A Survey of Deep Causal Models and Their Industrial Applications

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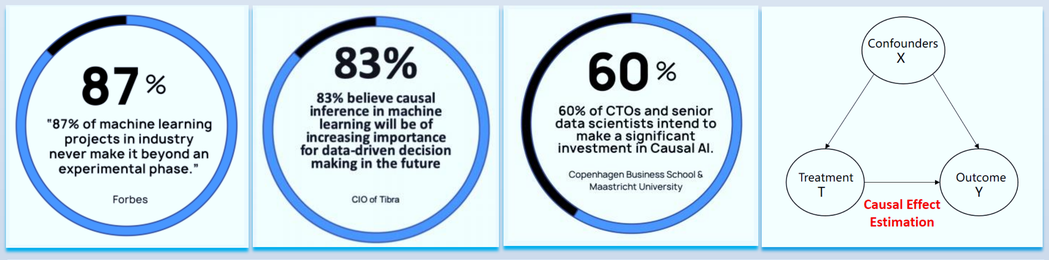
Problems: How to provide a overview of the latest applications of deep causal models in industry

■ Introduction



Surveys	Highlights
The Development of Causal Reasoning	The origin and development of causal reasoning
Causality for Machine Learning	The connection between graphical causal effect estimation and machine learning
Causal Inference	Machine Learning Interpretability for Counterfactual Causal Reasoning
Toward Causal Representation Learning	Exploring causal variables in data through causal representation learning
Causal Machine Learning for Healthcare and Precision Medicine	Causal Machine Learning in clinical decision support systems
A Survey of Learning Causality with Data: Problems and Methods	The relationship between causal learning and machine learning in big data
A Survey on Causal Inference	Causal effect estimation of observational data in the potential outcomes framework
A Review and Roadmap of Deep Learning Causal Discovery in Different Variable Paradigms	An improved exploration of causal discovery from the perspective of deep learning and variable paradigms
Causal Machine Learning: A Survey and Open Problems	Five types of causal machine learning problems under structural causal models
Causal Inference in Recommender Systems: A Survey and Future Directions	Optimize the recommendation system by extracting causality through causal reasoning
Deep Causal Learning: Representation, Discovery and Inference	The significance of deep learning for solving traditional causal learning problems
A Survey of Deep Causal Models and Their Industrial Applications	Causal effect estimation in deep models with biased sample observations and challenges in current industrial applications

■ Preliminaries

Challenges: Representation learning, Debias estimation, Counterfactual inference

Definitions: Observed outcome, Counterfactual outcome, Dose, Covariates

Assumptions: Stable Sample Treatment Value, Ignorability, Overlap

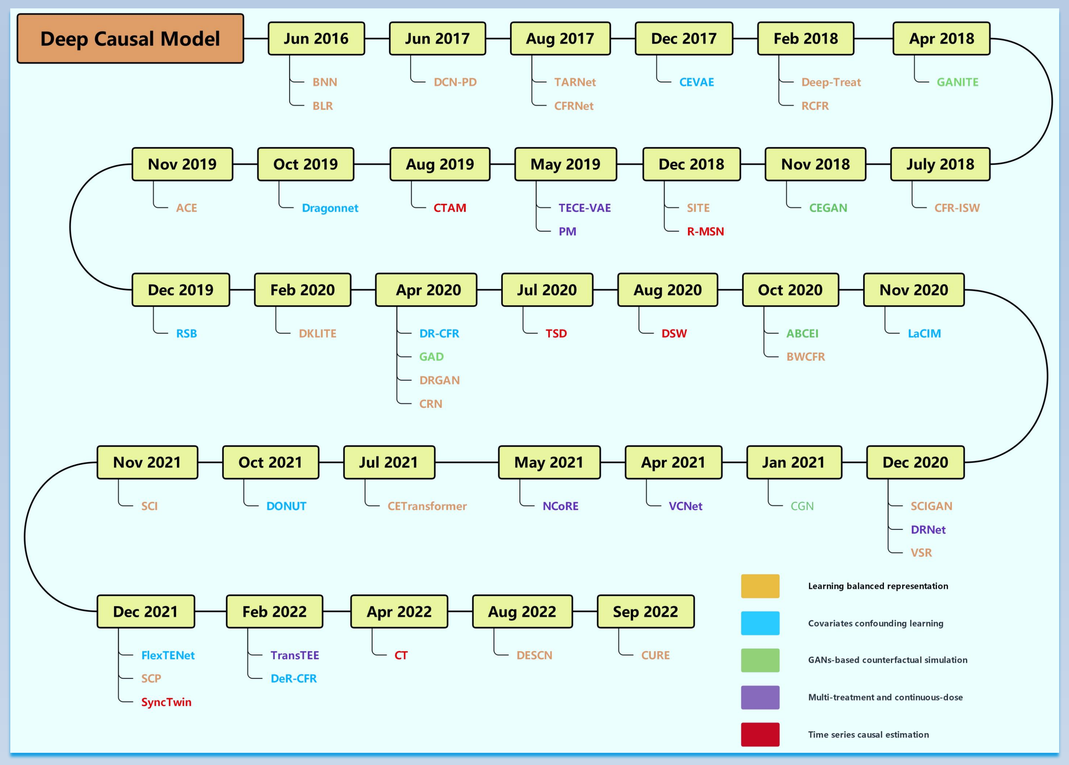
Treatments: Binary treatment, Multiple treatment, Continuous dose treatment

