

第一页为封面页

参赛队员姓名： Zhang Liu

中学： Anglo-Chinese Junior College

省份： Singapore

国家/地区： Singapore

指导教师姓名： Professor Ng Yin Kwee

论文题目： *When Siri Knows How You Feel: Study  
of Machine Learning in Automatic Sentiment  
Recognition from Human Speech*

# *When Siri Knows How You Feel: Study of Machine Learning in Automatic Sentiment Recognition from Human Speech*

Zhang Liu

Anglo-Chinese Junior College  
Singapore  
ifisay.617@gmail.com

Ng EYK

College of Engineering  
Nanyang Technological University (NTU)  
Singapore

*Abstract*— Opinions and sentiments are essential to human activities and have a wide variety of applications. As many decision makers turn to social media due to large volume of opinion data available, efficient and accurate sentiment analysis is necessary to extract those data. Hence, text sentiment analysis has recently become a popular field and has attracted many researchers. However, extracting sentiments from audio speech remains a challenge. This project explored the possibility of applying supervised Machine Learning in recognizing sentiments in English utterances on a sentence level. In addition, the project also aimed to examine the effect of combining acoustic and linguistic features on classification accuracy. Six audio tracks were randomly selected to be training data from 40 YouTube videos (monologue) with strong presence of sentiments. Speakers expressed sentiments towards products, films, or political events. These sentiments were manually labelled as negative and positive based on independent judgement of 3 experimenters. A wide range of acoustic and linguistic features were then analyzed and extracted using sound editing and text mining tools respectively. A novel approach was proposed, which used a simplified sentiment score to integrate linguistic features and estimate sentiment valence. This approach improved negation analysis and hence increased overall accuracy. Results showed that when both linguistic and acoustic features were used, accuracy of sentiment recognition improved significantly, and that excellent prediction was achieved when the four classifiers were trained respectively, namely kNN, SVM, Neural Network, and Naïve Bayes. Possible sources of error and inherent challenges of audio sentiment analysis were discussed to provide potential directions for future research.

*Keywords* – *Sentiment Analysis; Natural Language Processing; Machine Learning; Affective Computing; Data Analytics; Speech Processing; Computational Linguistic.*

## I. INTRODUCTION

Sentiment analysis is the field of study that analyses opinions, sentiments, appraisals, attitudes, and emotions toward entities and their attributes [1]. Opinions and sentiments are essential to human activities and have a

wide variety of applications. As many decision makers turn to social media due to large volume of opinion data available, efficient and accurate sentiment analysis is necessary to extract those data. Business organizations in different sectors use social media to find out consumer opinions to improve their products and services. Political party leaders need to know the current public sentiment to come up with campaign strategies. Government agencies also monitor citizens' opinions on social media. Police agencies, for example, detect criminal intents and cyber threats by analyzing sentiment valence in social media posts. In addition, sentiment information can be used to make predictions, such as in stock market, electoral politics and even box office revenue. Moreover, sentiment analysis that moves towards achieving emotion recognition can potentially enhance psychiatric treatment as emotions of patients are more accurately identified.

Since 2000, researchers have made many successful attempts in text sentiment analysis. In comparison, audio sentiment analysis does not seem to receive as much attention. It is, however, equally significant as text sentiment analysis. Many people in the contemporary society share their opinions using online-based multimedia platforms such as YouTube videos, Instagram stories, TV talk shows and TED talks. It is difficult to manually classify sentiments in them due to the sheer amount of data. With the help of machine automation, we can recognize, with an acceptable accuracy, the general sentiments about certain products, movies, and socio-political events, hence aiding decision-making process of corporations, societal organizations and governments.

This project explored the possibility of using a

machine learning approach to recognize sentiments accurately and automatically from natural audio speech in English. In addition, the project also aimed to examine the effect of combining acoustic and linguistic features on classification accuracy. Training data consisted of 150 speech segments extracted from 6 YouTube videos of different genres. Both acoustic features and linguistic features was examined in order to increase the accuracy of automatic sentiment recognition. Sentiments were categorized into 2 target classes, positive and negative.

## II. LITERATURE REVIEW

There were previous attempts to combine acoustic and linguistic features of speech in sentiment analysis. Chul & Narayanan (2005) [2] explored the detection of domain-specific emotions (negative and non-negative) using language and discourse information in conjunction with acoustic correlates of emotion in speech signals. The database consists of spoken speech obtained from a call center application. using. Their results showed that combining all the information, rather than using only acoustic information, improved emotion classification by 40.7% for males and 36.4% for females. This study suggested a comprehensive range of features and provided some insights for my project: acoustic features (Fundamental Frequency (F0), Energy, Duration, Formants), and textual features (emotional salience, discourse information). However, with its speech data collected from a call center, the research focused on emotions in human-machine interactions, rather than in natural human speech.

Another research, Kaushik & Sangwan & Hansen (2013) [3], provided an alternative source of speech data - YouTube videos. In this study, the authors proposed a system for automatic sentiment detection in natural audio streams on social media platform such as YouTube. The proposed technique used Part of Speech (POS) tagging and Maximum Entropy modeling (ME) to design a text-based sentiment detection model. Using decoded Automatic Speech Recognition (ASR) transcripts and the ME sentiment model, the proposed system was able to estimate sentiments in YouTube videos. Their results showed that it was possible to perform sentiment analysis on natural spontaneous speech data despite poor word error rates. This study provided a systematic approach and proved that audio sentiment analysis is possible. It did not, however, include

enough acoustic features of audio speech, possibly due to the limitation of document-level analysis.

Ding, *et al.* proposed a *holistic lexicon-based approach* [4] to solve the problem of insufficient acoustic features by exploiting external evidences and linguistic conventions of natural language expressions. Inspired by above work, a simplified sentiment score model was proposed in this project. The model was useful in sentence level audio speech analysis. The detail of the method will be explained in section III.

## III. METHODOLOGY

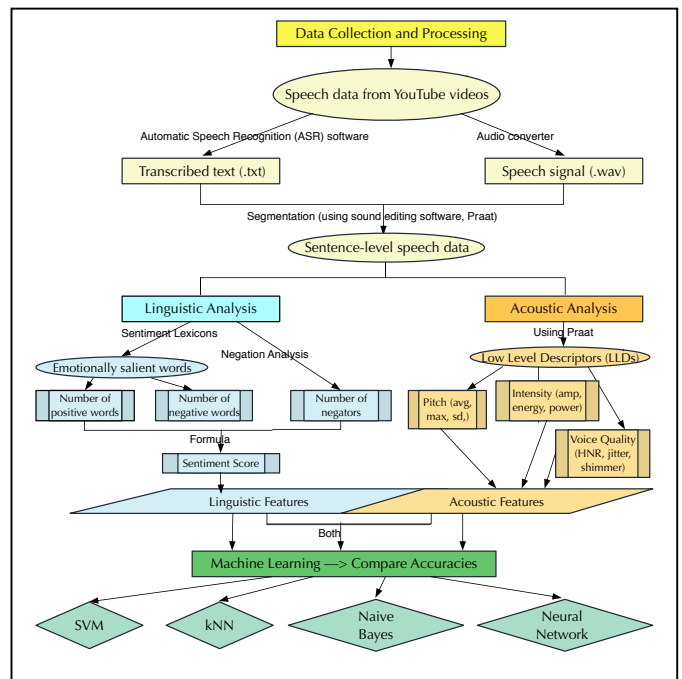


Figure 1. An overview of the methodology.

