CS 388 Methods
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Annotated Bibliography

1) SURVEYING COVID-19 STATUS THROUGH TWITTER LANGUAGE PROCESSING (NLP)

***Twitter Catches The Flu: Detecting Influenza Epidemics using Twitter***
Eiji Aramaki, Sachiko Maskawa, and Mizuki Morita. 2011. Twitter Catches The Flu: Detecting Influenza Epidemics using Twitter. In *Proceedings of the 2011 Conference on Empirical Methods in Natural Language Processing*, Association for Computational Linguistics, Edinburgh, Scotland, UK., 1568–1576. Retrieved August 26, 2020 from https://www.aclweb.org/anthology/D11-1145

- Method:
    - Among 300 million collected tweets 2008 November ~ 2010 June via Twitter API, the authors extract 0.4 million tweets that contain the word "influenza"
    - Training data: 5,000 human-annotated tweets (Positive(+1)/Negative(-1))
    - Test data (separated into four periods - winter 2008, summer 2009, winter 2009, and summer 2010 - because of three dropout periods due to Twitter API modification)
    - trained the SVM-based classifier using the influenza corpus
    - Sentence classification "based on a machine learning classifier under the bag-of-words (BOW) representation"; the machine learning method SVM (RBF kernel) performed the best in terms of time and accuracy
- Evaluation: assessed the detection performance using influenza reports provided by the Japanese IDSC
- Challenge: "Extracting Google web search queries that correlate with an influenza epidemic demonstrates high accuracy, but is inaccessible because a few corporations own the queries"
- Conclusions:
    - "In most seasons, the proposed SVM approach shows higher correlation than the simple word lookup method."
    - "All methods suffer from news bias in excessive news periods."
    - "Tweets have advantages in early stage detection"
    - "Human action (web search and tweets) highly corresponds to the real influenza before the epidemic peaks"
    - "Twitter texts precisely reflect the real world, and the NLP technique can extract the useful information from Twitter stream"
- Takeaway: There are widely available Twitter datasets, if not extracted through the API. It would be interesting to predict COVID cases on US in-person college campuses this coming winter, through analyzing social media posts by geolocation (areas, towns, cities where universities/colleges are located).

***Use of Twitter social media activity as a proxy for human mobility to predict the spatiotemporal spread of COVID-19 at global scale***

Donal Bisanzio, Moritz U. G. Kraemer, Isaac I. Bogoch, Thomas Brewer, John S. Brownstein, and Richard Reithinger. 2020. Use of Twitter social media activity as a proxy for human mobility to predict the spatiotemporal spread of COVID-19 at global scale. *Geospatial Health* 15, 1 (June 2020). DOI:https://doi.org/10.4081/gh.2020.882

- The paper discusses the "observational study" that "analyzed the movement of people from Wuhan and the global spread of (COVID-19) until January 30, 2020.
- The authors "assumed that most COVID-19 cases reported outside of China were linked to exposure … in Wuhan"
- Method:
    - "Each tweet has a unique user ID, latitude, longitude, and date"
    - Authors "used the Wilcoxon's rank test to compare the distance of visited locations and major airports connected to Wuhan from confirmed COVID-19 cases with known location"
    - Observed the "location visited by the study cohort of Twitter users who were followed-up for 30 days after having tweeted at least two times … from Wuham …"
    - Calculated IDVI for each country
- Conclusion:
    - The authors "anticipated that several locations that had yet to report COVID-19 cases by Jan. 30, 2020 were expected to have cases … soon".
    - "Immediate concern for outbreak containment were … locations … in Central and South East Asia … easily accessible via direct flights, by road or sea from Wuhan"
    - "Countries with moderate to low IDVI, such as Indonesia, Pakistan, and Turkey" should have been on high alert and develop COVID-19 response plans"
- Takeaway: Although a very insightful paper, there are a lot of spelling errors. Perhaps if user geolocations were public, we may have been able to control the virus earlier - but, privacy.

