

Figure 5: The $\delta(c, \Delta)$ function for six different codes.

for healthcare using reverse time attention mechanism. In Advances in Neural Information Processing Systems. 3504–3512.

- [9] Edward Choi, Andy Schuetz, Walter F Stewart, and Jimeng Sun. 2016. Using recurrent neural network models for early detection of heart failure onset. *Journal* of the American Medical Informatics Association 24, 2 (2016), 361–370.
- [10] Yujuan Feng, Xu Min, Ning Chen, Hu Chen, Xiaolei Xie, Haibo Wang, and Ting Chen. 2017. Patient outcome prediction via convolutional neural networks based on multi-granularity medical concept embedding. In 2017 IEEE International Conference on Bioinformatics and Biomedicine (BIBM). IEEE, 770–777.
- [11] Djordje Gligorijevic, Jelena Stojanovic, and Zoran Obradovic. 2016. Disease types discovery from a large database of inpatient records: A sepsis study. *Methods* 111 (2016), 45–55.
- [12] Yoni Halpern, Steven Horng, Youngduck Choi, and David Sontag. 2016. Electronic medical record phenotyping using the anchor and learn framework. *Journal of the American Medical Informatics Association* 23, 4 (2016), 731–740.
- [13] Sepp Hochreiter and Jürgen Schmidhuber. 1997. Long short-term memory. Neural computation 9, 8 (1997), 1735–1780.
- [14] Diederik P Kingma and Jimmy Ba. 2014. Adam: A method for stochastic optimization. arXiv preprint arXiv:1412.6980 (2014).
- [15] Carrie N Klabunde, Arnold L Potosky, Julie M Legler, and Joan L Warren. 2000. Development of a comorbidity index using physician claims data. *Journal of clinical epidemiology* 53, 12 (2000), 1258–1267.
- [16] Harlan M Krumholz, Yun Wang, Jennifer A Mattera, Yongfei Wang, Lein Fang Han, Melvin J Ingber, Sheila Roman, and Sharon-Lise T Normand. 2006. An administrative claims model suitable for profiling hospital performance based on 30-day mortality rates among patients with heart failure. *Circulation* 113, 13 (2006), 1693–1701.
- [17] Nathan Levitan, A Dowlati, SC Remick, HI Tahsildar, LD Sivinski, R Beyth, and AA Rimm. 1999. Rates of initial and recurrent thromboembolic disease among patients with malignancy versus those without malignancy. *Risk analysis using Medicare claims data. Medicine (Baltimore)* 78, 5 (1999), 285–91.
- [18] Zachary C Lipton, David C Kale, Charles Elkan, and Randall Wetzel. 2015. Learning to diagnose with LSTM recurrent neural networks. arXiv preprint arXiv:1511.03677 (2015).
- [19] Fenglong Ma, Radha Chitta, Jing Zhou, Quanzeng You, Tong Sun, and Jing Gao. 2017. Dipole: Diagnosis prediction in healthcare via attention-based bidirectional recurrent neural networks. In Proceedings of the 23rd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining. ACM, 1903–1911.
- [20] Riccardo Miotto, Fei Wang, Shuang Wang, Xiaoqian Jiang, and Joel T Dudley. 2017. Deep learning for healthcare: review, opportunities and challenges. *Briefings in bioinformatics* (2017).
- [21] Phuoc Nguyen, Truyen Tran, Nilmini Wickramasinghe, and Svetha Venkatesh. 2017. Deepr: A Convolutional Net for Medical Records. *IEEE journal of biomedical and health informatics* 21, 1 (2017), 22–30.
- [22] Trang Pham, Truyen Tran, Dinh Phung, and Svetha Venkatesh. 2016. Deepcare: A deep dynamic memory model for predictive medicine. In Pacific-Asia Conference

on Knowledge Discovery and Data Mining. Springer, 30-41.

- [23] Sanjay Purushotham, Chuizheng Meng, Zhengping Che, and Yan Liu. 2017. Benchmark of Deep Learning Models on Large Healthcare MIMIC Datasets. arXiv preprint arXiv:1710.08531 (2017).
- [24] Alvin Rajkomar, Eyal Oren, Kai Chen, Andrew M Dai, Nissan Hajaj, Peter J Liu, Xiaobing Liu, Mimi Sun, Patrik Sundberg, Hector Yee, et al. 2018. Scalable and accurate deep learning for electronic health records. arXiv preprint arXiv:1801.07860 (2018).
- [25] Narges Razavian, Jake Marcus, and David Sontag. 2016. Multi-task prediction of disease onsets from longitudinal laboratory tests. In *Machine Learning for Healthcare Conference*. 73–100.
- [26] Sebastian Schneeweiss, John D Seeger, Malcolm Maclure, Philip S Wang, Jerry Avorn, and Robert J Glynn. 2001. Performance of comorbidity scores to control for confounding in epidemiologic studies using claims data. *American journal of epidemiology* 154, 9 (2001), 854–864.
- [27] Mike Schuster and Kuldip K Paliwal. 1997. Bidirectional recurrent neural networks. IEEE Transactions on Signal Processing 45, 11 (1997), 2673–2681.
- [28] Ying Sha and May D Wang. 2017. Interpretable Predictions of Clinical Outcomes with An Attention-based Recurrent Neural Network. In Proceedings of the 8th ACM International Conference on Bioinformatics, Computational Biology, and Health Informatics. ACM, 233–240.
- [29] Donald H Taylor Jr, Truls Østbye, Kenneth M Langa, David Weir, and Brenda L Plassman. 2009. The accuracy of Medicare claims as an epidemiological tool: the case of dementia revisited. *Journal of Alzheimer's Disease* 17, 4 (2009), 807–815.
- [30] Ashish Vaswani, Noam Shazeer, Niki Parmar, Jakob Uszkoreit, Llion Jones, Aidan N Gomez, Łukasz Kaiser, and Illia Polosukhin. 2017. Attention is all you need. In Advances in Neural Information Processing Systems. 6000–6010.
- [31] Joan L Warren, Linda C Harlan, Angela Fahey, Beth A Virnig, Jean L Freeman, Carrie N Klabunde, Gregory S Cooper, and Kevin B Knopf. 2002. Utility of the SEER-Medicare data to identify chemotherapy use. *Medical care* 40, 8 (2002), IV-55.
- [32] Pranjul Yadav, Michael Steinbach, Vipin Kumar, and Gyorgy Simon. 2017. Mining Electronic Health Records: A Survey. arXiv preprint arXiv:1702.03222 (2017).
- [33] Yan Yan, Elena Birman-Deych, Martha J Radford, David S Nilasena, and Brian F Gage. 2005. Comorbidity indices to predict mortality from Medicare data: results from the national registry of atrial fibrillation. *Medical care* 43, 11 (2005), 1073– 1077.
- [34] Zichao Yang, Diyi Yang, Chris Dyer, Xiaodong He, Alex Smola, and Eduard Hovy. 2016. Hierarchical attention networks for document classification. In Proceedings of the 2016 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies. 1480–1489.
- [35] Kaiping Zheng, Wei Wang, Jinyang Gao, Kee Yuan Ngiam, Beng Chin Ooi, and Wei Luen James Yip. 2017. Capturing Feature-Level Irregularity in Disease Progression Modeling. In Proceedings of the 2017 ACM on Conference on Information and Knowledge Management. ACM, 1579–1588.