

APPENDIX A
REPORT FROM THE EXPERT STUDY

In our expert study, we visited a private fund company and invited three traders to use our system to assist in their daily tasks. The first session of the study is training, during which the users are instructed on the functionality, visualization design, and detailed usage of the system. The second session of the study is test, during which the users are required to complete two tasks: 1) factor analysis, i.e., identify relevant keyword factors to the rise and fall of a particular stock in a given time range, analyze the correlation between these factors and the stock price movement; 2) model analysis, i.e., evaluate the accuracy of the prediction model, i.e., when the model performs well and when the model performs badly. After completing each task, the users answer a list of questions on the pros, cons, and user experience in applying the system. All the study sessions last no longer than one hour for each expert user, and they are paid \$150 for their time.

A. *Expert A (Manager)*

1) *Factor Analysis Task:*

Question: *How does the system help you in completing the task? (pros)*

Answer: I think one important feature is to synthesize most relevant keywords to the stock price together in an intuitive interface. The interface also allows us to query and test our hypothesize, then evaluate with the prediction model.

Question: *How could the system be improved to better support the task? (cons)*

Answer: In our analysis, factors could be not only the textual keywords and phrases, but also the trading information such as the position of tradings, stock prices, etc. Multiple stocks can also be integrated into the same view to see which factor is more important to a group of stocks, e.g., those in the auto sector.

2) *Model Analysis Task:*

Question: *How does the system help you in completing the task? (pros)*

Answer: Previously, in our model building and analysis process, there is few visualization tool involved! We need to type in command to search for the model performance in particular stock and time period. With this tool, some of the process is automated and we can get a lot of signals together in the same view, which is really informative. Another cool thing is that I can share my findings with my colleague more easily and quickly.

Question: *How could the system be improved to better support the task? (cons)*

Answer: The feedbacks of the model can be more explicit. Now it shows the timeline of actual stock prices and the predicted price, in which I could not judge when it earns or loses. In fact, you could draw the yield curve of the prediction model directly (Note: this has been implemented in the latest version of DeepClue according to the suggestion).

Question: *What is the experience in using the system? (UE)*

Answer: Very good. As I said, previously we do not have relevant visualization tool for displaying the modeling result. After using your tool, I feel the intuitive display can potentially help us in the daily operation. The interactions also help a lot as we need more detailed information, though it will be better if the interaction can be customized according to our demands.

B. *Expert B*

1) *Factor Analysis Task:*

Question: *How does the system help you in completing the task? (pros)*

Answer: Choose the right keywords relevant to the selected stock. Look into the relationship of these keywords and the stock price. The keywords after analysis can also work as a hint for further improving the prediction model. Also, the engineering of the system brings myriad helps in filtering the spam words and translating the non-English words, which we need to process manually now.

Question: *How could the system be improved to better support the task? (cons)*

Answer: I think it might help if the prediction can be narrowed down to the second level and the news can be classified into within-trading-hour and after-trading-hour. This can have a significant impact to the actual trading.

2) *Model Analysis Task:*

Question: *How does the system help you in completing the task? (pros)*

Answer: It helps me to calibrate the prediction error of the model in a daily basis.

Question: *How could the system be improved to better support the task? (cons)*

Answer: The bar charts beneath the stock price curve could be improved with more labels to clarify its meaning. The display of stock price changes can also be based on some measure relative to the composite index of the stock market.

Question: *What is the experience in using the system? (UE)*

Answer: It's good experience. The system can recommend keywords according to the history of the stock price and prediction. We can also add interesting keywords ourselves. The visualization of the temporal changes of keywords, prices, and their correlations are also impressive, so that now we can find them in the same view. However, on visualizing the modeling result, we still need some intuitive display of the model accuracy (Note: this is similar to the request of the yield curve).

C. *Expert C*

1) *Factor Analysis Task:*

Question: *How does the system help you in completing the task? (pros)*

Answer: I think the primary aid is on the statistics of keywords and their influence to the stock price. Previously these factors and the relationship to the stock price are somehow embedded in our mental map. This tool helps to visualize such relationship and we can validate our mental map and tune the models based on newly gained information. Also, for the keyword factors, it is also very helpful in this tool to display the content of the news where the keyword appears.

Question: *How could the system be improved to better support the task? (cons)*

Answer: I would like to have a keyword store which can be displayed upon selecting relevant keywords for analysis. For each keyword factor, it will also help if there is a summary of its polarity with the stock price change (e.g., positively or negatively correlated). The keywords that are consistent in the correlation might be more important in real usage.

