Graph signal processing and graph machine learning

Course overview and closing synthesis

Represent relationships.
Design the computation.
Test what the graph contributes.

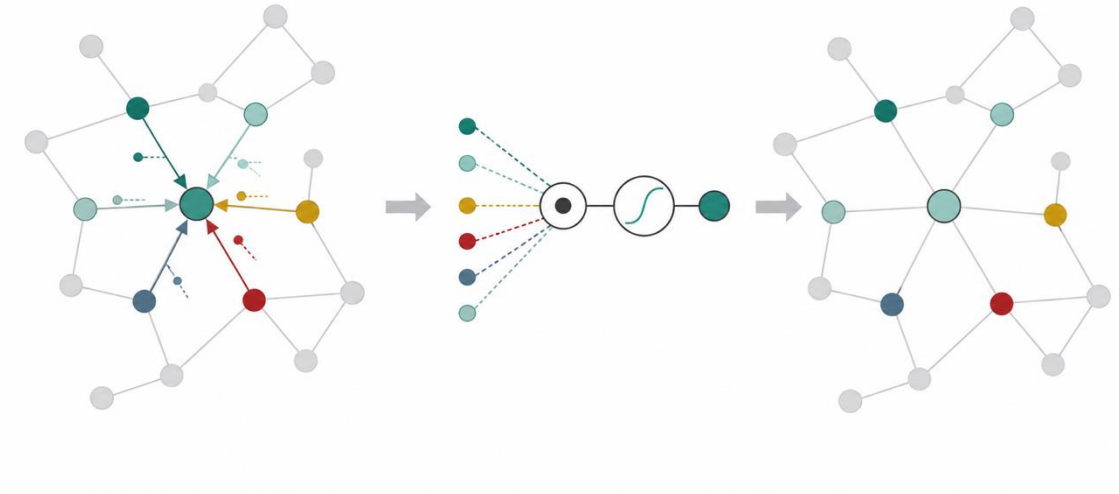
Local graph operations create learned representations

Graph operator

Defines neighbors and graph frequencies.

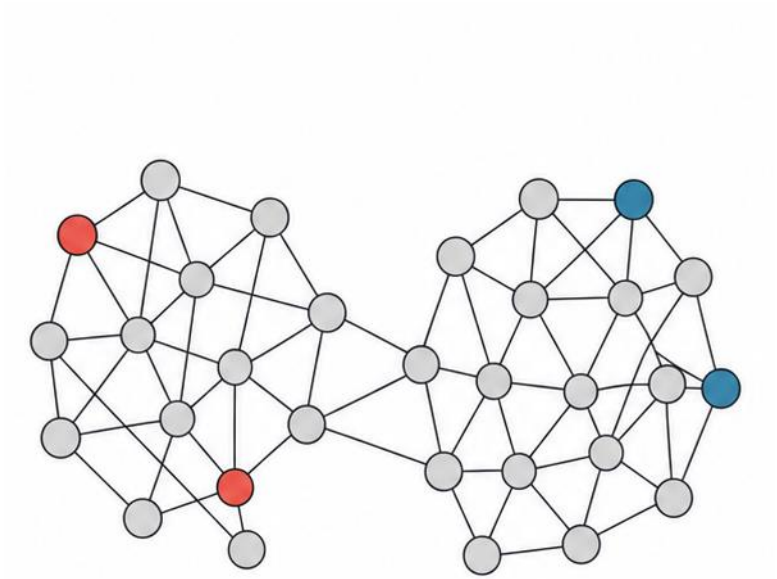
Filter and nonlinearity

Mix information, transform features, repeat.



Shared rules respect node relabeling.

Graph structure and node features provide different evidence



Given graph

Use edges and features to infer labels or signals.

Unknown graph

Construct or learn relationships from measurements.

