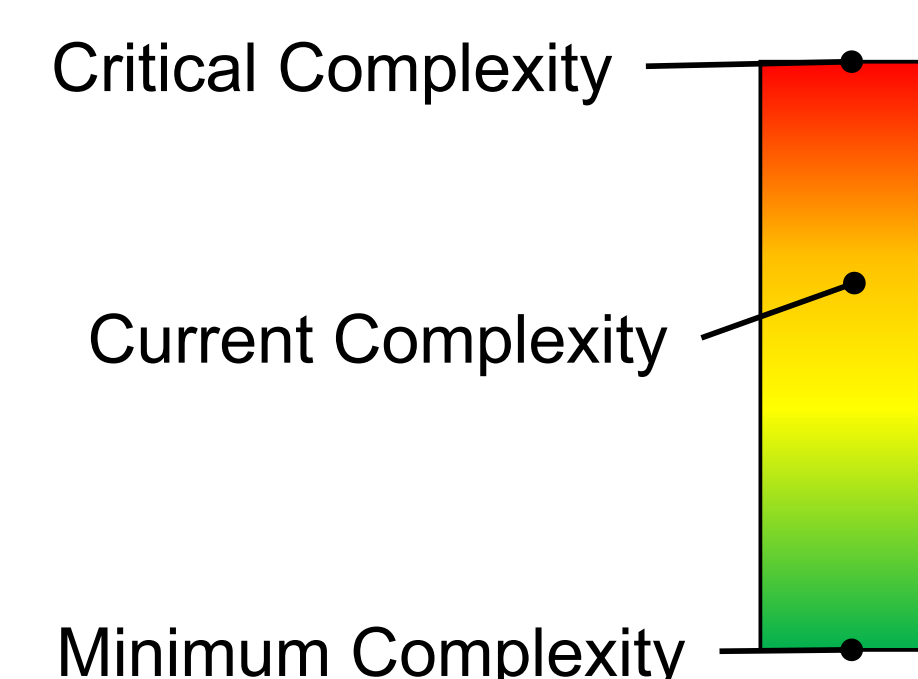Elevator failure
Engine failure

Carbon-Z ® T-28

Background

Complexity of a dynamical system is defined as a function of the morphology and the information entropy of the system [1]. Structure is an essential property of the dynamical systems, for it to perform functions, by enabling the flow of information in the system. Many times, the structure of the system is not completely known. In such a case, it can be estimated using elements of information