SEKE 2010

A Multi-State Bayesian Network for Shill Verification in Online Auctions

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Acknowledgment

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WE HAVE A STRONG TEAM!

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- Background and Motivations
- Shill Detection and Verification
- Bayesian Network for Shill Verification
- Training and Conditional Probability Table
- A Case Study with Experimental Results
- Conclusions and Future Work

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Online Auctions & Shilling Behaviors

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- Different types of auctions
  - Increase-price auction (English auction)
  - Decrease-price auction (Dutch auction)
  - Second-price sealed-bid auction (Vickrey auction)
- English auction has become the most popular one in online auction houses (e.g., eBay).
- A shill bidding is a <u>deliberate activity</u> of placing bids in order to artificially raise the price of an auctioned item.
- Although most of the online auction houses prohibit shilling behaviors, it is easy for malicious users to disguise themselves and put in shill bids in online auctions.

While two auctions with the same type of auctioned items are running concurrently, a shill bidder might put bids in the auction with higher bidding price rather than the one with lower bidding price in order to drive up the price in one auction.

- We call this type of shilling behavior *concurrent shilling.*
- Other types of shilling behaviors include: reserve price shilling, competitive shilling etc.
- Shilling behaviors can be detected in real-time using existing approaches such as the real-time model checking approach.
- However, we cannot guarantee a bidder with shilling behaviors must be a shill bidder – needs to be verified using additional evidence.

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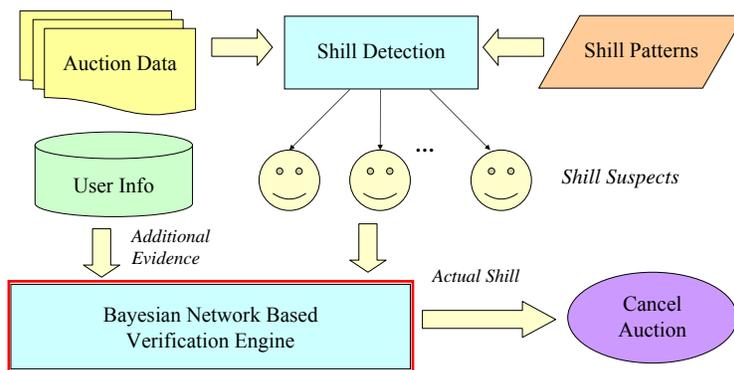
- Bayesian network (BN) or belief network is a probabilistic graph model
  – can be used to capture uncertain knowledge in a natural and efficient way.
  – models the dependencies among variables and gives a concise specification of full joint probability distribution.
- Calculate the posterior probability for a query variable *X*, given a set of observed evidence **e** for a set of evidence variables **E**.

$$\mathbf{P}(X \mid \mathbf{e}) = \alpha\, \mathbf{P}(X, \mathbf{e}) = \alpha \sum_{\mathbf{y}} \mathbf{P}(X, \mathbf{e}, \mathbf{y})$$

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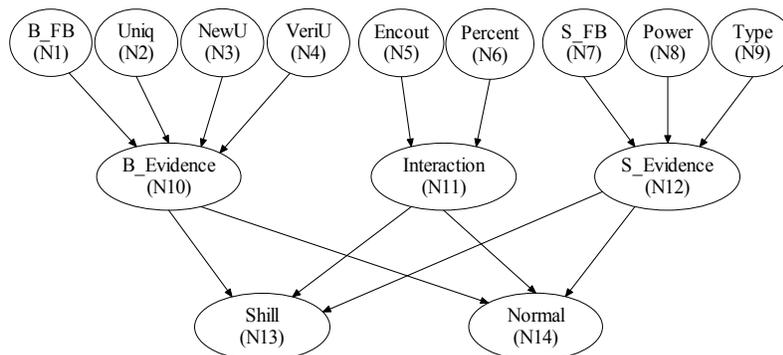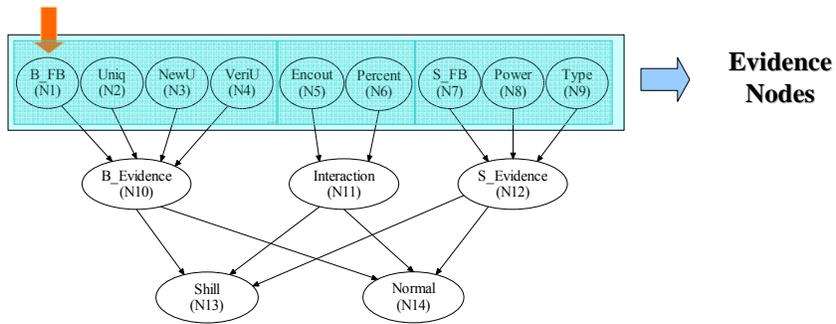
Evidence Nodes