***Proceedings of the First Workshop on Social Media Analytics***

Aron Culotta. 2010. Towards detecting influenza epidemics by analyzing Twitter messages. In *Proceedings of the First Workshop on Social Media Analytics* (SOMA '10), Association for Computing Machinery, New York, NY, USA, 115–122. DOI:https://doi.org/10.1145/1964858.1964874

- The paper points out the faults in existing methods, such as the "expensive surveys of hospitals across the country" which has the "lag times of one to two weeks for influenza reporting"
- The paper draws from the method of "estimating a population's health from internet activity (Google's Flu Trends service)
- Method:
    - Gather and identity "influenza-related messages" on Twitter ("500,000 messages in the span of 10 weeks")

    - Analyze through regression models to "correlate search term frequency with influenza statistics reported by the CDC"
- Conclusion: The "best model achieves a correlation of .78 with CDC statistics by leveraging a document classifier to identify relevant messages"
- No full access. It would be very helpful for the research to gain access.

***Flu Detector - Tracking Epidemics on Twitter***

Vasileios Lampos, Tijl De Bie, and Nello Cristianini. 2010. *Flu Detector - Tracking Epidemics on Twitter.* In Machine Learning and Knowledge Discovery in Databases (Lecture Notes in Computer Science), Springer, Berlin, Heidelberg, 599–602. DOI:https://doi.org/10.1007/978-3-642-15939-8_42

- This paper introduces the "automated tool with a web interface for tracking the prevalence of influenza-like illness".
- Method:
    - The goal is to "compute a flue-score from Twitter corpus on a daily basis"
    - The authors collected 40 weeks of Twitter corpus from 49 urban centers and weekly local reports
    - They applied the Bolasso (LASSO) method to "perform feature selection" to apply on regression models
- Takeaway: The paper focuses less on the results/findings. The conclusion is unclear. The model appears easily applicable in other locations.

***Twitter and Census Data Analytics to Explore Socioeconomic Factors for Post-COVID-19 Reopening Sentiment***

Md Mokhlesur Rahman, G. G. Md Nawaz Ali, Xue Jun Li, Kamal Chandra Paul, and Peter H. J. Chong. 2020. *Twitter and Census Data Analytics to Explore Socioeconomic Factors for Post-COVID-19 Reopening Sentiment*. Social Science Research Network, Rochester, NY. Retrieved August 27, 2020 from https://papers.ssrn.com/abstract=3639551

- This paper "investigates the sentiment of people towards reopening the US economy and finds the underlying socioeconomic factors that are associated with prominent public sentiment" (pg. 2)
- Method:
    - The authors collected Twitter data of/from 51 states.
    - Twitter-generated sentiment results were integrated with the US Census data (which included "socioeconomic characteristics of people (e.g. education, income, family, size, and employment status".
    - a binary logit model was used to generate results.
- Evaluation: 56.18 % accurate in classifying sentiments
- Conclusion:

    - "Family households, people with low education levels, people in the labor force, low-income people, and people with higher house rent are more interested in reopening the economy."
    - "Households with a high number of members and high income are less interested to reopen the economy"
    - Policymakers should appropriately allocate resources to "mitigate the impacts of pandemics"
- Takeaway: This journal also includes a literature review- refer to it as an example. Similar approach to Wuhan-Bombardy. This journal evaluates the sentiments of each state as a whole, thus the lower accuracy rate.

***Examining the Impact of COVID-19 Lockdown in Wuhan and Lombardy: A Psycholinguistic Analysis on Weibo and Twitter***

Yue Su, Jia Xue, Xiaoqian Liu, Peijing Wu, Junxiang Chen, Chen Chen, Tianli Liu, Weigang Gong, and Tingshao Zhu. 2020. Examining the Impact of COVID-19 Lockdown in Wuhan and Lombardy: A Psycholinguistic Analysis on Weibo and Twitter. *International Journal of Environmental Research and Public Health* 17, 12 (January 2020), 4552. DOI:https://doi.org/10.3390/ijerph17124552

- Analyzing the " impact of COVID-19 lockdown on individuals' psychological states" in Wuhan, China and Lombardy, Italy
- Methods:
    - Fetched user's posts on Sina Weibo and Twitter two weeks prior and after the lockdown from the pool of users identified by geolocation
    - Utilized the simplified Chinese version of LIWC and Italian LIWC (Language Inquiry and Word Count); word categories, including 'home', 'humans', 'religion', 'certain', 'inhibition'; selected the word categories to make two datasets comparable
    - "Compared the frequencies of 51 LIWC categories"
- Results:
    - China: "attention to group, religion, and emotions"; potential decrease in negative emotions; decrease in 'money', 'time', 'motion' words; increase in 'religion', 'human', 'social' words.
    - Italy: "increase in 'home' words"; "decreased stress, focus on leisure activities"
- Takeaway: Such an interesting analysis! I wonder what the results will be if we apply this method on US social media posts, comparing frequencies by months or so. I predict there would have been an increase in 'home' words, but I doubt there would be a decrease in 'money' and 'time' words. This analysis is also interesting because the emotional states of people in different countries will be different, according to how the government is handling the COVID-19 situation - some countries may have higher increase in 'negative emotion' words than others.