### 3.1 DATABASE

The speech data used in the experiments were obtained from YouTube, a social media platform. This source was chosen because thousands of YouTube users share their personal opinions or reviews on their channels. Hence, there is a huge amount of accessible speech data containing sentiment valence. More importantly, their ways of speaking are usually closest to natural, spontaneous human speech. Six videos were randomly selected from 40 YouTube videos that had strong presence of negative or positive sentiments. Subject matters included: 1) Product Review; 2) Movie Review; 3) Political Opinion.

During the pre-processing stage, the videos were converted into ‘.wav’ files. Speech transcriptions were generated using the Automatic Speech Recognition (ASR) software, Speechmatics (<https://www.speechmatics.com>) and checked manually to increase reliability. Each sound file (.wav) was then edited in the vocal toolkit, Praat (<http://www.fon.hum.uva.nl/praat/>), to match the transcriptions to corresponding sound segments. The TextGrid annotation (as shown in Figure 2) included 2 tiers, transcription text and numbering, which were useful in keeping track of the data. Meanwhile, the sound file was segmented into smaller sections containing 1 to 5 sentences of relevant meaning and the same sentiment. Each segment was pre-assigned a sentiment label (‘negative’ or ‘positive’) based on independent judgement of 3 experimenters so as to minimise bias and subjective errors. There was a total of 150 sound segments (including 70 positive, 80 negative) in the data set. The segmentation process was necessary as most opinion videos contain mixed sentiments.

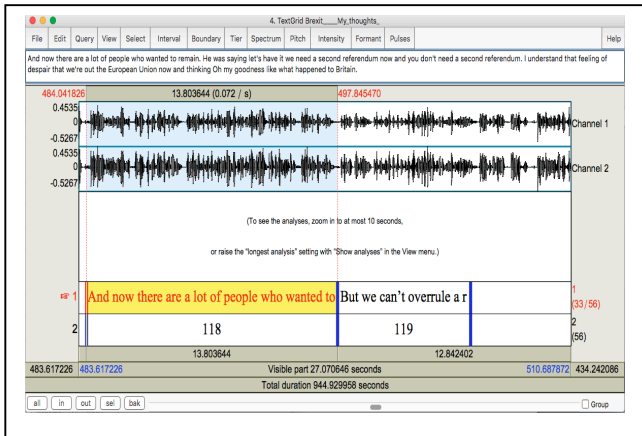


Figure 2. Using Praat to annotate speech.

### 3.2 FEATURE EXTRACTION

#### 3.2.1 LINGUISTIC FEATURES

Natural Language Processing toolkit, Orange 3-Text Mining, was used in this stage. Speech transcripts were transformed into lowercase, tokenized into words, and normalized using WordNet Lemmatizer. Part of Speech (POS) tagger was used to label each word as, for instance, a noun, a verb or an adjective, in order to preserve the linguistic function of each word in the sentence. The workflow and text processor parameters were shown in Figure 3 and 4.

Textual feature extraction was done by filtering the emotionally salient words (negatively connoted words and positively connoted words). Words in the training corpus were

looked up against Harvard General Inquirer and Opinion Lexicon by Bing, Liu [5] to decide if they were negatively or positively connoted. The frequencies of negatively and positively connoted words in each segment were then counted respectively and the numerical values were stored in the training data set.

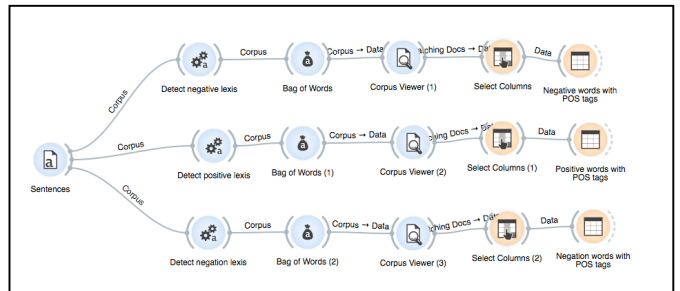


Figure 3. Orange 3 Text Mining workflow.

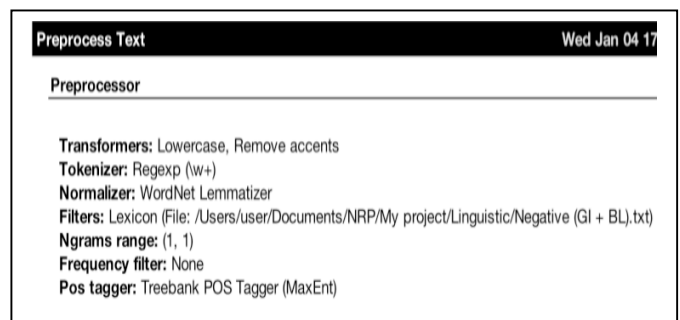


Figure 4. Text preprocessor parameters.

For negation cues, a similar approach was adopted to look up words against a list of explicit negation cues (compiled manually) as shown in Table I.

TABLE I. LIST OF NEGATION CUES

aint	doesnt	havent	lacks	nobody	prevent
arent	dont	havnt	mightnt	none	rarely
barely	doubt	improbable	mustnt	nor	scarcely
cannot	few	isnt	neednt	not	seldom
cant	hadnt	lack	neither	nothing	shant
darent	hardly	lacked	never	nowhere	shouldnt
didnt	hasnt	lacking	no	oughtnt	unlikely
wasnt	werent	without	wouldnt	little	

Last but not least, a simplified ‘‘Sentiment Score’’ model was proposed to ‘‘integrate’’ all the linguistic features that provide emotion-related information. The Sentiment Score reflected the sentiment of an opinion, with sentiment defined as the valence. For every opinion segment  $O$ , a

sentiment score,  $f(O)$ , was calculated using the formula below:

$$f(O) = pos(O) - neg(O) + 2 \times \left( \sum (-1)^{neg\_pos(w)} - \sum (-1)^{neg\_neg(w)} \right),$$

where  $pos(O)$  is the number of positive words in the opinion segment,  $O$ ;  $neg(O)$  is the number of negative words in the opinion segment,  $O$ ;  $neg\_pos(w)$  is the number of times each positive word is negated, and similarly,  $neg\_neg(w)$  is the sum of the number of times each negative word is negated. Note that  $\sum (-1)^{neg\_pos(w)}$  and  $\sum (-1)^{neg\_neg(w)}$  were counted manually to give the most reliable values. The following are some advantages of this model.