Bidder Feedback (N1) represents a range of feedback score
values for a particular bidder.

Unobservable Nodes
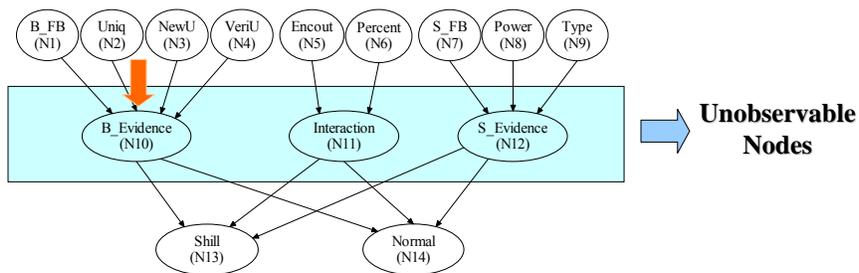
Bidder Evidence Level (N10) is evaluated based on the
bidder's evidence information from its parent nodes.
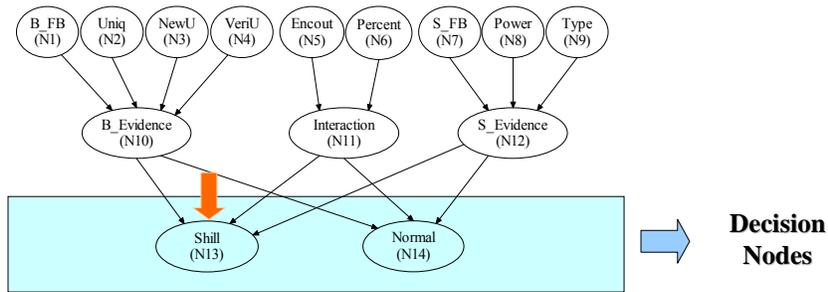
Shill Bidder (N13) indicates whether a bidder suspect is an actual shill given additional evidence.

Node	Bi State	Multi State
N1	Low/High	None/Yellow/Blue/Turquoise/Other
N2	Low/High	1 / 2-5 / 6-15 / Other
N3	True/False	True/False
N4	True/False	True/False
N5	Low/High	Low/High
N6	Low/High	No more than 30 / 31-80 / Other
N7	Low/High	None/Yellow/Blue/Turquoise/Other
N8	Low/High	None/Bronze/Other
N9	Store/Private	Store/Private
N10	Low/High	Low/High
N11	Weak/Strong	Weak/Strong
N12	Low/High	Low/High
N13	Yes/No	Yes/No
N14	Yes/No	Yes/No

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- Represent the prior knowledge of the BN as conditional probability tables (CPT) associated with each node in the network.
- The prior knowledge of the BN can be derived from eBay auction data as well as user information.
- Retrieved auction data from eBay for the query "laptop." Auction data for a total of 109 auctions with 1127 bidders was accumulated.
- Created the training data set using shill bidding patterns.