2) *Model Analysis Task:*

Question: *How does the system help you in completing the task? (pros)*

Answer: The intuitive display of prediction models, the actual stock price change, and their correlation. The intuitive display of keywords, the stock price change, and their correlation. The display of important news and its impact on the stock price change, which can help investors make their key investment decisions.

Question: *How could the system be improved to better support the task? (cons)*

Answer: The list of news could be improved by adding some quantitative measures on each news, e.g., the influence on the stock price (Note: this has been implemented in the latest version of DeepClue). The latest news are more important to the trading, so the latest news can be shown on the top of the list (Note: this has been implemented by adding the sort-by-date button on the news list).

Question: *What is the experience in using the system? (UE)*

TABLE I: The prediction accuracy of DeepClue over the stock price movement of companies in S&P 500. Both the news title and news content are used as input data in the training, development and test sets. The LSTM and CNN models lead to a high time complexity to train with the news content, and the results are not included.

Model	Phase	Days	Accuracy (%)									
			AAPL	GOOG	BAC	WMT	GM	XOM	BA	GSPC	T	Average
DeepClue	train	1425	67.9	58.3	75.8	55.5	61.1	79.4	49.5	65.1	68.0	64.5
	dev	178	60.4	59.9	62.6	55.0	66.0	65.4	63.2	59.8	63.7	55.0
	test	177	45.7	48.7	47.6	51.5	53.8	53.8	44.0	51.7	52.3	49.9

TABLE II: The prediction accuracy over the weekly stock price movement of companies in S&P 500. For each day, the collection of news titles in a previous week (5 trading days before the current day) are used to predict the stock price change of the next week (5 trading days starting from the current day).

Model	Phase	Days	Accuracy (%)									
			AAPL	GOOG	BAC	WMT	GM	XOM	BA	GSPC	T	Average
DeepClue	train	1425	66.0	72.2	71.6	54.1	58.0	64.6	66.6	71.4	63.8	65.3
	dev	178	56.1	58.1	53.5	51.6	57.3	56.1	58.3	57.8	58.3	56.4
	test	177	52.6	47.6	53.2	51.0	48.4	49.4	52.4	45.6	55.6	50.6
LSTM	train	1425	68.8	64.9	65.7	62.1	71.4	57.6	69.1	56.4	53.3	63.3
	dev	178	57.5	53.3	57	60.9	54.8	56.6	55.3	56.4	57.4	56.6
	test	177	54.3	52.5	50	47.5	43.4	52.9	49	53.8	52.4	50.6
CNN	train	1425	52.2	51.1	50	51.7	49.6	48.1	50.8	55.8	52.8	51.3
	dev	178	58.3	53.3	53.1	56.6	54	59.2	57	58.6	60	56.7
	test	177	50.2	51.1	51.8	47.5	55.7	42.3	50	53.4	50	50.2

TABLE III: The prediction accuracy over the monthly stock price movement of companies in S&P 500. For each day, the collection of news titles in a previous month (20 trading days before the current day) are used to predict the stock price change of the next month (20 trading days starting from the current day).

Model	Phase	Days	Accuracy (%)									
			AAPL	GOOG	BAC	WMT	GM	XOM	BA	GSPC	T	Average
DeepClue	train	1425	66.4	53.3	64.8	63.2	68.6	62.2	58.4	65.5	61.8	62.7
	dev	178	56.9	57.3	55.8	52.0	57.2	56.9	57.5	57.3	53.0	56.0
	test	177	49.6	55.9	51.0	49.4	47.9	51.4	51.2	46.7	44.3	49.7
LSTM	train	1425	61.7	51.1	51.6	53.3	49.7	53.2	57.5	56.2	57.6	54.7
	dev	178	60	54.7	57.5	53.4	54.4	54.6	57.5	58.5	61.6	56.9
	test	177	48.1	46.8	54.1	48.3	55.7	53.5	53.4	51.9	51.4	51.5
CNN	train	1425	49.8	51	50.4	48.1	49.5	48.9	51.8	45.1	53.3	49.8
	dev	178	56.5	54.7	55	60.1	60.2	55.7	54.2	60.6	61.6	57.6
	test	177	46.6	52.6	45.9	46.1	51.4	42.3	51.2	51.9	51	48.8

Answer: The tool can help to complete some basic task in our everyday job. The interface is very completed and achieves a high engineering standard. The interactions on the interface also helps in our usage.