- 1) The problem of multiple negation can be solved. When a word is negated twice (with our loss of generality, suppose it is a positive word, as in “can’t live without”), the formula will correctly give a positive value that signifies positive sentiment.
- 2) It allows semi-automation negation analysis and has potential to be developed into a fully automated process.

### 3.2.2 ACOUSTIC FEATURES

Acoustic features of the sound segments were extracted manually using built-in functions in Praat, as shown in Figure 5. In order to achieve a more comprehensive representation of the sound, I chose a sufficiently wide range of acoustic features: intensity (amplitude, total energy, mean power), pitch (maximum pitch, average pitch, standard deviation, mean absolute slope), and voice quality (jitter, shimmer, Mean harmonics-to-noise ratio). Considering the inherent differences in pitch between females and males, an attribute “gender” was included to normalise the data.

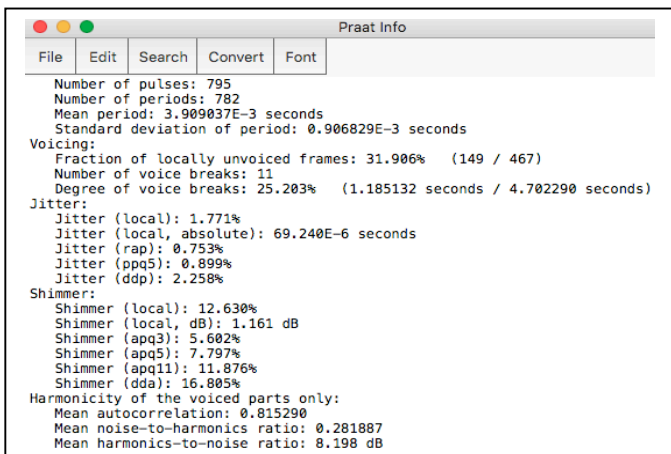


Figure 5. Extracting acoustic features using Praat.

### 3.3 MACHINE LEARNING

In the Orange Canvas Software [6], kNN, NN, Naïve Bayes and SVM were used to evaluate the proposed method. Extracted features were sent to appropriate classifier (Figure 6). Sentiment label (positive, negative) was selected as the target class and the rest of the features as attributes. Stratified 10-folds cross-validation method was used to measure model performance. Hence, each time the dataset was split into ten folds and one out of ten folds was randomly selected for testing. After multiple experiments, optimal configuration for each classifier was determined and used in the machine learning process.

TABLE II. OPTIMAL CONFIGURATION FOR DIFFERENT CLASSIFIERS

Classifier	Optimal Configurations
<b>k Nearest Neighbors</b>	<ul style="list-style-type: none"> <li>▪ k = 74 (weighting by distances)</li> <li>▪ Euclidean (normalize continuous attributes)</li> </ul>
<b>Naïve Bayes</b>	<ul style="list-style-type: none"> <li>▪ Prior: Relative Frequency</li> <li>▪ Conditional: M-Estimate (parameter = 2.0)</li> <li>▪ Size of LOESS window = 1.0</li> <li>▪ LOESS sample points = 11</li> <li>▪ Adjust threshold</li> </ul>
<b>Neural Network</b>	<ul style="list-style-type: none"> <li>▪ Hidden layer neurons = 11</li> <li>▪ Regularization factor = 1.0</li> <li>▪ Max iterations = 300</li> <li>▪ Normalize data</li> </ul>
<b>Support Vector Machine</b>	<ul style="list-style-type: none"> <li>▪ C-SVM (C = 1.00)</li> <li>▪ Linear Kernel, x- y</li> <li>▪ Numerical tolerance = 0.0010</li> <li>▪ Estimate class probabilities</li> <li>▪ Normalize data</li> </ul>

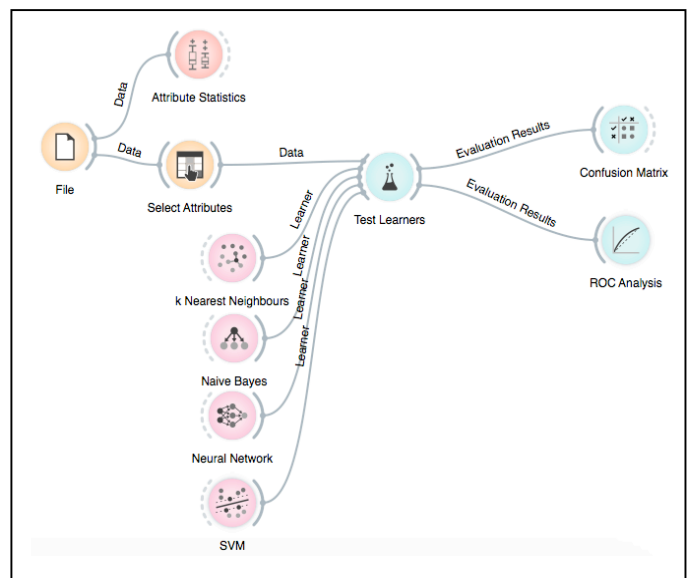


Figure 6. Illustration for machine learning workflow.

## IV. RESULTS AND DISCUSSIONS

### 4.1 RESULTS ANALYSIS

The evaluation will be focused on Area Under the ROC Curve (AUC) as it has “better statistical foundations than most other measures” [7] ROC Area Benchmark: 1.0: perfect prediction; 0.9: excellent prediction; 0.8: good prediction; 0.7: mediocre prediction; 0.6: poor prediction; 0.5: random prediction; <0.5: something wrong. [7] As shown in Table II, accuracy improved significantly when both acoustic and linguistic features were used, instead of only acoustic features or only linguistic features. When both acoustic and linguistic features were extracted, excellent classification of sentiments was achieved when the four classifiers were trained, with kNN, SVM and Neural Network having higher accuracies. The shapes of ROC curves for these four classifiers resembled the shape of ROC curve for excellent prediction (Figure 7 and 8).