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- **High and Irregular Incremental Bids**: Shill bids have a tendency to be relatively high as compared to other bids placed by normal bidders.
- **Early and Middle Stage Bidding:** Most shills only bid in the initial and middle stages of an auction, but stop bidding in the final stage to avoid winning the auction.
- **Total Increase in Price**: An interesting observation is the total increase in the price of an item due to a single bidder. Thus, it is a good clue to shilling.

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VeriU (N4)	NewU (N3)	Uniq (N2)	B_FB (N1)	P(N10 = H)
F	T	L	L	0.83
F	T	L	H	0.00
F	T	H	L	0.15
F	T	H	H	0.00
F	F	L	L	0.86
F	F	L	H	0.15
F	F	H	L	0.30
F	F	H	H	0.10

VeriU (N4)	NewU (N3)	Uniq (N2)	B_FB (N1)	P(N10 = H)
F	F	1	None	0.93
F	F	1	Yellow	0.75
F	F	1	Blue & Torq	0.72
F	F	1	Other	0.10
F	F	<=5	None	0.89
F	F	<=5	Yellow	0.87
F	F	<=5	Blue & Torq	0.87
F	F	<=5	Other	0.10
F	F	<=15	None	0.30
F	F	<=15	Yellow	0.25
F	F	<=15	Blue & Torq	0.10
F	F	<=15	Other	0.10
F	F	Other	None	0.00
F	F	Other	Yellow	0.00
F	F	Other	Blue & Torq	0.00
F	F	Other	Other	0.00

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- Developed a Bayesian network toolkit for both of the bi-state and multi-state BN.
- The conditional probabilities for query variables *Shill* and *Normal*, given evidence **e**, can be calculated

$$\mathbf{P}(Shill \mid \mathbf{e}) = \alpha\, \mathbf{P}(Shill, \mathbf{e}) = \alpha \sum_{\mathbf{y}} \mathbf{P}(Shill, \mathbf{e}, \mathbf{y})$$

$$\mathbf{P}(Normal \mid \mathbf{e}) = \alpha\, \mathbf{P}(Normal, \mathbf{e}) = \alpha \sum_{\mathbf{y}} \mathbf{P}(Normal, \mathbf{e}, \mathbf{y})$$

- Thresholds for determining shills are defined as:

$$P(shill \mid \mathbf{e}) \geq 0.8 \text{ and } P(normal \mid \mathbf{e}) < 0.30 \Rightarrow Shill$$

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HP HDX 16t Notebook Bidding History

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Bidder (FB)	Bid Amount	Bid Time	Bidder (FB)	Bid Amount	Bid Time
*3***3 (27)*	US $630.00	Oct-16-09 08:19:12 PDT	*9***a (1)*	US $200.00	Oct-10-09 12:40:10 PDT
*p***t (299)*	US $621.00	Oct-15-09 18:34:38 PDT	*g***e (245)*	US $112.50 [§]	Oct-09-09 15:49:21 PDT
*p***t (299)*	US $611.00 [§]	Oct-15-09 18:34:38 PDT	*9***a (1)*	US $110.00	Oct-10-09 12:39:56 PDT
*g***e (245)*	US $601.00	Oct-14-09 16:59:59 PDT	*g***e (245)*	US $102.50 [§]	Oct-09-09 15:49:21 PDT
*p***t (299)*	US $601.00	Oct-15-09 17:54:10 PDT	*9***a (1)*	US $100.00	Oct-10-09 12:39:43 PDT
*g***e (245)*	US $561.00 [§]	Oct-14-09 16:59:59 PDT	*g***e (245)*	US $61.00 [§]	Oct-09-09 15:49:21 PDT
*p***t (299)*	US $551.00	Oct-12-09 17:09:44 PDT	*9***a (1)*	US $60.00	Oct-10-09 12:39:27 PDT
*8***1 (29)*	US $550.00	Oct-14-09 12:31:54 PDT	*g***e (245)*	US $51.00 [§]	Oct-09-09 15:49:21 PDT
*p***t (299)*	US $510.00 [§]	Oct-12-09 17:09:44 PDT	*9***a (1)*	US $50.00	Oct-10-09 12:39:04 PDT
*g***e (245)*	US $500.00	Oct-09-09 15:49:21 PDT	*g***e (245)*	US $31.00 [§]	Oct-09-09 15:49:21 PDT
*m***s (4)*	US $500.00	Oct-10-09 16:49:22 PDT	*a***a (21)*	US $30.00	Oct-09-09 13:58:29 PDT
*g***e (245)*	US $405.00 [§]	Oct-09-09 15:49:21 PDT	*g***e (245)*	US $26.00 [§]	Oct-09-09 15:49:21 PDT
*m***s (4)*	US $400.00	Oct-10-09 16:49:00 PDT	*a***a (21)*	US $25.00	Oct-09-09 13:58:02 PDT
*g***e (245)*	US $202.50 [§]	Oct-09-09 15:49:21 PDT	*a***a (21)*	US $0.99 [§]	Oct-09-09 13:58:02 PDT
[§] Automatic bid using eBay proxy bidding system.			*Starting Price*	US $0.99	Oct-09-09 08:20:59 PDT