2) ANALYZE, VISUALIZE, PREDICT COVID-19 CASES (on US college campuses after starting in-person class) (DATA SCIENCE)

***Report 9: Impact of non-pharmaceutical interventions (NPIs) to reduce COVID19 mortality and healthcare demand***

N. Ferguson, D. Laydon, G. Nedjati Gilani, N. Imai, K. Ainslie, M. Baguelin, S. Bhatia, A. Boonyasiri, Z. Cucunuba Perez, G. Cuomo-Dannenburg, A. Dighe, I. Dorigatti, H. Fu, K. Gaythorpe, W. Green, A. Hamlet, W. Hinsley, L. Okell, S. Van Elsland, H. Thompson, R. Verity, E. Volz, H. Wang, Y. Wang, P. Walker, C. Walters, P. Winskill, C. Whittaker, C. Donnelly, S. Riley, and A. Ghani. 2020. *Report 9: Impact of non-pharmaceutical interventions (NPIs) to reduce COVID19 mortality and healthcare demand*. DOI:https://doi.org/10.25561/77482

- Authors discuss that multiple intervention should be used (one intervention is not enough): mitigation to slow the spread, suppression to reduce and maintain the case numbers
- Discusses infection rate from existing datasets (like China), the methods behind the transmission model, the assumptions behind the model, and challenges (mitigation and suppression must be maintained until vaccine is developed)
- **Analyzes the impact of "five different non-pharmaceutical interventions (NPI)" implemented "individually and in combination" with "a pessimistic assumption"**
- "Mitigation is not viable option without overwhelming healthcare systems"; suppression is necessary;
- Conclusion:
    - Population-wide social distancing, in combination with home isolation has potential to suppress transmission; this optimal mitigation policies (home isolation, home quarantine, social distancing) **might reduce peak healthcare demand by 2/3 and deaths by ½**
    - This Imperial College London journal **influenced the UK government** to implement social distancing measures!
- Takeaway: This journal demonstrated a good example of **approaching the datasets with detailed epidemiological research questions** (such as modeling/analyzing mitigation policies, individually and in combination) to achieve insightful conclusions from epidemiological modelling.

***Feasibility of controlling COVID-19 outbreaks by isolation of cases and contacts***

Joel Hellewell, Sam Abbott, Amy Gimma, Nikos I. Bosse, Christopher I. Jarvis, Timothy W. Russell, James D. Munday, Adam J. Kucharski, W. John Edmunds, Fiona Sun, Stefan Flasche, Billy J. Quilty, Nicholas Davies, Yang Liu, Samuel Clifford, Petra Klepac, Mark Jit, Charlie Diamond, Hamish Gibbs, Kevin van Zandvoort, Sebastian Funk, and Rosalind M. Eggo. 2020. Feasibility of controlling COVID-19 outbreaks by isolation of cases and contacts. *The Lancet Global Health* 8, 4 (April 2020), e488–e496. DOI:https://doi.org/10.1016/S2214-109X(20)30074-7

- A mathematical model was used to "assess **if isolation and contact tracing are able to control onwards transmission from imported cases** of COVID-19".
- Implemented a branching process mode; ran 1000 simulations of each combination of R0; explored two scenarios of delay (short and long) between symptom onset and isolation

- In quantifying the potential effectiveness of contact tracing and isolation of cases, the authors concluded that "**highly effective contact tracing and case isolation"** can control a new outbreak of COVID-19 **within 3 months**.
- This model can be modified "to assess the potential success of local response efforts".
- I believe this model is only effective when either the government is able to force people to report and isolate, or if citizens are conscious enough to report and isolate.

