Reinforced Federated Graph Domain Generalization with Dynamic Aggregation Strategy

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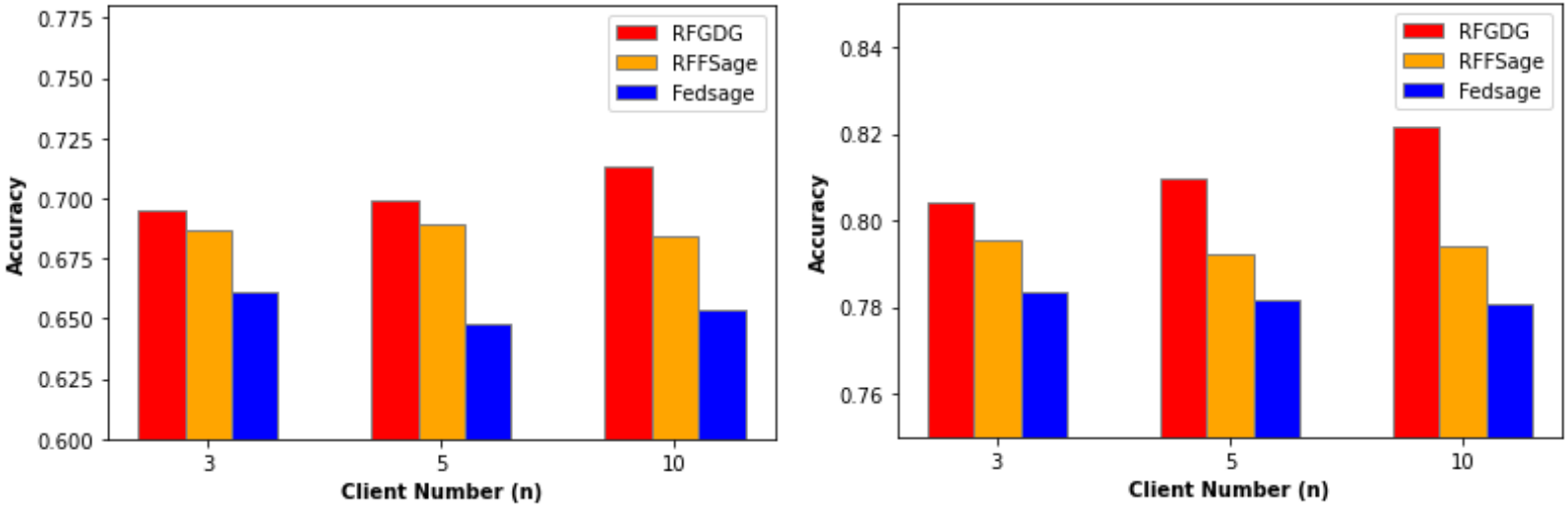
Problems & Ideas

- Problems of federated graph learning approaches:
  - Existing federated graph methods suffer poor generalization from client data heterogeneity and strict privacy constraints.
  - Centralized graph model training is difficult due to strict privacy regulations and sensitive graph data.
- Ideas: A reinforced federated graph domain generalization (RFGDG) combining Fourier feature generalization and reinforcement learning-based aggregation improves accuracy across heterogeneous clients.



Classification accuracy comparisons on Twitter (left) and Weibo (right) datasets under varying numbers of clients. Our proposed method RFGDG consistently achieves higher accuracy compared to baseline methods (RFFSage and FedSage). Particularly, as client numbers increase, RFGDG shows more prominent performance improvement, demonstrating its superior adaptability and robustness in scenarios with higher client heterogeneity.

Main Contributions

- Contributions:
  - A reinforced federated graph domain generalization (RFGDG) framework combining federated learning with Random Fourier Feature transformation, effectively improving feature generalization across heterogeneous clients;
  - A dynamic aggregation strategy utilizing reinforcement learning to adaptively optimize client contributions, significantly enhancing global model accuracy and robustness;
  - Extensive experiments conducted on real-world datasets validate that the proposed RFGDG outperforms state-of-the-art federated graph methods under various scenarios with different data heterogeneity.