TABLE III. AUC WHEN DIFFERENT CLASSIFIERS & FEATURES ARE USED

Classifier	AUC (acoustic features only)	AUC (linguistic features only)	AUC (Both acoustic features & linguistic features)
kNN	0.8750	0.8420	0.9321 > 0.9
Naïve Bayes	0.7964	0.8348	0.8929 ≈ 0.9
Neural Network	0.9018	0.8384	0.9304 > 0.9
SVM	0.8589	0.8607	0.9429 > 0.9

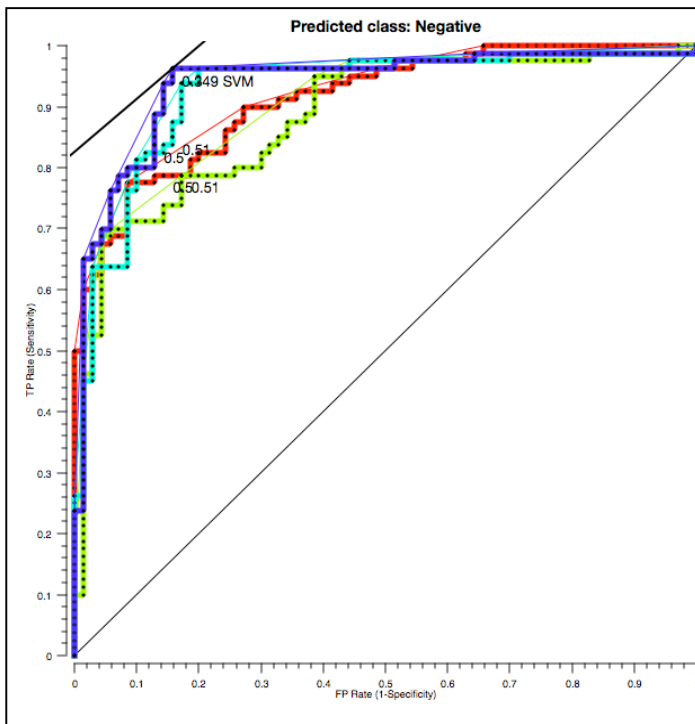


Figure 7. ROC curves for different classifiers when both acoustic and linguistic features were used.

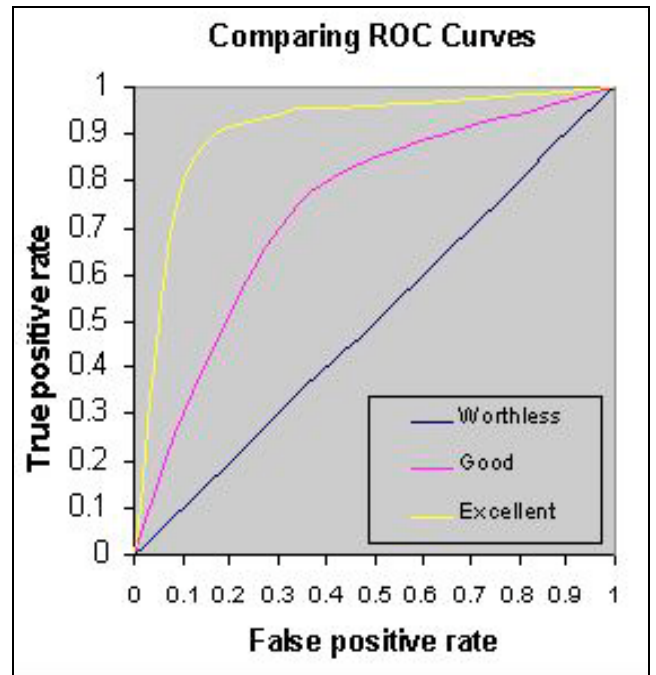


Figure 8. Shapes of ROC curves indicate different levels of accuracy. [8]

### 4.2 LIMITATIONS AND SOURCES OF ERROR

The speech corpus might not be large enough. There has to be sufficient representation of the different sentiments and different speech types in order for more comprehensive learning, and hence more accurate recognition. A standard sentiment analysis database could be used as a benchmark to compare the accuracy of this linguistic/acoustic model against other models. The average Word Error Rate of the Automated Speech Recognition (ASR) software Speechmatics is reported to be 33%. Hence, transcription errors might still be present even after manual check, affecting the accuracy of linguistic analysis. Negation analysis is subject to human error and there might be inaccurate detection of context-specific meanings of polysemes<sup>1</sup>.

### 4.3 INHERENT CHALLENGES

Sentiment analysis is a challenging task due to ambiguities in language, such as subtlety, concession, manipulation, sarcasm and ironies in speech. To address this problem, an accurate conclusion might entail examination of other features such as physiological symptoms (blood pressure etc.) and facial expressions. Although inaccuracies arising from ambiguities could be minimized by analyzing data from

<sup>1</sup> A word or lexical unit that has several or multiple meanings

multiple dimensions, cultural differences and multilinguality<sup>2</sup> further complicate the process. Due to differences in cultural backgrounds, the ways people express their sentiments vary among individuals. (For example, the way a Japanese expresses a sentiment differs from the way an American expresses the same sentiment). Moreover, sentiment expressions depend on contexts of speech, and hence vary even for the same person at different times. In addition, the speakers might constantly change subject or compare with another subject, which might be hard to detect.

There are also issues with mutual interpretability. Interjections that express feelings (such as “urggghh”) might be deemed as irrelevant by the machine. It might be hard, if not impossible, for the machine to “master” contextual knowledge such as some exophoric references<sup>3</sup> to historical figures (“the German dictator”, which refers to Hitler). The issue becomes more significant when dialects are used. For example, the negation analysis is based on Standard English usage, which might not be useful for other varieties of English. Speakers of certain dialects like African American Vernacular English (AAVE) usually employ double negatives to emphasize the negative meaning.

## V. CONCLUSION AND FUTURE WORK

In this study, we have built a machine learning model combining acoustic and linguistic features. As the results have shown, this model has significantly higher accuracy than models with only acoustic or only linguistic features. Under this model, excellent prediction can be achieved. Although limitations and challenges are real and a considerable amount of manual work is necessary, the positive results of this study have clearly suggested to the possibility of achieving a fully automated audio sentiment analysis in future.

Based on the limitations and challenges discussed in section IV, the following three main directions of research are proposed.

1. From *audio* sentiment analysis towards *video* sentiment analysis by incorporating facial expression features, and further towards *multi-dimensional* sentiment

analysis by incorporating physiological features such as blood pressure and heart rate.

2. From *semi-automatic* sentiment analysis towards *fully automatic* sentiment analysis, by reducing the amount of manual processing of data.
3. From *sentiment* recognition towards *emotion* recognition, by enabling classification of specific emotions such as fear, anger, happiness, sadness.

Artificial Intelligence (AI) is becoming an increasingly interdisciplinary field. To achieve the above research goals, cross-discipline cooperation is crucial. Solutions to the challenges of language/emotion recognition and understanding can be inspired by diverse fields from mathematics and sciences, which provide us with quantitative methods and computational models, to humanities and fine arts, which shed light on qualitative analysis and feature selection. From a neuroscience perspective, learning about how the human brain perceives and processes sentiments and emotions might inspire a better machine learning architecture for sentiment prediction. Mathematical modelling could be useful as well: the high complexity of emotions should be captured more comprehensively by mapping the emotion of each utterance in multi-dimensional vector space. Linguistics theories also imply that language is meaningless without context (the socio-cultural background of the speaker, the conversation setting, and the general mood). It is a timely reminder for Natural Language Processing (NLP) researchers to go beyond *content analysis* – dissecting language as an isolated entity only made up of different parts of speech – and aim for “*context analysis*”. Without being context-aware, AI will only be machines with “high Intelligence Quotient (IQ)” but “low emotional intelligence quotient (EQ)”. Emotion theory in drama and acting also provides some insights for developing affective, sentient AI. For example, emotions can be conveyed through subtle means such as silence, cadence, and paralinguistic features (Kinesthetics and Proxemics etc.). This will give us directions in selecting and extracting features salient to sentiment.

