Estimating True Post-Click Conversion via Group-stratified Counterfactual Inference

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Background

CTR & CVR live the heart in many industrial system.

- Users without ads promoting are also counted for charging in CTR and CVR.
- $\geq$ 75% users click-through users would occur even without recommendations

$\Rightarrow$ Identity users who are truly affected by the promoted ads

i.e. users that would make a conversion under ads, but no conversion without ads.

Reconsider the two metrics in the aspect of counterfactual framework

Estimating True Post-Click Conversion via Group-stratified Counterfactual Inference

- *New metric TCVR*
- *Evaluation method under Rubin Causal Model*
- *Group-stratified Counterfactual Inference*
- *Extensive Experiments on Huawei datasets*

Methodology

Table 1: *Five groups of users in advertisement scenarios with counterfactual overview.* C(T = 0) and C(T=1) refer to the click behaviors (1 for click) of users when he/she is exposed (T=1) to the promoted ad or not (T=0), respectively. And Y(T = 0) and Y(T=1) refer to the download behaviors (1 for download) of users when he/she is exposed (T=1) to the promoted ad or not (T=0), respectively.

Groups	C(T=0)	C(T=1)	Y(T=0)	Y(T=1)
A	0	0	0	0
B	0	0	1	1
C	0	1	0	0
D	0	1	0	1
E	0	1	1	1

Methodology

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- the drawbacks of the CTR and CVR
- users that are truly affected by the promoted ads

Group A: non-interested users.
Group B: always download
Group C: click iff exposed
Group D: click & download iff exposed
Group E: free-rider effect

- C, D, E tends to click the ads.

$p(C) + p(D) + p(E)$ in terms of CTR.

- D, E tends to click and download the ads.

$p(D) + p(E)$ in terms of CVR.

- D is the group that makes true post-click conversion rate.

$p(D)$ in terms of maximizing the ads effects.

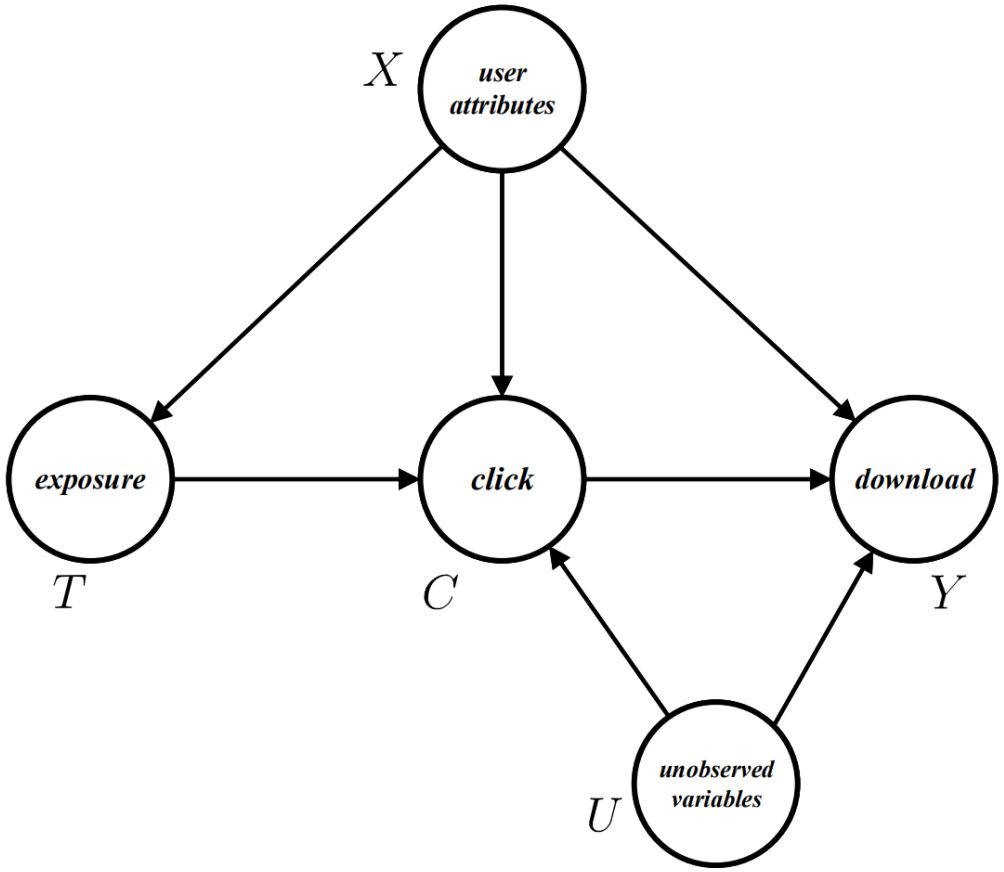
- $\frac{p(D)}{p(C)+p(D)+p(E)}$ represents the click effects.