***Leveraging Data Science To Combat COVID-19: A Comprehensive Review***

Siddique Latif, Muhammad Usman, Sanaullah Manzoor, Waleed Iqbal, Junaid Qadir, Gareth Tyson, Ignacio Castro, Adeel Razi, Maged N. Kamel Boulos, Adrian Weller, and Jon Crowcroft. 2020. Leveraging Data Science To Combat COVID-19: A Comprehensive Review. (April 2020). DOI:https://doi.org/10.36227/techrxiv.12212516.v1

- Survey growing body of research vetted through peer-review process; a comprehensive review on using data science on COVID-19; systemize data science activities;
    - Overview of epidemic models: compartmental models, Bayesian hierarchical modeling, parameterising (pg. 2)
    - Accurate predictions through simulation modeling [**Imperial College London that made the UK implement social distancing measures 21], [modeling infectious disease dynamics, global health 22**]
    - South Korea's testing campaign, contact tracing, smartphone [24, 25, 26]
- Summarize and share **public datasets, repositories** with updated papers/datasets to facilitate accessibility (pg. 3):
    - Case data = {(key attributes: geolocation, date of confirmation, symptoms, travel history), (datasets: Johns Hopkins University [71], Kaggle daily cases [76], nCOV2019 national, municipal health reports of patients [75]), (common application: data visualization, predictive analytics}}
    - Textual data = {(Twitter datasets [78 ID, 66 text], **[85]**), **NLP ! ! ! [86, 87, 88]**, clinical studies information extraction [91], **language processing model [92]**, the White House}
    - https://github.com/Data-Science-and-COVID-19/Leveraging-Data-Science-To-Combat-COVID-19-A-Comprehensive-Review
    - https://cgdv.github.io/challenges/COVID-19/datasource/
- Provide bibliometric analysis;
- Discuss pressing research problems (estimating mortality risk, automated tools, thermal imaging, breathing sound), common challenge and pitfalls;
    - Usage of social media, Bluetooth technology to trace/check/document people, vs. concerns of privacy breach
    - Misinformation surrounding COVID-19 [39]
- Idea: It will also be interesting to visualize/predict COVID cases by the size of the university/college. US college campuses are more relevant and new, than South Korean cases.

***Predictions, role of interventions and effects of a historic national lockdown in India's response to the COVID-19 pandemic: data science call to arms***
Debashree Ray, Maxwell Salvatore, Rupam Bhattacharyya, Lili Wang, Jiacong Du, Shariq Mohammed, Soumik Purkayastha, Aritra Halder, Alexander Rix, Daniel Barker, Michael Kleinsasser, Yiwang Zhou, Debraj Bose, Peter Song, Mousumi Banerjee, Veerabhadran Baladandayuthapani, Parikshit Ghosh, and Bhramar Mukherjee. 2020. Predictions, role of interventions and effects of a historic national lockdown in India's response to the COVID-19 pandemic: data science call to arms. *Harv Data Sci Rev* 2020, Suppl 1 (2020). DOI:https://doi.org/10.1162/99608f92.60e08ed5

- The paper projects COVID-19 infection in regards to the duration of lockdown, and further studies "the short- and long- term impact of an initial 21-day lockdown … in India compared to other less severe non-pharmaceutical interventions"
- Method: The authors use "a Bayesian extension of the Susceptible-Infected-Removed (eSIR) model"
- Conclusion:
    - The well-implemented lockdown reduces cases in a short term and provides "time to prepare its healthcare and disease-monitoring system".
    - It needs "measures of suppression in place after the lockdown for increased benefit"
    - "Longer lockdown (42-26 days) is preferable to substantially "flatten the curve""
- Takeaway: There are pages of helpful visualization- refer for data science visualization. The authors specifically include the improved method in response to peer-reviewer's feedback.

3) EDGE DETECTION FOR SCANNED IMAGES OF CUNEIFORM TABLETS (MACHINE LEARNING)

***A computational approach to edge detection***
John Canny. 1986. A computational approach to edge detection. *IEEE Transactions on Pattern Analysis and Machine Intelligence*. (1986).