---

<sup>2</sup> Multilinguality is a characteristic of tasks that involve the use of more than one natural language. (Kay, n.d.)

<sup>3</sup> *Exophoric reference* is referring to a situation or entities outside the text. (University of Pennsylvania, 2006)

## REFERENCES

- [1] Liu, Bing. (2015). *Sentiment Analysis: Mining Opinions, Sentiments, and Emotions*. Cambridge University Press.
- [2] Chul Min Lee & Shrikanth S. Narayanan. (2005). Toward Detecting Emotions in Spoken Dialogs. *IEEE TRANSACTIONS ON SPEECH AND AUDIO PROCESSING, VOL. 13, NO. 2, MARCH 2005*.
- [3] Kaushik, Lakshmish & Sangwan, Abhijeet & Hansen, John H.L. (2013). A Holistic Lexicon-Based Approach to Opinion Mining. *IEEE*.
- [4] Ding, Xiaowen, Bing Liu, and Philip S. Yu. A Holistic Lexicon-Based Approach to Opinion Mining. In *Proceedings of the Conference on Web Search and Web Data Mining (WSDM- 2008)*. 2008.
- [5] Minqing Hu and Bing Liu. "Mining and Summarizing Customer Reviews." Proceedings of the ACM SIGKDD International Conference on Knowledge Discovery and Data Mining (KDD-2004), Aug 22-25, 2004, Seattle, Washington, USA
- [6] Demšar, J., Curk, T., & Erjavec, A. (2013). Orange: Data mining toolbox in Python. *Journal of Machine Learning Research, 14*, 2349–2353.
- [7] Unknown. Cornell University. (2003). Retrieved from: [https://www.cs.cornell.edu/courses/cs578/2003fa/performance\\_measures.pdf](https://www.cs.cornell.edu/courses/cs578/2003fa/performance_measures.pdf)
- [8] Tape, Thomas G. (n.d.). *Interpreting Diagnostic Tests*. University of Nebraska Medical Center. Retrieved from: <http://gim.unmc.edu/dxtests/roc3.htm>



## ACKNOWLEDGMENT

I would like to express my sincere gratitude to my project supervisor Professor Eddie Ng for being open-minded about my project topic, without which I could not have been able to delve deep into my field of interest. His insightful suggestions and unwavering support has guided me through doubts and difficulties.

## Resume

### ZHANG LIU

119 Dover Road, ACSI Boarding School, Singapore, S139656

(65) 85156883

zhangliu.sci@gmail.com

---

#### Education

---

<b>Anglo-Chinese Junior College, Singapore</b>	2016-2017
<b>Swiss Cottage Secondary School, Singapore</b>	2014-2015
<b>No. 13 Middle School, Urumqi, Xinjiang, China</b>	2010-2013

#### Activities

---

- **Organizer**, Swiss Cottage Secondary School Secondary One Orientation (2014)
- **Organizer**, Student Council Recruitment (2014)
- **Participant**, Science and Technology Endowment Program (STEP) - National University of Singapore (NUS) Sunburst Brain Camp (2017)
- **Participant**, National University of Singapore (NUS) International Olympiad in Informatics (IOI) Workshop (2014)

#### Leadership

---

- **Vice-President (Talent Development)**, Science and Mathematics Council (SMC), Anglo-Chinese Junior College (2016-2017)
- **President**, Mathematics and Computing Club, Anglo-Chinese Junior College (2016-2017)
- **Overall In-Charge (IC)**, Open House CCA Showcase, CCA Exhibition & CCA Recruitment (2017)
- **Event IC**, Vietnam Educational Program – SOS Village (2016)
- **Assistant Event IC**, Heyday (2016)
- **Assistant Event IC and Computer Science Question Setter**, International C. B. Paul Quiz (2017)
- **Committee Chairman**, International Biomedical Quiz (2016 & 2017), International C. B. Paul Quiz (2016 & 2017), International Young Whizzes Challenge (2016)
- **Prefect**, Student Council Training and Development Committee, Swiss Cottage Secondary School (2014-2015)
- **Team Leader**, RoboCup (2015), SMU Youth Innovation Challenge (2015), National Junior Robotics Competition (2014)

#### Research Experience

---

##### 1. Research Student

**April 2016 - April 2017**

- College of Engineering (Mechanical Aerospace Engineering), Nanyang Technological University, Singapore Mentor: Associate Professor Ng, Yin Kwee, Eddie (<http://www.mae.ntu.edu.sg/aboutus/FacultyandStaff/Faculty/Pages/mykng.aspx>)
- Research topic: Machine Learning and Sentiment Analysis

## 2. Research Student

Feb 2017- April 2017

- Yale-NUS College, Singapore Mentor: Assistant Professor Jean Liu (<https://www.yale-nus.edu.sg/about/faculty/jean-liu/>)
- Research topic: the neuroscience and psychology of love

## 3. Research Intern

June 9th to 20<sup>th</sup>, 2014

- Centre for Research and Applied Learning in Science, Science Centre Singapore Research topic: build an automated lighting system with Arduino and sensors

## Projects and Publications

---

1. **“When Siri Knows How You Feel: Application of Machine Learning in Automatic Sentiment Recognition in Human Speech”**
  - Presented in International Researchers’ Club Conference on Science Engineering and Technology (2017) and won the Best Paper Award
  - Paper accepted and will be presented at the SAI Future of Information and Communications Conference (IEEE technically sponsored) (2018)
  - Presented at Nanyang Research Program (2016/17)
  - Presented at Singapore Science and Engineering Fair (2017)
2. **Effects of Broad-Spectrum Antibiotics on The Clinical Outcomes of Pneumonia** (2017)
  - Presented at Beijing Youth Science Creation Competition (2017)
3. **Multi-Perspective Research on Autism Spectrum Disorder** (2017)
  - Presented at the Science and Technology Endowment Program (STEP) - National University of Singapore (NUS) Sunburst Brain Camp (2017)
4. **Neuroscience of Love**
  - Published in the *Brain Book*, Chapter 6 (2017)
5. **CRADLE Automatic LED Lighting System** (2014)

## Honors and Awards

---

- **Best Paper Award**, International Researchers’ Club Conference on Science, Engineering and Technology (2017)
- **Gold**, Nanyang Research Program (2016/17)
- **Silver**, Beijing Youth Science Creation Competition (2017): **Represented Singapore** at international event
- **Bronze**, Singapore Science and Engineering Fair (2017) (highest award for Robotics)
- **Bronze**, Singapore National Olympiad in Informatics (2017 & 2016 & 2015)
- **Silver**, Singapore Mathematics Olympiad (Senior) (2014)
- **Honourable Mention**, Singapore Mathematics Olympiad (Open) (2016)
- **Distinction**, Australian Mathematics Competition (2016)
- **Distinction**, Computational and Algorithmic Thinking (CAT) (2016)
- **Top 20 Runners**, Anglo-Chinese Junior College Intra-School Cross Country (2016)
- **Represented the school** in National Inter-School Cross Country Championship (2015)