APPENDIX B USER STUDY MATERIAL

The user study material is available at the below link (the submission site does not allow to upload zip files):
http://lcs.ios.ac.cn/~shil/share/DeepClue_UserStudy.zip

TABLE IV: The prediction accuracy of DeepClue using different price movement definition. The first group of rows apply the change of stock price from the close of a previous day to the close of the current day. The second group of rows apply the change of stock price from the open of the current day to the close of the current day.

Price Movement Definition	Phase	Days	Accuracy (%)									
			AAPL	GOOG	BAC	WMT	GM	XOM	BA	GSPC	T	Average
Close~Close	train	1425	83.8	87.8	93.8	52.5	83.9	90.3	91.2	87.6	46.2	79.7
	dev	178	56.1	58.7	55.9	59.2	62.8	59.4	57.4	53.7	55.6	57.6
	test	177	56.4	58.1	52.4	55.1	56.8	52.4	60	56.4	55.8	55.9
Open~Close	train	1425	57.9	70.5	56.3	77.3	60.7	65.7	47.2	53.5	57.0	60.7
	dev	178	59.1	55.4	56.5	61.1	64.0	59.8	54.9	55.9	56.5	58.1
	test	177	48.8	46.7	52.0	52.3	57.1	50.9	46.0	55.1	51.2	51.1

TABLE V: The selected list of news titles containing semicolons that are either modified (M) or unchanged (U) to improve the prediction performance.

State	Date	Original News Title	Modified News Title
M	2007-01-18	Nasdaq down on Intel; Apple waxes and wanes	Apple waxes and wanes
	2007-04-13	Wall St up on M&A, retail sales; Apple falls late	Apple falls late
	2007-06-13	Indexes flat on rate worry; Texas Instruments falls	Indexes flat on rate worry
	2008-02-08	Corrected: Cisco gives weak outlook; tech shares down	tech shares down
	2009-01-29	Wall St. jumps on bank-rescue plan; Starbucks hit late	Wall St. jumps on bank-rescue plan
	2009-07-22	Wall St. climbs on Caterpillar; Apple shines late	Apple shines late
	2010-01-20	Wall St gains on Mass. vote bets, tech; IBM off late	Wall St gains on Mass. vote bets, tech
	2010-03-30	Wall Street rises on Apple; Honeywell raises view late	Wall Street rises on Apple
	2010-06-14	Most Read on Bloomberg: U.S. Stocks Fall; Apple Unveils iPhone; SAC Hires	Apple Unveils iPhone
	2010-06-15	Foxconn Chief's Brother to Open 100 China Apple Stores; Chang Uei Advances	Foxconn Chief's Brother to Open 100 China Apple Stores
	2010-07-20	U.S. Stocks Advance on Optimism About Earnings; Microsoft Rises	U.S. Stocks Advance on Optimism About Earnings
	2010-07-22	Asian Stocks Rise on Apple Profit, Commodity Prices; Japanese Shares Drop	Asian Stocks Rise on Apple Profit, Commodity Prices
	2012-08-21	Wall Street flat after rally; Apple biggest company ever	Apple biggest company ever
	2012-09-05	Wall Street cuts losses on Apple strength; FedEx down late	Wall Street cuts losses on Apple strength
	2012-10-03	Apple Maps Fiasco Sinks AutoNavi; Ctrip Gains: Overnight	Apple Maps Fiasco Sinks AutoNavi
	2013-12-24	U.K. Stocks Rise on IMF Outlook; ARM Gains on iPhone Pact	ARM Gains on iPhone Pact
2014-04-24	Wall Street snaps six-day run; Apple to split stock	Apple to split stock	
2014-04-25	Apple buoys Nasdaq; Ukraine weighs on broader market	Apple buoys Nasdaq	
2015-01-28	Wall Street falls 1 percent on earnings; Apple rallies late	Apple rallies late	
2015-04-29	Dow, S&P 500 end up with Merck, IBM; Nasdaq slips with Apple	Nasdaq slips with Apple	
U	2009-07-22	Apple's profit tops forecasts; Mac sales strong	Apple's profit tops forecasts; Mac sales strong
	2009-12-15	JP Morgan sees strong growth at Apple; ups target	JP Morgan sees strong growth at Apple; ups target