- Canny presents a "computational approach to edge detection," in which he defines three performance criteria as "good detection", "good localization", and "only one response to a single edge". Canny presents improvements to multiple processes of edge detection to enable accurate step edge detection and reduced noise.
- Notes:
    - Performance criteria (pg. 2). Penalty method (pg. 4)
    - "According to the first two criteria the optimal detector for step edges is a truncated step, or difference of boxes operator. The difference of boxes was used by Rosenfeld annThurston[25], and in conjunction with lateral inhibition by Herskovits and Binford[11]" (pg. 4) However, this didn't consider intersection, only considered a single point. Thus, the third criteria is necessary.
    - Auxiliary constraints, optimal operator, roof edge detector (pg. 5)
    - Detector for step edges, optimal filter (pg. 6)

    - Signal-to-noise ratio, first derivative of Gaussian operator, and its performance (pg. 9-10)
    - "Derived the optimal operator to deal with known image features in Gaussian noise". Next problem is "edge detection between textured regions" (pg. 11)
    - Estimating noise, "gain better separation between signal and noise" (pg. 11)
    - Visual example, "thresholding through hysteresis" (pg. 12)
    - One dimension: "characterize the position of a step edge in space with one position coordinate"
    - Two dimensions: "edge orientation"/"edge direction" (pg. 12)
    - Smooth window function (pg. 13)
    - "Choosing the width of the operator .. to give the best detection/localization tradeoff." "The first heuristic for choosing between operator outputs is that small operator widths should be used whenever they have sufficient Σ." "Local decision procedure that will enable us to decide whether to mark one or more edges when several operators in a neighborhood are responding." (pg. 14)
    - Directional masks, computation of mask, "goodness of fit" (pg. 17)
    - Good, but dense summary (pg. 19)
- Takeaway: Canny algorithm is chosen by several previously read papers as the best edge detection algorithm. This paper is extremely dense, with mathematical formulas and theoretical approach to edge detection. I need help to understand this paper.

***A Research on Improved Canny Edge Detection Algorithm (***5 citations***)***
Li J., Ding S. (2011) A Research on Improved Canny Edge Detection Algorithm. In: Zhang J. (eds) Applied Informatics and Communication. ICAIC 2011. *Communications in Computer and Information Science*, vol 228. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-23223-7_13

- "Improved Canny algorithm that B-spline function instead of Gaussian function";
- "Calculates gradient amplitude in 3×3 neighborhoods";
- "Selects thresholds on the basis of gradient histogram"
- No full access. Would like access to read more.

***Fast Edge Detection Using Structured Forests***
Piotr Dollár and C. Lawrence Zitnick. 2014. Fast Edge Detection Using Structured Forests. arXiv:1406.5549 [cs] (November 2014). Retrieved August 29, 2020 from http://arxiv.org/abs/1406.5549

- This paper presents "a structured learning approach to edge detection," a novel approach to "predicting local edge masks in a structured learning framework applied to random decision forests"
- Method:
    - "a general purpose method for learning structured random decision forest that robustly uses structured labels to select splits in the trees" (pg. 12)

    - Structured learning, random decision forests, information gain, high variance and preventing overfitting, mapping (pg. 2-3)
    - Parameters: "structured forest splitting parameters (e.g., m and k), feature parameters (e.g., image and channel blurring), and model and tree parameters (e.g. number of trees and data quantity)." (pg. 7)
    - Post-detection: use "sharpening and multiscale detection to enhance results" (pg. 8)
    - Berkeley Segmentation Dataset and Benchmark dataset; training takes ~20 minute (author mentions parallelization, but I don't understand)
- Evaluation: Accuracy is measured by "fixed contour threshold (ODS), per-image best threshold (OIS), and average precision (AP)" (pg. 7)
- Performance: "real time frame rates" and "state-of-the-art accuracy"; tested on two datasets
- Takeaway: This paper was mentioned by Xie-Tu's paper on HED as the best structured learning edge detection.

***Study and Comparison of Various Image Edge Detection Techniques***

Raman Maini and Aggarwal, Himanshu. Study and Comparison of Various Image Edge Detection Techniques. *International Journal of Image Processing (IJIP)* 3, 1, 12.

- The authors analyze and provide **visual comparisons of the most used Gradient and Laplacian techniques** using Matlab 7.0.
- The authors summarize and provide mathematical reasoning behind several algorithms, and especially discuss the Canny algorithm in detail
- The visual analyses on Sobel, Rober, and Canny methods on 3 different image types - a graphic image, a portrait photograph, and a noisy image - are provided, among which Canny performed the best
- Canny displayed a high level of performance because it utilizes "non-maximal suppression (yields thin lines)" and :hysteresis with thresholding".
- Question: Where can I find out if this paper is peer-reviewed?
- Takeaway: This conclusion points to the possibility that the Canny edge detection method may perform the best on cuneiform tablets. During literature review, I would like to read the journal in detail to find out what parameters were used by the authors.