- **1<sup>st</sup> Runner-up**, Swiss Cottage Intra-School Cross Country 'B' Division Girls' Championship (2015 & 2014)
- **High Distinction**, International Competitions and Assessments for Schools (ICAS) in Mathematics (2014)
- **Distinction**, International Competitions and Assessments for Schools (ICAS) in Science (2014)
- **Academic Book Prize for Top in Standards** (2014)
- **Academic Book Prize for Top in Additional Mathematics** (2014)
- **Top Student**, 2nd Preliminary Examinations (2013)
- **Third Prize**, China National Olympiad in Informatics in Province (NOIP) (2012)

## Membership

---

- **Member**, International Researchers' Club (IRC) Singapore (2017-)
- **Member**, ManiAC student journalist group, Anglo-Chinese Junior College (2016-2017)
- **Member**, Science and Technology Club, Swiss Cottage Secondary School (2014-2015)

## Areas of Expertise and Interest

---

1. **Programming languages:** Proficient: C/C++; Beginner: Python and JavaScript
2. **Software / tools:** Proficient: Statistical Package in Social Sciences (SPSS), Praat, Orange Canvas, Arduino, RoboLab, Mindstorm; Beginner: MATLAB
3. **Language skills:** Written and Verbal: English and Mandarin Chinese
4. **Research interests:** Computer Science, Natural Language Processing, Sentiment Analysis, Artificial Intelligence, Machine Learning, Affective Computing, Cognitive Science, Neuroscience, Computational Linguistics, Psycholinguistics, Sociolinguistics, Chemical Linguistics
5. **Personal interests:** language games and puzzles, long distance running, hiking, sci-fi movies and novels, poetry and literature, psychological thrillers, detective novels, meta-physics theories, Xiao (Chinese Flute), Indie music, MBTI analyses

**Name: NG YIN KWEE, Eddie (PI)**

**Employment History**

Name of Organization	Position Held	Period of Employment
Exxon Tankers Fleet	Marine Engineer	1983-1985
MPE-NTU	Lecturer	1992-1996
MPE-NTU	Senior Lecturer	1997-1998
MPE/MAE-NTU	Associate Professor	1999 -
MAE-NTU	Assistant Chair (Alumni)	Mar. 2008-31 Dec. 2012
National University Hospital (NUH)	Adjunct NUH Scientist	Sep. 2006 -

**Academic Qualifications**

Qualifications obtained & Class of Honors	Name of University	Year of Award
BEng, 1 <sup>st</sup> CL	Uni. of Newcastle upon Tyne	1988
PhD	Uni. of Cambridge	1992
Postgraduate Diploma in Teaching Higher Education	NIE-NTU	1995

**Professional Qualifications**

Fellow, Cambridge Commonwealth Society since 2003 by Cambridge Commonwealth Trust

**Professional Services**

No	Engaged Task	Occasion/Event	When (Period)
1	<b>Editor-in-Chief (Lead)</b>	Journal of Mechanics in Medicine and Biology (SCI-ISI index)	Since 2007
2	<b>Editor-in-Chief (Founding)</b>	Journal of Medical Imaging and Health Informatics (SCI-ISI index)	Since 2011
3	<b>Strategy Associate Editor-in-Chief</b>	World Journal of Clinical Oncology	Since 2010
4	Regional Editor	Computational Fluid Dynamics Journal	Since 1998
5	Associate Editor	Int. Journal of Rotating Machinery	Since 2004
6	Associate Editor	Chinese Medical Journals, Chinese Journal of Medicine	Since 2005
7	Associate Editor	Open Medical Informatics Journal	Since 2007
8	Associate Editor	Open Numerical Methods Journal	Since 2008
9	Associate Editor	Journal of Healthcare Engineering	Since 2009
10	Associate Editor	International Journal of Breast Cancer	Since 2010
11	Editor ( <a href="http://www.aspbs.com/jcp/">http://www.aspbs.com/jcp/</a> )	Journal of Scientific Conference Proceedings, ASP	Since 2011
12	Asian Editor ( <a href="http://www.aspbs.com/jbns/">http://www.aspbs.com/jbns/</a> )	Journal of Bionanoscience, ASP	Since 2011
13	Invited lecture speaker	9 <sup>th</sup> Int. Quantitative Infrared Thermography Conf., (Poland)	2-5 July 2008
14	Keynote lecture # K03	16 <sup>th</sup> International Conf. on Mechanics in Medicine & Biology, (Pittsburgh, USA)	23-25, July 2008
15	Keynote lecture # K06	2009 Int. Sym. on Biomechanics cum Annual Conference of Biomedical Engg, and workshop in NCKU, Taiwan	10-14, Dec. 2009
16	Plenary lecture # P18	2010 Int. Conf. on Medical Physiology (Cambridge Univ.)	23-25, Feb. 2010
17	Guest Editor	Int. Journal of Medical Systems (theme: D2H2)	May 2010
18	Guest Editor	Int. Journal of Computer Applications in Technology	2000 & 2004 each
19	Invited lecture speaker	2 <sup>nd</sup> International Workshop on Biomedical Engg. & Biomechanics, 2011 (Xian, China)	12-14 Aug. 2011
20	Invited keynote speech speaker with Honorarium and Accommodation of USD3k	IEEE Conference on Biomedical Engineering and Biotechnology, held in Macau, China.	May 28-30, 2012
21	Invited lecture speaker	Health Engineering 2012, UTM, Malaysia	Nov 29-Dec 1, 12
22	Invited Opening keynote speech speaker with Honorarium and	National Conference of Biomechanical Engineering, Vitoria, Brazil	April 25-28, 2013

	Accommodation		
23	Invited Opening keynote speech speaker with Honorarium and Accommodation	2 <sup>nd</sup> Conference on Biomedical Engineering and Biotechnology, Wuhan, China <a href="http://www.icbeb.org/photo.aspx?picture=1">http://www.icbeb.org/photo.aspx?picture=1</a> .	Oct. 11-13, 2013
24	Keynote lecture (invited)	IEEE 5 <sup>th</sup> Image Processing, Image Analysis & Real-time Imaging Symposium cum 2 <sup>nd</sup> Symposium on Acoustic, Speech & Signal Processing, UniMAP, Perlis, Malaysia	30 April 2014
25	Invited Opening keynote speech speaker	3 <sup>rd</sup> Conference on Biomedical Engineering and Biotechnology, Beijing, China	Sept. 25-28, 2014
26	Invited Opening keynote speech speaker	4th Conference on Biomedical Engineering and Biotechnology, Shanghai, China	18 – 20 Aug 2015
27	Invited Opening keynote speech speaker	2nd International Conference on Computational Methods in Engineering and Health Sciences, Malaysia.	19 – 20 Dec 2015
28	Invited Opening keynote speech speaker with Accommodation	Quantitative InfraRed Thermography Conference, Gdansk, Poland	04 – 08 Jul 2016
29	Invited Opening keynote speech speaker	5th Conference on Biomedical Engineering and Biotechnology, Hangzhou, China	01 – 04 Aug 2016
30	Invited Opening keynote speech speaker	3rd International Conference on Computational Methods in Engineering and Health Sciences, Kitakyushu city, Fukuoka, Japan	17 – 18 Dec. 2016
31	Invited Opening keynote speech speaker	6th Conference on Biomedical Engineering and Biotechnology, Guangzhou, China	17 – 20 Oct 2017