theory (Shannon's information entropy, mutual information). The complexity of the system is bounded. The upper bound is uncertainty dominated and relationships between the elements of the system are fuzzy. On the other hand, at the lower bound, the system functions in a deterministic structure-dominated fashion. The robustness of the system is a measure of margins between the current complexity to the critical complexity of the system.
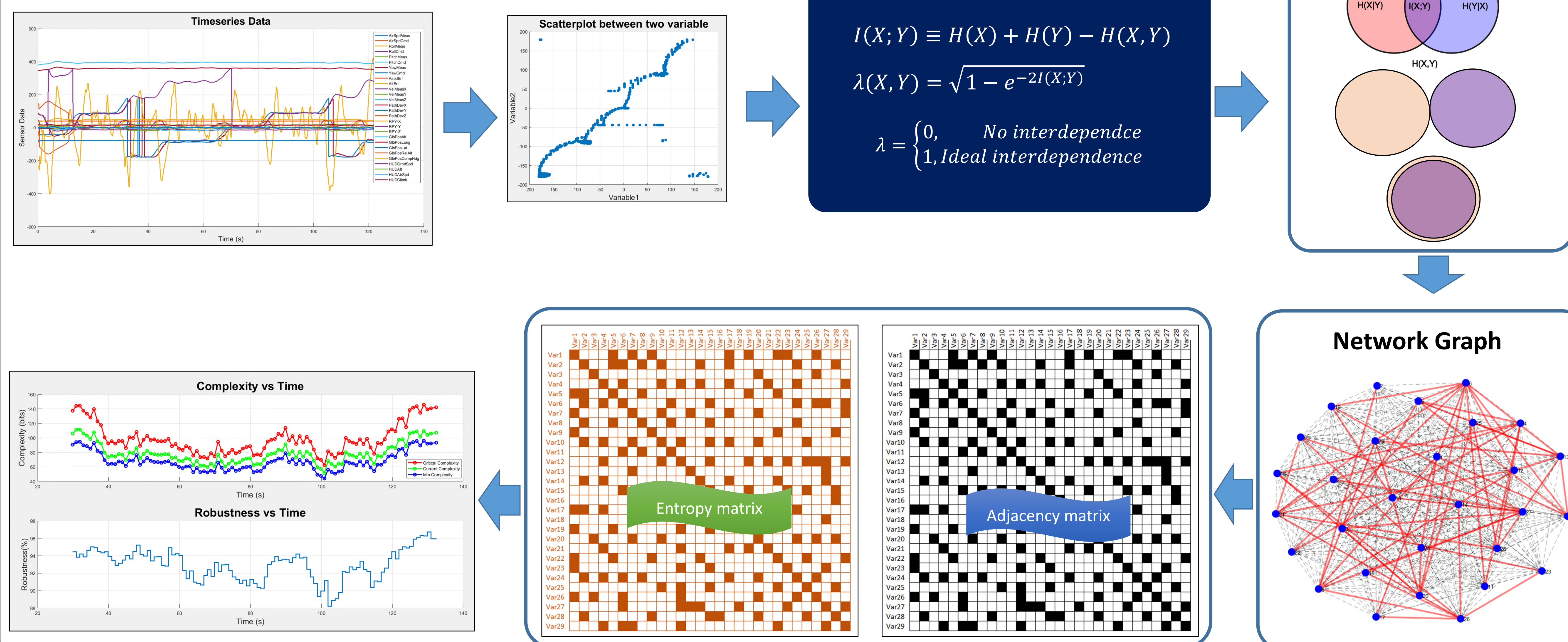
Complexity