Table 1 Comparison of Test Accuracy on Cora and Citeseer

Dataset	Federated	Graph	3 Clients		5 Clients		10 Clients	
			Test Set	Validation Set	Test Set	Validation Set	Test Set	Validation Set
Cora	FedAvg	GCN	0.8053±0.0021	0.7499±0.0125	0.8068±0.0087	0.7502±0.0085	0.7799±0.0038	0.6948±0.0066
		GAT	0.7997±0.0128	0.7436±0.0041	0.7736±0.0205	0.7469±0.0099	0.7097±0.0121	0.6647±0.0202
		SAGE	0.8143±0.0034	0.7558±0.0048	0.8025±0.0078	0.7576±0.0085	0.7745±0.0093	0.6857±0.0084
	FedProx	GCN	0.8096±0.0037	0.7481±0.0052	0.8081±0.0037	0.7524±0.0063	0.7798±0.0092	0.6901±0.0041
		GAT	0.8006±0.0127	0.7481±0.0072	0.7771±0.0074	0.7399±0.0207	0.7683±0.0124	0.6703±0.0109
		SAGE	0.8193±0.0053	0.7587±0.0074	0.8009±0.0094	0.7561±0.0085	0.7777±0.0089	0.6868±0.0166
	MOON	GCN	0.7932±0.0034	0.7328±0.0107	0.7941±0.0065	0.7478±0.0072	0.7691±0.0118	0.6894±0.0053
		GAT	0.7912±0.0089	0.7386±0.0027	0.7846±0.0093	0.7493±0.0128	0.7583±0.0013	0.6632±0.0047
		SAGE	0.8081±0.0035	0.7512±0.0084	0.7990±0.0048	0.7524±0.0038	0.7695±0.0116	0.6807±0.0058
	FedHiSyn	GCN	0.8137±0.0143	0.7521±0.0056	0.8096±0.0017	0.7513±0.0078	0.7805±0.0028	0.6924±0.0032
		GAT	0.8016±0.0106	0.7509±0.0063	0.7787±0.0165	0.7435±0.0171	0.7627±0.00074	0.6685±0.0158
		SAGE	0.8174±0.0093	0.7544±0.0061	0.8035±0.0081	0.7610±0.0048	0.7718±0.0059	0.6952±0.0102
	RFGDG		**0.8393±0.0184**	**0.8044±0.0041**	**0.8449±0.0118**	**0.7956±0.0007**	**0.7912±0.0051**	**0.7348±0.0052**
Citeseer	FedAvg	GCN	0.7250±0.0022	0.7156±0.0081	0.7231±0.0047	0.7027±0.0024	0.7297±0.0029	0.6863±0.0063
		GAT	0.7326±0.0054	0.7114±0.0018	0.7270±0.0043	0.6817±0.0099	0.7151±0.0024	0.6600±0.0131
		SAGE	0.7339±0.0017	0.7303±0.0054	0.7339±0.0011	0.6997±0.0039	0.7322±0.0034	0.6803±0.0063
	FedProx	GCN	0.7249±0.0023	0.7162±0.0045	0.7221±0.0026	0.7057±0.0054	0.7286±0.0052	0.6881±0.0045
		GAT	0.7306±0.0085	0.7141±0.0096	0.7263±0.0066	0.6835±0.0096	0.7132±0.0046	0.6573±0.0039
		SAGE	0.7352±0.0046	0.7282±0.0058	0.7291±0.0047	0.7021±0.0153	0.7281±0.0034	0.6907±0.0033
	MOON	GCN	0.7234±0.0014	0.7131±0.0053	0.7208±0.0033	0.6993±0.0029	0.7248±0.0087	0.6819±0.0075
		GAT	0.7298±0.0056	0.7085±0.0067	0.7226±0.0052	0.6784±0.0089	0.7115±0.0042	0.6547±0.0082
		SAGE	0.7258±0.0085	0.7266±0.0033	0.7264±0.0068	0.6974±0.0045	0.7258±0.0097	0.6842±0.0048
	FedHiSyn	GCN	0.7275±0.0035	0.7192±0.0083	0.7256±0.0023	0.7084±0.0030	0.7308±0.0049	0.6911±0.0041
		GAT	0.7315±0.0061	0.7148±0.0072	0.7295±0.0051	0.6866±0.0075	0.7192±0.0033	0.6635±0.0057
		SAGE	0.7362±0.0022	0.7328±0.0047	0.7352±0.0028	0.7025±0.085	0.7293±0.0058	0.6925±0.0075
	RFGDG		**0.7583±0.0045**	**0.7443±0.0035**	**0.7595±0.0063**	**0.7684±0.0022**	**0.7532±0.0081**	**0.7343±0.0068**