**Selected 10 publications:** to-date, Web of Science SCI-IF international journals (299), int. conf. proceedings (100), books (14) & textbook chapters (100). Total citation > 3300; H-Index: 35

**Ng, E. Y-K.** and Sudharsan, N.M. "An Improved 3-D Direct Numerical Modelling and Thermal Analysis of a Female Breast with Tumour", **International Journal of Engineering in Medicine**, Vol. 215, No. 1, (2001), Pp. 25 -- 37.

**Ng, E. Y-K.** and Sudharsan, N.M. "EFFECT OF BLOOD FLOW, TUMOUR AND COLD STRESS IN A FEMALE BREAST: A Novel Time-accurate Computer Simulation", **International Journal of Engineering in Medicine**, Vol. 215, No. H4, (2001), Pp.393-404.

**Ng, E. Y-K.**, Kaw, G.J.L, and Chang, W.M., "Analysis of IR Thermal Imager for Mass Blind Fever Screening", **Microvascular Research**, Vol. 68, No: 2, Reed Elsevier Science, Academic Press, USA. (2004), Pp. 104 -- 109.

**Ng, E. Y-K.** and Sudharsan, N.M., "Numerical Modelling in Conjunction with Thermography as an Adjunct Tool for Breast Tumour Detection", **BMC Cancer**, 4(17), Medline Journal (2004), 1--26. IF  $\approx$  2.9.

**Ng, E. Y-K.**, "Is Thermal Scanner Losing its Bite in Mass Screening of Fever due to SARS?", **Medical Physics**, American Association of Physicists in Medicine (2005), 32(1), 93--97. IF  $\approx$  2.5.

Ong, M.L. and **Ng, E. Y-K.**, "A Global Bioheat Model with Self-tuning Optimal Regulation of Body Temperature using Hebbian Feedback Covariance Learning", **Medical Physics**, (2005), Vol. 32, No: 12, Pp. 3819--3831.

**Ng, E. Y. K.** and Ng, W.K. "Parametric Optimisation of the Biopotential Equation for Breast Tumour Identification using ANOVA and Taguchi Method", **Medical & Biological Engineering & Computing**, Vol. 44, No. 1/2, Springer, Berlin. (2006), Pp. 131-139.

**Ng, E. Y-K** and Ooi, E.H., "Ocular Surface Temperature: A 3D FEM Prediction Using Bioheat Equation", **Computers in Biology and Medicine**, Elsevier, (2007), Vol. 37, No: 6, Pp. 829 -- 835.

**Ng, E. Y-K.**, et al., 2008, The use of tissue electrical characteristics for breast cancer detection: A perspective review, **Technology in Cancer Research and Treatment**, 7(4), 295-308 (*High SCI*)

**Ng, E. Y-K.**, "A Review of Thermography as Promising Non-invasive Detection Modality for Breast Tumour", **International Journal of Thermal Sciences**, Elsevier, Vol. 48, No. 5, (2009), pp. 849-855.

**Ng, E. Y-K.**, et al., "Prediction and Parametric Analysis of Thermal Profiles within Heated Human Skin using Boundary Element Method", **Philosophical Transactions A, The Royal Society**, Vol. 368, (2010), Pp. 655--678.

**Ng, E. Y-K.**, and M. Jamil, "Parametric sensitivity analysis of radiofrequency ablation with efficient experimental design: Combined effects of parameters and implications for various tissues", **International Journal of Thermal Sciences**, Vol. 80, No. June, (2014), pp. 41-47.

M. Jamil, **Ng, E. Y-K.**, "Statistical Modeling of Electrode Based Thermal Therapy with Taguchi Based Multiple Regression", **International Journal of Thermal Sciences**, Vol. 71, (2013), pp. 283-291.

M. Jamil, **Ng, E. Y-K.**, "To optimize the Efficacy of Bioheat Transfer in Electrode Based Thermal Therapy: A Physical Perspective", **International Journal of Thermal Biology**, Vol. 38, (2013), pp. 272-279.

M. Jamil, **Ng, E. Y-K**, "Evaluation of Meshless Radial Basis Collocation Method (RBCM) for Heterogeneous Conduction and Simulation of Temperature Inside the Biological Tissues", **International Journal of Thermal Sciences**, Vol. 68, (2013), pp. 42-52.

M. Jamil, **Ng, E. Y-K**, "Ranking of Parameters in Bioheat Transfer for Electromagnetic Heating Using Taguchi Analysis", **International Journal of Thermal Sciences**, Vol. 63, (2013), pp. 15-21.

#### On-going Postgraduate students

No	Student name (funding source)	PhD	Date joined (mm/yr)	Thesis Title
1	(IGS) Suriyanto	PhD	5 Jan 2014	Analysis of renography for quantitative means in differentiating renal obstruction
2	Alan Koh Fuhai, IPP with Lloyd's Register	PhD	5 Jan 2014	Probability model for ignition of gas ingested by a gas turbine
3	Low Chee Meng (LR, EDB-IPP)	PhD	Aug 2014	Mooring
4	Saxena Ashish	PhD	Jan 2016	Tracking vital health parameters using IR thermal imaging
5	Koh En Wei	MEng	Aug 2016	Decision support system for retinal health using digital fundus images
6	Muhammad Adam Bin Abdul Rahim	MEng	Aug 2016	Application of Thermography for the Detection of Diabetic Foot
7	Oh Shu Lih	MEng	Aug 2017	Application of Deep Convolutional Neural Network for the Identification of Sleep Apnea