$$CTR(X = x) = P(C|x) + p(D|x) + p(E|x)$$

$$CVR(X = x) = p(D|x) + p(E|x)$$

$$TCVR(X = x) = p(D|x)$$

Methodology



X: user attributes

T: ads exposure (instrumental variables)

C: click (binary variable)

Y: download (binary variable)

U: confounders, unobserved variables

Methodology

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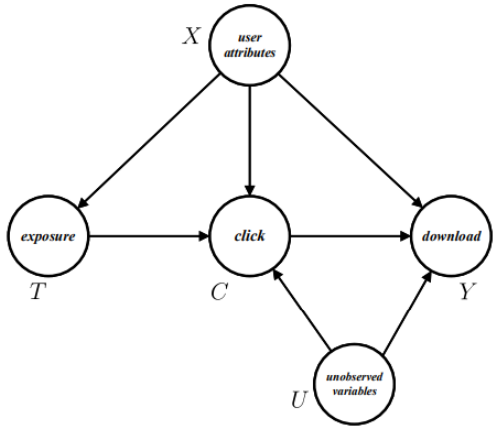


SUTV
Strong Ignorability

X: user attributes
T: ads exposure (instrumental variables)
C: click (binary variable)
Y: download (binary variable)
U: confounders, unobserved variables

$$p(Y=0,C=0|T=1,X)=p(A|X) \quad (1)$$
$$p(Y=1,C=0|T=1,X)=p(B|X) \quad (2)$$
$$p(Y=0,C=1|T=1,X)=p(C|X) \quad (3)$$
$$p(Y=1,C=1|T=1,X)=p(D|x)+p(E|X) \quad (4)$$
$$p(Y=1,C=1|T=0,X)=0 \quad (5)$$
$$p(Y=0,C=1|T=0,X)=0 \quad (6)$$
$$p(Y=1,C=0|T=0,X)=p(B)+p(E) \quad (7)$$
$$p(Y=0,C=0|T=0,X)=p(A)+p(C)+p(D) \quad (8)$$

The proposed TCVR formally denoted as

$$TCVR = p(Y=1|X,T=1) - p(Y=1|X,T=0).$$

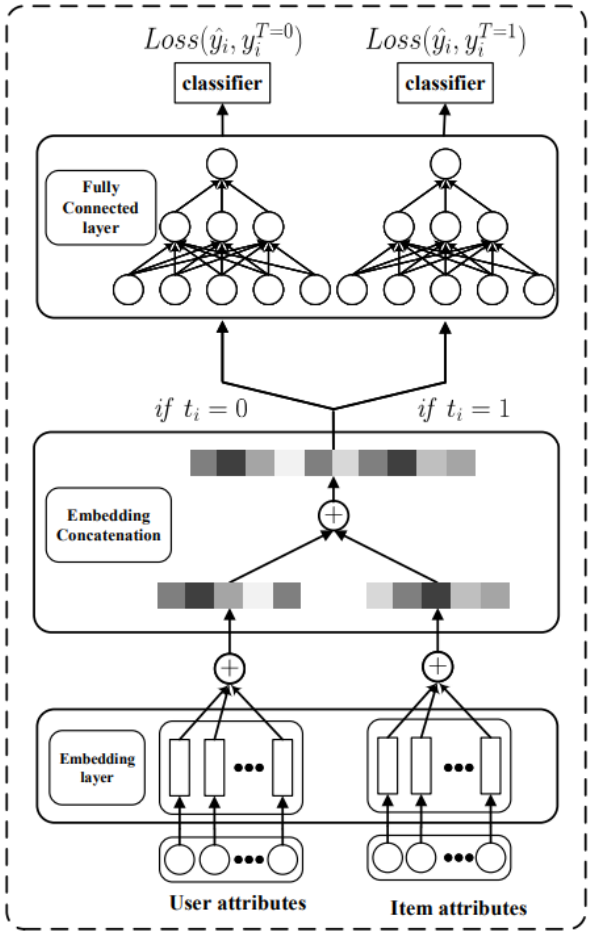
Furthermore, use Eq. (5)+(3)-(6)-(8), we have:

$$p(D|X) = p(Y=1|T=1,X) - p(Y=1|T=0,X);$$

Methodology

Metric	Probability Distribution
CACE of T on C	$p(C\|X) + p(D\|X) + p(E\|X)$
CACE of T on Y	$p(D\|X)$
LATE of C on Y	$\frac{p(D\|X)}{p(C\|X)+p(D\|X)+p(E\|X)}$
CTR	$p(C\|X) + p(D\|X) + p(E\|X)$
CVR	$p(D\|X) + p(E\|X)$
TCVR	$p(D\|X)$
free-rider metric	$\frac{p(E\|X)}{p(D\|X)+p(E\|X)}$

Methodology



(Group-stratified Counterfactual Inference, GCI)

To estimate $p(C = c, Y = y \mid T = t, X = x)$

$$\tilde{u_{i,j}} = Concat([u_i^{user}; u_j^{item}])$$

$$\tilde{u}_{i,j}^{(k)|T=t} = \sigma(W^{(k-1)|T=t} \tilde{u}_{i,j}^{(k-1|T=t)} + b^{(k-1)|T=t})$$

$$L = -\sum_{i \in \mathcal{D}_t} \hat{y}_i \log(W^{T=t} \cdot y_i^{T=t})$$

Methodology

Discussion on the violation of exclusion

- The exposure T affect Y only through click C, namely

Exposure T have not direct effect on download Y.

Table 8: Eight Groups of People in Advertisement Scenarios.