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Node	Shill Suspect		
	g***e	*m***s*	*9***a*
N1	Turquoise	None	None
N2	14	1	2
N3	False	False	False
N4	False	False	False
N5	2	1	4
N6	6	100	45
N7	Yellow	Yellow	Yellow
N8	None	None	None
N9	Private	Private	Private

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Multi-State Bayesian Network 1.00

File Edit Help About

Build Network | Display Node and Network | Display Cell Value | Probabilitic Inference

Get the Probability of an Event

Auction Number 320433835366   Calculate Probability

User Information

Seller Information
Seller Name: mrdevildog
Feedback Star: Yellow
Power Seller Level: None
Store Owner: false

Bidder Information
Bidder Name: 3***3
Feedback Star: Yellow
Number of Unique Sellers: 7
New User: false
Verified User: false
Number of Encounters: 1
Bid Percentage: 8

Bidder Name: p***t
Feedback Star: Turquoise
Number of Unique Sellers: 75

User Probability

Bidder Name: 3***3
Probability of being a Shill Bidder: 0.42864484
Probability of being a Normal Bidder: 0.65801245

Bidder Name: p***t
Probability of being a Shill Bidder: 0.34491795
Probability of being a Normal Bidder: 0.745573

Bidder Name: g***e
Probability of being a Shill Bidder: 0.34491798
Probability of being a Normal Bidder: 0.745573

Bidder Name: 8***1
Probability of being a Shill Bidder: 0.42864484
Probability of being a Normal Bidder: 0.65801245

Bidder Name: m***s
Probability of being a Shill Bidder: 0.80859745

Output

Bid Percentage- node created
Seller Feedback Star- node created
Power Seller- node created

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Probability of Being Shill / Normal Bidder		Shill Suspect		
		g***e	*m***s*	*9***a*
Bi-State	P(*shill* | **e**)	0.4008	0.6115	0.6391
	P(*normal* | **e**)	0.5687	0.3052	0.2590
Multi-State	P(*shill* | **e**)	0.3449	0.8086	0.7234
	P(*normal* | **e**)	0.7456	0.2607	0.2454

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- Provide a framework for shill detection and shill verification.
- Use a probabilistic inference system, namely a BN, to account for uncertainties with some degree of belief for shill verification.
- Demonstrate that a multi-state BN gives more accurate results as compared to a bi-state BN.

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- Use data mining approach to cluster auction data and provide a clearer picture of the knowledge domain.

- Improve the BN and discover more hidden node states for better results in shill verification.

- Incorporate our Bayesian network toolkit with an agent-based trustworthy online auction system.

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