#### Other Research Activities/Achievements (not captured above)

1	Chairman for 15 <sup>th</sup> Int. Conf. on Mechanics in Medicine and Biology (ICMMB-15 <sup>th</sup> , Singapore, 6-8 Dec. 2006)
2	Co-Convenor of the working group on thermal imagers under Medical Technology Standards Committee by SPRING, S'pore, (handling the inter. standardisation on ISO/TR 13154 & IEC 80601-2-59), 2006-2013
3	The "Most Innovative Speaker" Award for 3 <sup>rd</sup> International InfraMatrix Conference & Workshop, "Numerical Predictions of the Ocular Temperature as Alternative to IR Thermography", KL, Malaysia. (8-10 Nov. 2006).
4	Invited to conduct 3-days lectures in Heat Transfer, Thermodynamic and Mathematical Modeling to Masters (Medical Physics) and PhD students for Dept of Biomedical Imaging, U. of Malaya (2008).
5	Consulted during the on-going swine flu A-H1N1crisis for the setting up of thermal scanner on 1 <sup>st</sup> -line fever check by: Spring-S'pore; ISO/TR 13154:2009; Health Products Regulation Group of HAS; TTSH A&E; Madrid Hospital Foundation of Spain; Centre for Evidence-Based Medicine of Oxford University; STRIDE, Ministry of Defence of Malaysia etc.
6	Best Paper Award for the IRC-SET conference on Science, Engineering and Technology by International Researchers Club. Title: "When Siri Knows How You Feel: Application of Machine Learning in Automatic Sentiment Recognition from Human Speech", Aug. 2017

#### Postgraduate students trained to date (Masters or Ph.D. level):

19 Masters and 17 PhD respectively.

No	Student name	PhD	Date graduated (mm/yr)	PhD Thesis Title
1	N. M. Sudharsan	PhD	2000	Numerical modeling of female breast
2	Tan Swee Tiong	PhD	2006	Numerical studies of 3D developing laminar flow in microchannel
3	Zhong Liang	PhD	2006	Biomechanical Engineering Indices for Cardiac Function & Dysfunction during Filling and Ejection Phases
4	Ooi Ean Hin	PhD	2009	Studies of ocular heat transfer using the boundary element method
5	S. Vinithasree	PhD	2010	Early detection of breast cancer using bio-potential field technique
6	Tan Jen Hong	PhD	2010	Development of computer methods in the investigations of ocular surface temperature
7	Seyed Saeid Khalafvand	PhD	2013	Combined CFD/MRI analysis of left ventricular flow in heart failure
8	Muhammad Jamil	PhD	2014	Modeling of cell damage for cancer treatment
9	Jiao Lishi	PhD	2014	Study of Femtosecond Laser Pulse Drilling
10	Koh Wei Xiang Martin	PhD	2016	Complex Interactions between Tidal Turbine System, Multiple

	(ERIAN-IGS, JIP)			Wakes and Seabed Terrain in Energy Capture Array and its associated Environment Issues
11	Chew Kok Hon (DNU, EDB-IPP)	PhD	2017	Optimal Structural Design for Ocean Renewables (Wind) Energy System
12	Chow Jeng Hei (EDB-IPP-DHI)	PhD	2017	Coupled CFD and depth integrated modelling of marine structures
13	Koh Jian Hao (NPGS, JIP)	PhD	2017	Wave loads on floating platforms under special and complex conditions
14	Abdulqadir Aziz Singapore Wala (LR, EDB-IPP)	PhD	2017	Aerodynamics Modelling of Floating Offshore Wind Turbines
15	Ijaz Fazil Syed Ahmed Kabir (RSS)	PhD	2017	Improvement of BEM analysis to incorporate stall delay effect and the study of atmospheric boundary layer effect on the wake characteristics of nrel phase VI Turbine
16	Tejas Canchi, (LKCMedicine's RSS)	PhD	2017	Mechanistic and Pathological Study of the Genesis, Growth, and Rupture of Abdominal Aortic Aneurysms
17	Nikhil Garg	PhD	2017	The Effects of Atmosphere-Ocean-Wave Coupling During Tropical Cyclone

**Number of post-doctorates and PhD students currently in the lab:**

Nil for PDF.

The recently completed externally funded project "Discrete Thermal Data Analysis using ANN" by Lifeline Biotechnologies, Inc. (# RCA2-NTU, though <\$500k) has granted 3 patents (with Lifeline Biotechnologies, Inc. NV, received USD10m of investment in USA) and related good journal papers as listed below:

Method/Process: "A Device for Analyzing Thermal Data Based on Breast Surface Temperature for the Detection for Use in Determining Cancerous Conditions".	US Patent No: 8,185,485 B2
System Utility: "A System for Analyzing Thermal Data Based on Breast Surface Temperature to Determine Suspect Conditions"	US Patent No: 8,231,542 B2
Method Utility: "Methods for collecting and Analyzing Thermal Data Based on Breast Surface Temperature to Determine Suspect Conditions"	US Patent No: 8,226,572 B2

1. M. EtehadTavakol, S. Sadri, Ng, E.Y.K, 2010, Application of K- and Fuzzy c-means for Color Segmentation of Thermal Infrared Breast Images, Journal of Medical Systems, 34(1):35-42. (IF=1.064)
2. Tan, JMY, Ng, E.Y.K., R Acharya U, Keith, L.G., and Holmes, J., 2008, Comparative Study on the use of Analytical Software to Identify the Different Stages of Breast Cancer using Discrete Temperature Data, Journal of Medical Systems. 33(2):141-153 (IF=1.064)
3. Ng E.Y.K., et al., 2007, Detection and Classification of Breast Cancer using Neural Classifiers with First Warning Thermal Sensors, Information Sciences, 177(20):4526-4538. (IF: 3.095)
4. Tan & Ng E.Y.K. et al, 2007, A Novel Cognitive Interpretation of Breast Cancer Thermography with Complementary Learning Fuzzy Neural Memory Structure, Expert System With Applications, 33(3): 652-666. (IF= 2.596)

Another 2 externally funded projects "Biopotential field detection of breast cancer" and "Thermal imaging of eye diseases" by Tote-Board-Ngee Ann Gong-Xi (with TTSH & NUH respectively, though <\$500k) have also resulted some related good journal papers as listed below:

1. Tan JH, Ng E.Y.K, Rajendra Udyavara Acharya, Chee C, 2009, Infrared Thermography on Ocular Surface Temperature: A Review, Infrared Physics & Technology, 52(4):97-108. (IF=1.037)
2. Tan & Ng et al, 2010, Evaluation of Tear Evaporation from Ocular Surface by Functional Infrared Thermography, Medical Physics, 37(11):6022-6034. (IF=3.871)
3. Ooi EH, Ng EY.K., 2008, Simulation of Aqueous Humor Hydrodynamics in Human Eye Heat Transfer, Computers in Biology and Medicine, 38(2):252-262. (IF: 1.272)
4. Ng Y.K., S Vinitha Sree, K H Ng and G. Kaw, 2008, *The use of tissue electrical characteristics for breast cancer detection: A perspective review*, Technology in Cancer Research and Treatment, Vol. 7, No. 4, pp. 295-308.
5. Ng Y.K., Ng Wan Kee, Sim SJL, Rajendra Acharya U, 2007, *Numerical Modelling of Biofield Potential for Detection of Breast Tumor*, Computers in Biology and Medicine, Vol. 37, No. 8, pp. 1121-1132. (Q1 J.)





