數學系課程核心教材內容

<table>
<tr><td colspan="4" rowspan="2">課程名稱:(中文) 深度學習專題
(英文) Topics in Deep Learning</td><td>開課單位</td><td>應用數學碩士班</td></tr>
<tr><td>課程代碼</td><td></td></tr>
<tr><td>學分數</td><td>3</td><td>必/選修</td><td>選</td><td>開課年級</td><td>一</td></tr>
<tr><td colspan="6">Primary Objective
This course is a hands-on introduction to data-driven modeling for dynamical systems, with all methods developed and tested in Python or MATLAB. Students learn how to:
(i) extract structure from data using matrix decompositions and modal methods,
(ii) identify governing equations and reduced models,
(iii) interpret dynamics through operator and spectral perspectives
(iv) build learning-based surrogates for prediction and control.
Rather than presenting a catalog of techniques, we emphasize a small set of broadly useful ideas—chosen for clarity and transferability—and show how they connect to classical numerical analysis and applied optimization. Topics progress from foundational algorithms to research-level tools, making the course suitable for advanced undergraduates and early graduate students in engineering and physical sciences.</td></tr>
<tr><td colspan="6">Grading method: Homework (40%), Midterm or Report (30%), Report (30%)</td></tr>
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建議參考書目	1. Kutz, J. N. (2013). Data-driven modeling & scientific computation: methods for complex systems & big data. OUP Oxford. 2. Boyce, W. E., DiPrima, R. C., & Meade, D. B. (2021). Elementary differential equations and boundary value problems. John Wiley & Sons. Ch9 3. Brunton, S. L., & Kutz, J. N. (2022). Data-driven science and engineering: Machine learning, dynamical systems, and control. Cambridge University Press. 4. https://faculty.washington.edu/kutz/kutz_book_v2.pdf#page=479.73 5. https://fluids.ac.uk/files/meetings/KoopmanNotes.1575558616.pdf 6. Li, Z., Kovachki, N., Azizzadenesheli, K., Liu, B., Bhattacharya, K., Stuart, A., & Anandkumar, A. (2020). Fourier neural operator for parametric partial differential equations. arXiv preprint arXiv:2010.08895. 7. Lu, L., Jin, P., & Karniadakis, G. E. (2019). Deeponet: Learning nonlinear operators for identifying differential equations based on the universal approximation theorem of operators. arXiv preprint arXiv:1910.03193.

課程大綱

單元主題	內容綱要	上課週數
Initial and Boundary Value Problems of Differential Equations	1. Initial Value Problems: Euler, Runge–Kutta and Adams Methods 2. Error Analysis for Time-Stepping Routines 3. Linear Operators and Computing Spectra 4. Neural Networks for Time Stepping	3-4
Matrix Decompositions	1. The Singular Value Decomposition (SVD) 2. Principal Components, Diagonalization and SVD 3. Dynamic Mode Decomposition (DMD)	3-4

Koopman Operator Theory	1. Koopman Operator Theory	3
Spatio-Temporal Data and Dynamics	1. Modal Expansion Techniques for PDEs 2. The POD Method and Symmetries/Invariances 3. Sparse Identification of Nonlinear Dynamics (SINDy) 4. Deep Learning Paradigms for Time-Space Stepping	3-4
Fancy Topisc	1. Data Assimilation Methods 2. DeepONet 3. Transformers and Foundation Models	2-3

Students may select any paper or chapter from Kutz (2013), "Data-Driven Modeling & Scientific Computation: Methods for Complex Systems & Big Data", for an in-class presentation.
Presenters will earn extra credit, but the chosen topic must be approved by the instructor beforehand.