	C(0)	C(1)	Y(0)	Y(1)
A	0	0	0	0
B	0	0	1	1
C	0	1	0	0
D	0	1	0	1
E	0	1	1	1
F	0	0	1	0
G	0	0	0	1
H	0	1	1	0

$$p(Y=0,C=0|T=1,X)=p(A|X)+p(F|X) \quad (23)$$

$$p(Y=1,C=0|T=1,X)=p(B|X)+p(G|X) \quad (24)$$

$$p(Y=0,C=1|T=1,X)=p(C|X)+p(H|X) \quad (25)$$

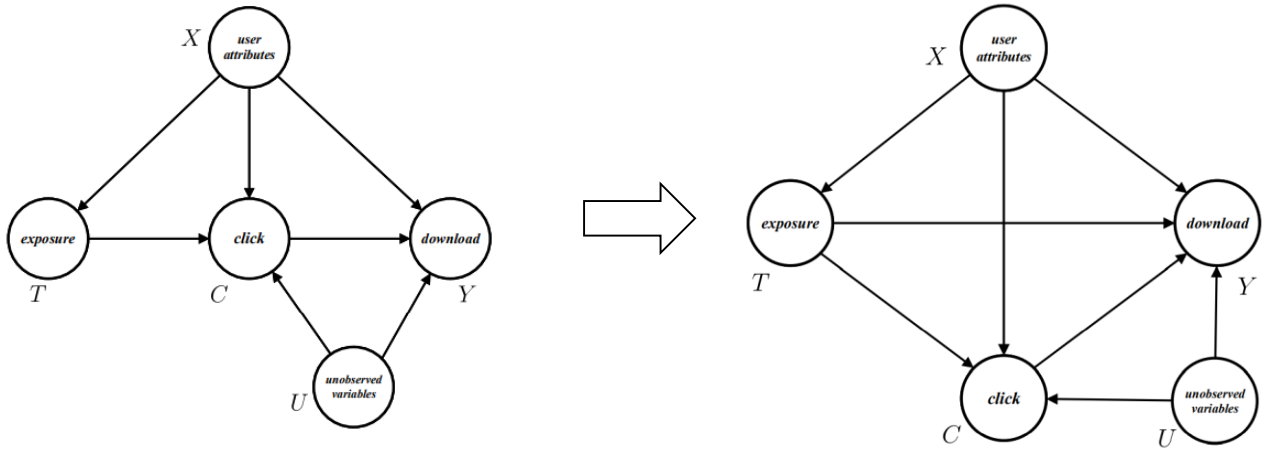
$$p(Y=1,C=1|T=1,X)=p(D|x)+p(E|X) \quad (26)$$

$$p(Y=1,C=1|T=0,X)=0 \quad (27)$$

$$p(Y=0,C=1|T=0,X)=0 \quad (28)$$

$$p(Y=1,C=0|T=0,X)=p(B|X)+p(E|X)+p(F|X)+p(H|X) \quad (29)$$

$$p(Y=0,C=0|T=0,X)=p(A|X)+p(C|X)+p(D|X)+p(G|X) \quad (30)$$



- CTR、CVR unbiased
- TCVR reliable under GCI

Experiment

Datasets. Online advertising system a with duration of 15 days to categorize user behaviors.

	Exposed^{1st}	Exposed^{2nd}	Click^{2nd}	Conversion
Group A	1	0		0
Group B	1	0		1
Group B+E	0			1
Group C	1	1	1	0
Group D+E	1	1	1	1

Experiment

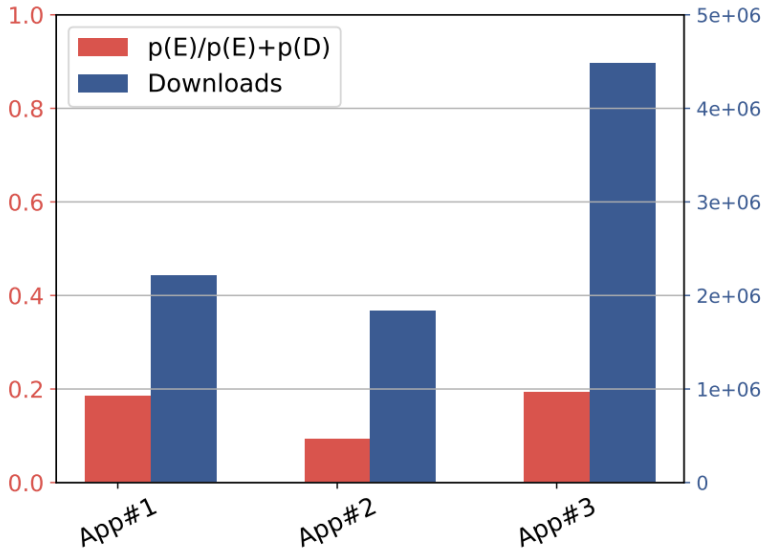


Figure 3: The probability of free-rider metric of three apps and the corresponding number of downloads.

App #1 : 2,208,868 downloads, 0.184
App #2 : 1,829,707 downloads, 0.093
App #3 : 4,486,693 downloads, 0.194

- Mature apps would have large free-rider metrics .
- Users are unlikely to download an unknown app only their intentions.

Conclusion

- we formalize a new evaluation metric TCVR in online advertising systems.
- We address the problem of the free-rider effect in CVR optimized advertising strategy.
- A novel model(GCI) is proposed under a counterfactual learning framework to solve the above challenges.
- Experimental results confirm both our analysis on reasonableness of TCVR and the effectiveness of our GCI.

Q & A

Thanks