***Theory of Edge Detection (***Zero-crossing***)***

D. Marr, E. Hildreth, and Sydney Brenner. 1980. Theory of edge detection. *Proceedings of the Royal Society of London. Series B. Biological Sciences* 207, 1167 (February 1980), 187–217. DOI:https://doi.org/10.1098/rspb.1980.0020

- Conclusion: "Simplify the detection of intensity changes by dealing with the image separately at different resolutions," then apply "the spatial coincidence assumption." (pg. 211) Suggests the Laplacian of Gaussian operator. **Zero-crossing**.
- Notes:

    - "Intensity changes, which occur in a natural image" can be detected by applying "the second derivative of a Gaussian" filter, often without needing the filter to be "orientation-dependent". Intensity changes are due to "surface discontinuities ... , reflectance or illumination boundaries," which are all "spatially localized". The theory presented in the paper explains "the operation of forming oriented zero-crossing segments from the output of … second derivative of a Gaussian filter"
    - Intensity change has "a corresponding peak in the first directional derivative ... , a zero-crossing in the second directional derivative intensity" (pg. 192)
    - Zero-crossing segment, amplitude.
    - Spatial coincidence assumption: "the minimum number of channels required is two"; "provided the two channels are reasonably separated in the frequency domain, and their zero-crossings agree, the combined zero-crossings can be taken to indicate the presence of an edge in the image." (pg. 201-2)
    - The authors' "definition of an edge rests lightly on the early assumptions of theorem 1 about directional derivatives and heavily on the constraint of spatial localization" (pg. 211)
- Takeaway: Canny cites this study, and two others by the same author (Marr) in his paper "A computational approach to edge detection", where he references the similarity of his work to "one-dimensional Marr-Hildreth edge detector" and "choosing between different Laplacian of Gaussian channels" presented in Marr-Hildreth's paper. (Canny, 692).

***Extracting old persian cuneiform font out of noisy images (handwritten or inscription)***

Seyed Muhammad Hossein Mousavi and Vyacheslav Lyashenko. 2017. Extracting old persian cuneiform font out of noisy images (handwritten or inscription). *In 2017 10th Iranian Conference on Machine Vision and Image Processing (MVIP)*, 241–246. DOI:https://doi.org/10.1109/IranianMVIP.2017.8342358

- The paper presents recognizing Achaemenid scripts using optical character recognition (OCR) with 92% accuracy.
- Final outputs: "extraction of cuneiform font, Persian and English transcription of sentences, sentence pronunciation and translation of a substantial number of extracted Persian and English words."
- In the process, the paper utilizes image processing techniques to eliminate noises.
- One of the challenges I will encounter in the project is reducing the noise without compromising the inscriptions, since the purpose of 'fat-cross' is for the scripts to be studied. I believe this paper is highly relevant in understanding which methods or parameters to apply for cuneiform tablets.

***Holistically-Nested Edge Detection***

Saining Xie and Zhuowen Tu. 2015. Holistically-Nested Edge Detection. 1395–1403. Retrieved August 29, 2020 from https://openaccess.thecvf.com/content_iccv_2015/html/Xie_Holistically-Nested_Edge_Detection_ICCV_2015_paper.html

- The authors present a new edge detection algorithm, "Holistically-Nested Edge Detection (HED)," which tackles two problems: "(1) holistic image training and prediction and (2) multi-scale and multi-level feature learning". The authors are confident with their advancement.
- Method:
    - New algorithm/deep learning model built upon "fully convolutional neural networks and deeply-supervised nets" (pg. 8)
    - "Configurations of multi-scale deep learning: "multi-stream learning", "skip-layer network learning", "single model on multiple inputs", "holistically-nested networks"
    - "FCN and skip-layer architecture"; using deep supervision (pg. 5)
    - Datasets: BSD500 dataset, NYU Depth dataset
- Inspirations:
    - "Early pioneering methods": Sobel [20], zero-crossing [27, 37], Canny detector [4]
    - Information theory: Statistical Edges [22], Pb [28], gPb [1]
    - "Learning-based methods (reliant on human design)": BEL [5], Multi-scale [30], Sketch Tokens [24], Structured Edges (BEST) [6, 28]
    - "Convolutional Neural Networks (emphasize the importance of automatic hierarchical feature learning)": N^4-Fields [10], Deep-Contour [34], DeepEdge [2], and CSCNN [19]
- Evaluation: F-score, speed
- Questions: What does the training data look like? Is that what is referred to as the "ground truth"?