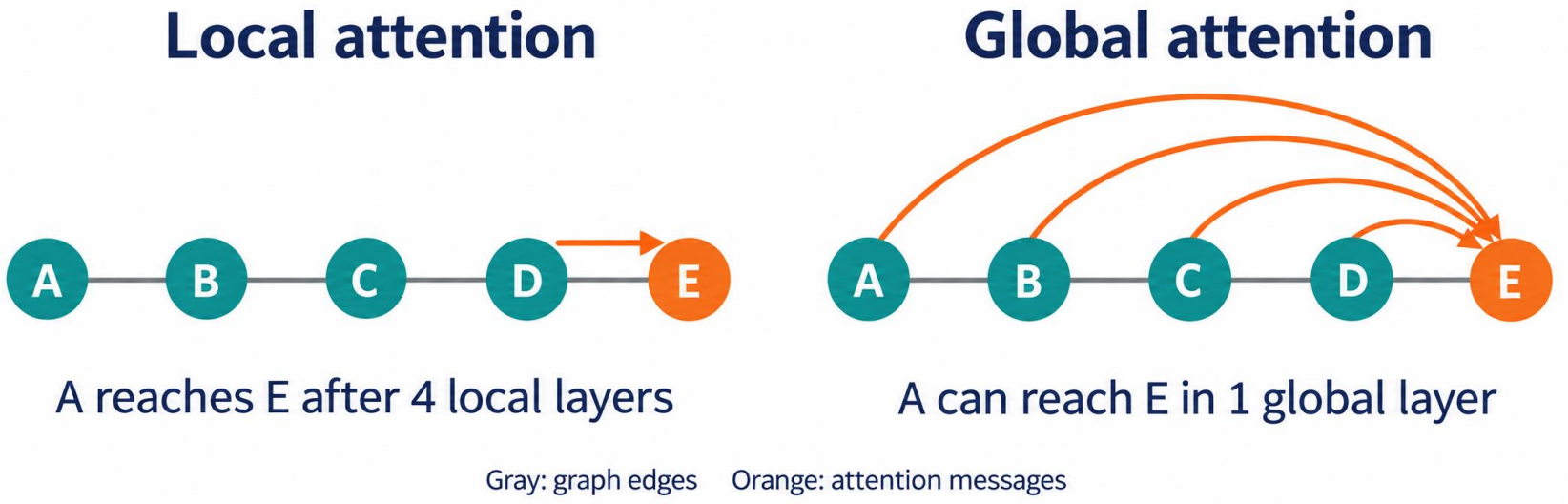
The task determines which relationships are informative.

Four properties explain different model behaviors

Expressivity	Distinguishing structures relevant to the task.
Oversmoothing	Repeated mixing can reduce useful node distinctions.
Oversquashing	Relevant distant inputs can have weak influence.
Stability	Controlling output change under graph perturbations.

Choose a diagnostic that matches the suspected limitation.

Attention changes mixing weights and communication routes



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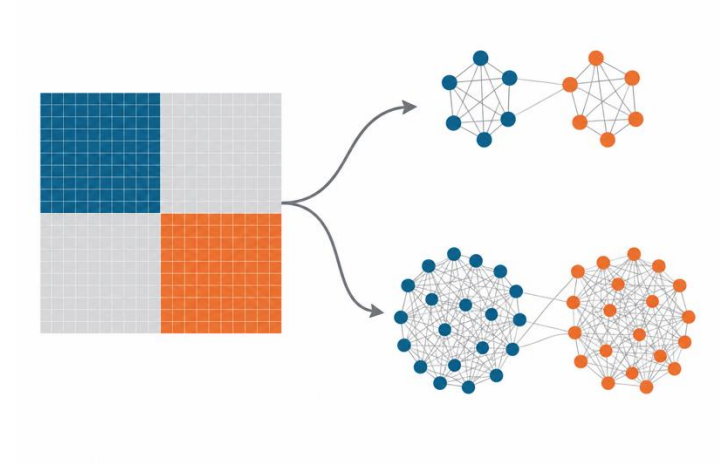
Learn weights over graph neighbors.

Graph transformers

Combine broad attention with graph structure.

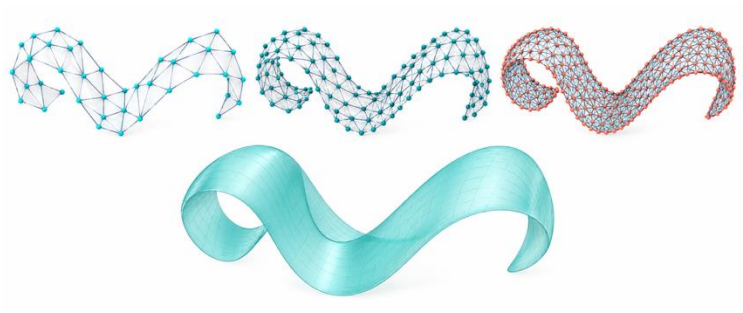
Transfer requires a shared reference and an explicit test

Graphon limit



Shared connectivity rule

Manifold limit



Shared geometric domain

Foundation model

Reuse pretrained parameters across tasks or domains.

State what changes, what stays fixed, and how success is measured.

New tasks change what the model must produce

Generate graphs

Learn a distribution of structures.

Autoregressive models, VAEs, and diffusion

Predict the future

Condition on the history available at a cutoff.

Signal forecasting and temporal interactions

Answer with evidence

Use graph relationships to support a language task.

Graph features, joint reasoning, and graph retrieval

A useful experiment tests the contribution of the graph

Example: traffic forecasting

Temporal baseline	Use the observed signal history.
Road-graph model	Add spatial relationships between sensors.
Edge ablation	Change the edges while keeping the architecture fixed.

Match information access and forecast horizons. Report accuracy and cost.

A reusable approach to graph learning

Formulate the problem	Define nodes, edges, signals, and the prediction target.
Choose the computation	Match locality, structure, and history to the task.
State the assumptions	Identify the symmetry, prior, and transfer setting.
Build the evidence	Use a baseline, a focused ablation, and a valid split.

Thank you for your work and contributions to the course.