Magnetohydrodynamic Eigenfunction classification with a Neural Network

TSV10

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Motivation

- Information on stability of fusion devices can be obtained from the energy principle of ideal MHD.
- For small-field perturbations, normal modes can be associated with a generalized eigenvalue problem, which is solved numerically (e.g. CAS3D, CKA).
- The resultant eigenmodes, f can be of different types. They are usually classified **manually** by looking at the 2D Fourier decomposed modes structure $\varphi_{m,n}(s)$.
- The data is summarized in the MHD spectrum plot.

MHD spectrum

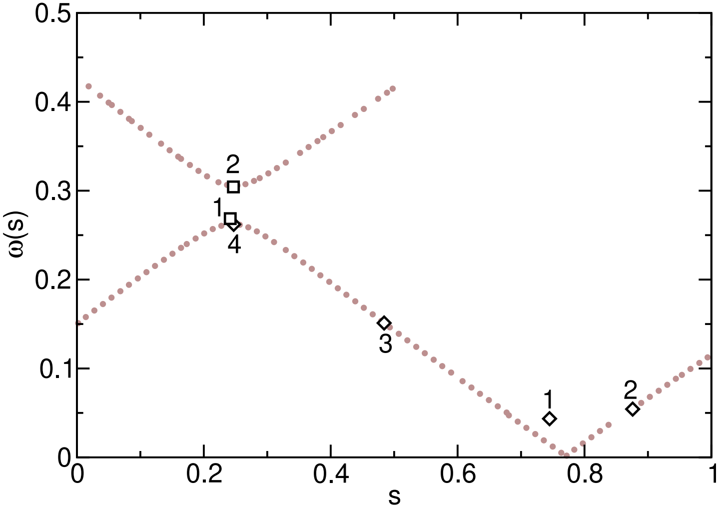


Figure: Example MHD spectrum

Continuum and Gap modes

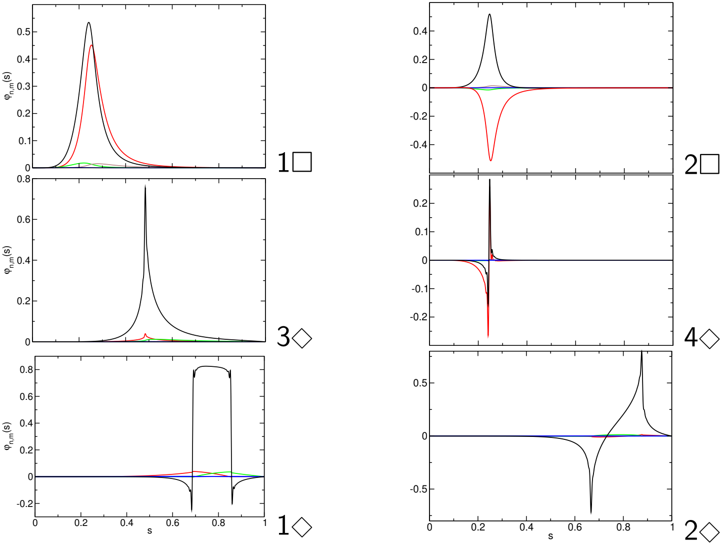


Figure: Example eigenfunctions selected from the previous spectrum.

2D Fourier decomposition of modes

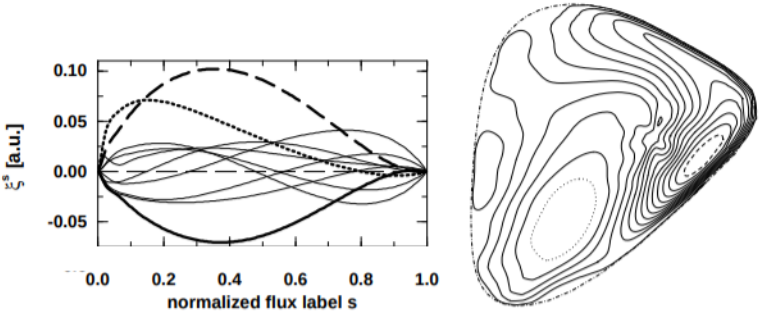


Figure: Example global fast magnetic compression mode in W7-AS.

Eigenvalue Classification Algorithm (ECA)

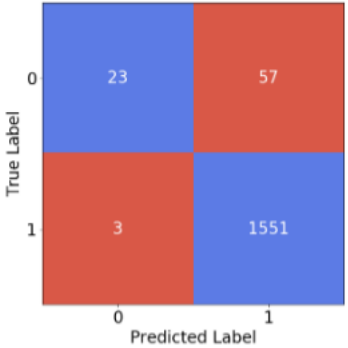
$$\underbrace{\boxed{f} \overset{\text{FT}}{\mapsto} \boxed{\begin{matrix} \varphi_{0,0} & \varphi_{1,0} & \cdots \\ \varphi_{0,1} & \varphi_{1,1} & \cdots \\ \vdots & \vdots & \ddots \end{matrix}} \overset{\text{NN}}{\mapsto} \boxed{\begin{matrix} l_{0,0} & l_{1,0} & \cdots \\ l_{1,0} & l_{1,1} & \cdots \\ \vdots & \vdots & \ddots \end{matrix}} \overset{\text{F}}{\mapsto} \boxed{l}}_{\boxed{f} \overset{ECA}{\mapsto} \boxed{l}}$$

Figure: Schematic breakdown of the ECA. FT represents a 2D Fourier decomposition of the eigenfunction f. NN is the Neural Network that assigns a label $l_{m,n}$ to each of the Fourier modes $\varphi_{m,n}$. F stands for the filter that infers the eigenfunction label l from various $l_{m,n}$.

Advantages of the approach

$$f \overset{\text{FT}}{\mapsto} \phi_{m,n} \overset{\text{NN}}{\mapsto} l \qquad vs \qquad f \overset{\text{FT}}{\mapsto} \phi_{m,n} \overset{\text{NN}}{\mapsto} l_{m,n} \overset{\text{F}}{\mapsto} l$$

- Allows to generate much more data.
- Error proof.



Results

Automated classification of 93.6% of the data, leaving the remaining 6.4% for classification by a user defined filtering procedure.

Test set A

NN

group	*count*
0	83
1	0
2	0
3	0
4	2

actual

group	*count*
non-gap	83
gap	3

Test set B

NN

group	*count*
0	104
1	9
2	3
3	1
4	0

actual

group	*count*
non-gap	117
gap	0

Table 2: The result of applying the ECA on the test sets.

Possible areas of improvements

- Replace the 1D CNN with a NN designed for 'anomaly detection'.
- Include more types of modes, possibly unconverged and modes of mixed type.
- Enlarging the database, assuring generalizabilty.