***Edge Detection Techniques - An Overview***

Djemel Ziou and Salvatore Tabbone. 1998. Edge Detection Techniques - An Overview. *International Journal of Pattern Recognition and Image Analysis* 8, (1998), 537–559.

- This paper is mainly divided into discussing 1) characteristics of edges, 2) properties of detectors, 3) methodology of edge detection, 4) the mutual influence between them and 5) the main idea behind the major edge detection techniques
- There are two types of evaluation methods: "**subjective evaluation" by humans and "objective evaluation"** (e.g. "figure of merit" [1, 88], [49], [115]); ideally both should be used together [39]; (further evaluation methods are discussed in pg. 23)
- Eval. methods should take into account improving smoothing and differentiation techniques, and "the subsequent use of edges, the specification of the detector, and the characteristics of the real image" (pg. 24)
- While this journal is introduced broad enough methods/algorithms for my project, the authors state the journal surveys algorithms that were suitable/influenced their work (aka not a exhaustive paper)
- Further citations to check: improvements [38], automatically selects detector [126], [128]; influence of edge characteristics on the performance of detectors [1,49,48,115,19,66]; **more surveys papers [17, 114, 123, 75, 68]**
- Takeaway: I am now introduced to the foundational knowledge of each step in the edge detection process - smoothing, differentiation, and labeling. This paper also cited many insightful, niche

researches in various processes of edge detection algorithms/methods. It seems like it would be ideal to process tablet scans with **contextual edge detection that utilize the edge combination method**.

- Questions: How can I better understand localization? How can I implement a contextual edge detection method?

- Notes on edge detection (ED) methods, characteristics, algorithms:
  - Edges correspond to discontinues, two regions having almost constant, but different, grey levels
  - The purpose of ED is "to localize variations of the image grey level and to identify the physical phenomena which produced them" (pg. 8)
  - Majority of ED algorithms are adapted to step edges
  - Step edges: localized as positive maxima or negative minima of the first-order derivative; a combination of several infection points,
  - Double step edge: two inflection points in the vicinity of each other; has visuals about different step edge types
  - Junction/corner: 2D feature, two or more edges meet; several junction models
  - There is a variety of edge detectors that differ in purpose; **mainly two classes: no prior knowledge, contextual** (used in applications where images always include same objects)
  - **The process: Differentiation -> smoothing -> labeling**
  - Differentiation: computation of the necessary derivatives to localize the edges; lots of math;
  - Smoothing: noise reduction but consequently loss of information
  - Scale/regularization parameter: e.g. cubic spline, the Green function, or the Gaussian
  - "Non-linear filtering is more successful than linear filtering, but linear filtering is more common in edge detection"
  - Edge labeling: "localizing edges and increasing signal-to-noise ratio by suppressing false edges" (pg. 9)
  - Multi-scale approach: obtaining "a description of an image at different scales by applying an edge detector at different scales and combining the recovered edge information" (pg. 13)
  - **Edge combination: "similar edges are combined to form a single image" (14)**
  - Photometric character: noise, steepness, edge type; (More influence of edge characteristics information on pg. 20)
  - Geometric character: smoothness, subpixel, orientation;
  - **Higher the noise energy, lower the signal/noise ratio, greater the delocalization error;**
  - For single-step edge, lower the edge steepness, lower the signal/noise ratio, greater the delocalization error;
  - For double edge, delocalization error is greater, due to mutual **influence** between two steps.
  - Step edge detection: Prewitt and Sobel masks (fixed 3 x 3 size, more info pg. 25), Rosenfeld and Thurston (smoothing operation, noise-sensitive?);

- **Parametric fitting** (pg. 26; Hueckel's technique [42, 43]; Nayar [77] less info. loss with dimensionless edge **parametric manifold**);
- **Optimal enhancement** (pg. 27)
- Lines respond to local extrema of the grey level image; majority of algo. developed for **binary images** [2, 11, 103] a few for grey level images; more algorithms and its authors on pg. 29.
- (pg. 33) "Implementation includes convolution masks (sensitive to scale increases), Fourier transform, hierarchical correlation, numerical filtering, etc.; should be efficient, run in a reasonable amount of time (increasing scale should not drastically affect the computation time), etc."