Metrics: ATE、ITE、ATT、CATE、PEHE、RMSE、MISE、DPE、PE

Datasets: IHDP、Jobs、Twins、News、ACIC、TCGA、MIMIC III

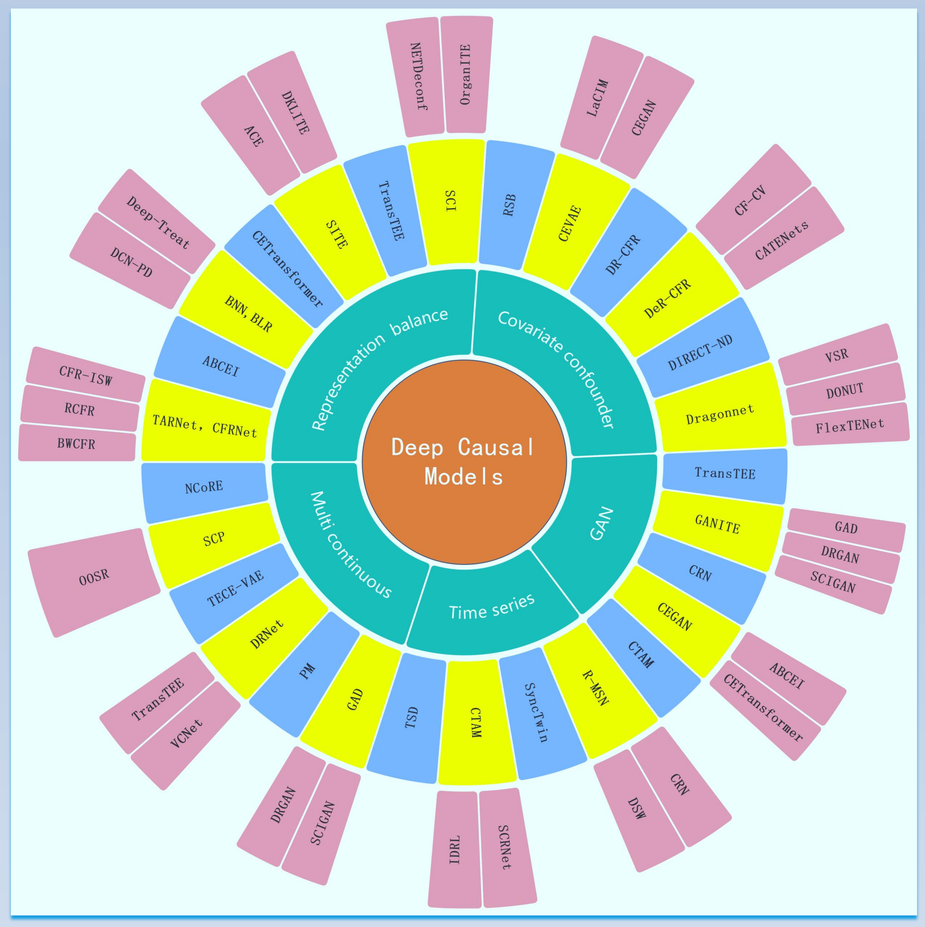
Materials and Methods: Development of Deep Causal Models

■ A Timeline of Development



We present the development timeline about 50 classical deep causal models from June 2016 to November 2022.

■ Model Classification



1) Learning balanced representations;
2) Covariate confounding learning;
3) Time series causal learning;
4) GANs based Counterfactual simulation;
5) Multi treatment and continuous dose treatment.

Summary: Typical Deep Causal Models and Their Industrial Applications

■ Deep Frameworks on Classical Causal Models ■Current Status of Industrial Applications ■Future Prospect

Models	GAN	AE	RNN	Transformer
DCN-PD				
BNN		✓		
CFRNet		✓		
CEVAE		✓		
Deep-Treat		✓		
RCFR		✓		
GANITE	✓			
CEGAN	✓			
SITE		✓		
R-MSN			✓	
PM		✓		
TECE-VAE		✓		
CTAM	✓	✓		
Dragonnet		✓		
ACE		✓		
RSB		✓		
DKLITE		✓		
GAD	✓			
CRN	✓		✓	
TSD			✓	
ABCEI	✓	✓		
BWCFR		✓		
LaCIM		✓		
SCIGAN	✓	✓		
DRNet		✓		
VSR		✓		
VCNet		✓		
NCoRE		✓		
CETransformer	✓	✓		✓
DeR-CFR		✓		
SCI		✓		
WUNT				✓
FlexTENet		✓		
SCP		✓		
CGN	✓	✓		
SyncTwin			✓	
TransTEE	✓	✓		✓
DESCN		✓		
CURE		✓		✓
DSW		✓	✓	
CT	✓	✓	✓	✓

It is inseparable from the proposal of deep network models such as statistical theory, biological application scenarios and the reliable assumptions of Robin causal model.

	Application Scenario	Problem
Marketing	Maximizing the return on investment	Estimate users' purchase probability with different incentives
E-commerce	Recommender systems with causality	Address selection bias, exposure bias, position bias and conformity bias in recommender systems
Financial	Estimating the impact of policies	Solve the biased problem of non-A/B experiment to measure the intervention effect
Economic	Gaining transparent strategies	Learn causal effects from surrogate experiments with selection-biase and imperfect compliance
Medical	Precision medicine	Explore quantitative individual-level effect of a treatment with assignment bias
Educational	Determine best policies and practices	Effectiveness of an intervention is multifaceted and complex