Table 3 Comparison of Test Accuracy on Twitter and Weibo

Dataset	Federated	Graph	3 Clients		5 Clients		10 Clients	
			Test Set	Validation Set	Test Set	Validation Set	Test Set	Validation Set
Twitter	FedAvg	GCN	0.6416±0.0229	0.7647±0.0012	0.8184±0.0006	0.5949±0.0086	0.8251±0.0003	0.5953±0.0025
		GAT	0.6995±0.0127	0.7070±0.0140	0.7796±0.0046	0.5853±0.0113	0.7956±0.0025	0.5781±0.0004
		SAGE	0.7391±0.0126	0.8278±0.0045	0.8310±0.0033	0.7142±0.0056	0.8476±0.0063	0.7205±0.0033
	FedProx	GCN	0.6264±0.0015	0.7624±0.0312	0.8203±0.0064	0.6252±0.0054	0.8208±0.0120	0.8249±0.0075
		GAT	0.6807±0.0226	0.7735±0.0143	0.7917±0.0027	0.5144±0.0187	0.8095±0.0010	0.5912±0.0041
		SAGE	0.7385±0.0034	0.8160±0.0113	**0.8407±0.0034**	0.7944±0.0068	**0.8532±0.0095**	0.8113±0.0044
	MOON	GCN	0.6324±0.0145	0.7532±0.0114	0.8194±0.0054	0.6035±0.0065	0.8035±0.0053	0.6481±0.0087
		GAT	0.6871±0.0156	0.7426±0.0068	0.7843±0.0063	0.5674±0.0134	0.7948±0.0034	0.5861±0.0064
		SAGE	0.7284±0.0079	0.8043±0.00104	0.8215±0.0015	0.7681±0.0023	0.8317±0.0073	0.7392±0.0018
	FedHiSyn	GCN	0.6586±0.0151	0.7751±0.00218	0.8224±0.0058	0.6325±0.0087	0.8256±0.0041	0.7745±0.0063
		GAT	0.7045±0.0132	0.7831±0.0039	0.7963±0.0072	0.6031±0.0074	0.8079±0.0056	0.6098±0.0017
		SAGE	0.7407±0.0108	0.8243±0.0041	0.8352±0.0044	0.7822±0.0047	0.8454±0.0066	0.8051±0.0081
	RFGDG		**0.7693±0.0184**	**0.8394±0.0046**	0.7755±0.0006	**0.8436±0.0078**	0.7775±0.0037	**0.8661±0.0068**
Weibo	FedAvg	GCN	0.5664±0.0072	0.5359±0.0048	0.6703±0.0043	0.5739±0.0182	0.6708±0.0095	0.5955±0.0014
		GAT	0.5841±0.0128	0.4911±0.0045	0.5703±0.0020	0.5567±0.0172	0.5785±0.0041	0.5220±0.0033
		SAGE	0.6420±0.0094	0.6795±0.0010	0.6871±0.0084	0.6141±0.0212	0.6936±0.0045	0.6620±0.0063
	FedProx	GCN	0.6170±0.0013	0.5378±0.0117	0.6810±0.0017	0.6084±0.0072	0.7083±0.0054	0.5936±0.0027
		GAT	0.6314±0.0102	0.5944±0.0034	0.5827±0.0067	0.5842±0.0017	0.5708±0.0093	0.5408±0.0043
		SAGE	0.6458±0.0068	0.6714±0.0058	0.6796±0.0010	0.6776±0.0142	0.7077±0.0053	0.6864±0.0031
	MOON	GCN	0.5874±0.0051	0.5271±0.0063	0.6609±0.0016	0.5682±0.0079	0.6876±0.0012	0.5917±0.0045
		GAT	0.6114±0.0067	0.5794±0.0021	0.5635±0.0044	0.5463±0.0078	0.5596±0.0077	0.5204±0.0068
		SAGE	0.6378±0.0066	0.6702±0.0087	0.6743±0.0035	0.6334±0.0088	0.6897±0.0028	0.6785±0.0042
	FedHiSyn	GCN	0.6271±0.0075	0.5314±0.0063	0.6815±0.0024	0.6151±0.0085	0.7052±0.0062	0.6036±0.0055
		GAT	0.6418±0.0052	0.6025±0.0012	0.5988±0.0011	0.5891±0.0076	0.6913±0.0023	0.6855±0.0091
		SAGE	0.6545±0.0071	0.6753±0.0016	0.6854±0.0044	0.6718±0.0059	0.7032±0.0087	0.6825±0.0036
	RFGDG		**0.7083±0.0045**	**0.6815±0.0218**	**07058±0.0167**	**0.6916±0.0304**	**0.7196±0.0024**	**0.7094±0.0227**

Accuracy comparisons of federated graph methods, showing superior performance of RFGDG across multiple datasets and client numbers.