$$C \triangleq f(S \underline{o} E)$$

Where
S represents an $N \times N$ adjacency matrix,
E is an $N \times N$ entropy matrix,
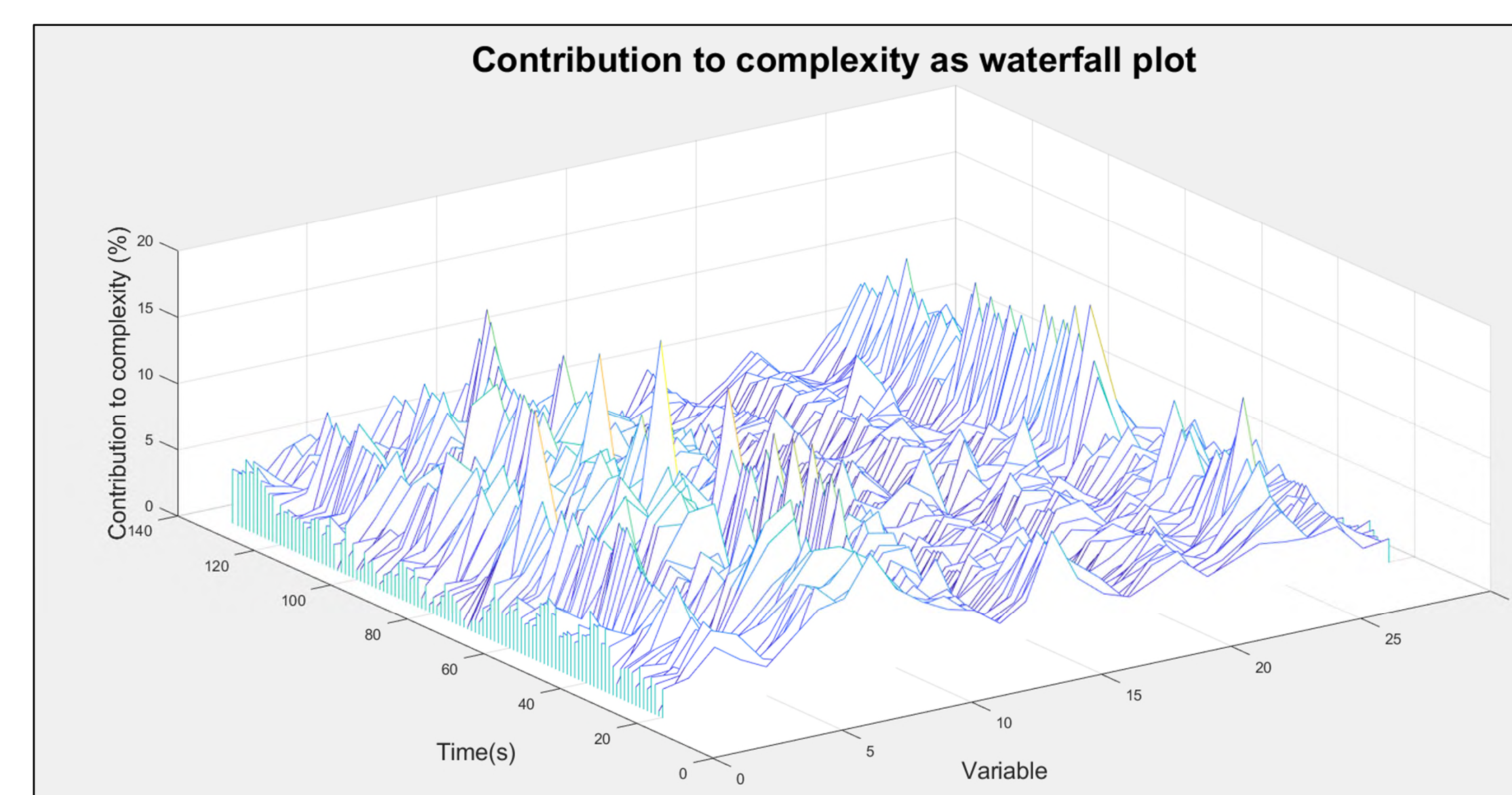$\underline{o}$ is the Hadamard matrix product operator
f is a norm operator

Critical Complexity
Current Complexity
Minimum Complexity

Methodology

Time series data [2] processing :
Sensor sampling rate from 1-50 Hz

$$I(X;Y) \equiv H(X) + H(Y) - H(X,Y)$$
$$\lambda(X,Y) = \sqrt{1 - e^{-2I(X;Y)}}$$
$$\lambda = \begin{cases} 0, & No\ interdependce \\ 1, & Ideal\ interdependence \end{cases}$$

Information Entropy

H(X) H(Y)
H(X|Y) I(X;Y) H(Y|X)
H(X,Y)

Network Graph

Entropy matrix

Adjacency matrix

Complexity Profile

Complexity profile is estimated using Gene Knockout (KO) technique

Contribution to complexity as waterfall plot

Conclusions

Time series data from the dynamical system, can be analyzed to estimate the structure of the system. Secondary processing of the structure may reveal critical modes of the system. Future work will concentrate on using Random Matrix Theory, to reveal underlying influence of the modes on the systemic behaviour.

References

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2. Keipour A, Mousaei M, Scherer S. ALFA: A dataset for UAV fault and anomaly detection. The International Journal of Robotics Research. 2021;40(2-3):515-520. doi:10.1177/0278364920966642
3. G. A. Darbellay, "The mutual information as a measure of statistical dependence," Proceedings of IEEE International Symposium on Information Theory, 1997, pp. 405-, doi: 10.1109/ISIT.1997.613342.

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