

Dynamic Spatial-Temporal Indoor Environmental Satisfaction Prediction Using Graph

Embeddings: A Case Study on SDE4

Mahmoud Mohamed Abdelrahman

Department of Building, School of Design and Environment, National University of Singapore,
4 Architectural Drive, Singapore.

15 April 2020

References

- [1] H. Zhang, E. Arens, C. Huizenga, and T. Han, "Indoor Environmental Quality (IEQ) Title Thermal sensation and comfort models for non-uniform and transient environments: Part III: whole-body sensation and comfort Publication Date Thermal sensation and comfort models for non-uniform and transient enviro," 2009.
- [2] I. Asadi, N. Mahyuddin, and P. Shafigh, "A review on indoor environmental quality (IEQ) and energy consumption in building based on occupant behavior," *Facilities*, vol. 35, no. 11–12, pp. 684–695, 2017, doi: 10.1108/F-06-2016-0062.
- [3] S. Vilcekova, L. Meciariova, E. K. Burdova, J. Katunská, D. Kosicanova, and S. Doroudiani, "Indoor environmental quality of classrooms and occupants' comfort in a special education school in Slovak Republic," *Build. Environ.*, vol. 120, pp. 29–40, 2017, doi: 10.1016/j.buildenv.2017.05.001.
- [4] S. K. Wong, L. Wai-Chung Lai, D. C. W. Ho, K. W. Chau, C. Lo-Kuen Lam, and C. Hung-Fai Ng, "Sick building syndrome and perceived indoor environmental quality: A survey of apartment buildings in Hong Kong," *Habitat Int.*, vol. 33, no. 4, pp. 463–471, 2009, doi: 10.1016/j.habitatint.2009.03.001.
- [5] K. Chau, C. Wing, S. Wong, C. Lam, C. Ng, and C. Ng, "Sick building syndrome and perceived indoor environmental quality: A survey of apartment buildings in Hong Kong," *Habitat Int.*, 2015.
- [6] Z. Gou and S. S. Y. Lau, "A survey of sick building syndrome: Workplace design elements and perceived indoor environmental quality," in *10th International Conference on Healthy Buildings 2012*, 2012, vol. 1, pp. 658–663.
- [7] I. Syazwan Aizat, J. Juliana, O. Norhafizalina, Z. a Azman, and J. Kamaruzaman, "Indoor Air Quality and Sick Building Syndrome in Malaysian Buildings," *Glob. J. Health Sci.*, vol. 1, no. 2, pp. 126–135, 2009.
- [8] A. P. Jones, "Indoor air quality and health," *Atmos. Environ.*, vol. 33, pp. 4535–4564, 1999.
- [9] M. Qi, X. Li, E. Zhu, and Y. Shi, "Evaluation of perceived indoor environmental quality of five-star hotels in China: An application of online review analysis," *Build. Environ.*, vol. 111, pp. 1–9, 2017, doi: 10.1016/j.buildenv.2016.09.027.
- [10] D. Moschandreas, R. N.-I. J. of, and undefined 2008, "Do certified sustainable buildings perform better than similar conventional buildings?," *inderscienceonline.com*.
- [11] S. Altomonte, S. Schiavon, M. G. Kent, and G. Brager, "Indoor environmental quality and occupant satisfaction in green-certified buildings," *Build. Res. Inf.*, vol. 47, no. 3, pp. 255–274, Apr. 2019, doi: 10.1080/09613218.2018.1383715.

- [12] A. Gadotti, R. A.-9th W. C. M. C. Relevant, and undefined 2016, "A survey of evaluation methods used for holistic comfort assessment."
- [13] H. Tang, Y. Ding, and B. Singer, "Interactions and comprehensive effect of indoor environmental quality factors on occupant satisfaction," *Build. Environ.*, vol. 167, 2020, doi: 10.1016/j.buildenv.2019.106462.
- [14] D. Heinzerling, S. Schiavon, T. Webster, and E. Arens, "Indoor environmental quality assessment models: A literature review and a proposed weighting and classification scheme," *Build. Environ.*, vol. 70, pp. 210–222, 2013, doi: 10.1016/j.buildenv.2013.08.027.
- [15] M. Ncube and S. Riffat, "Developing an indoor environment quality tool for assessment of mechanically ventilated office buildings in the UK - A preliminary study," *Build. Environ.*, vol. 53, pp. 26–33, Jul. 2012, doi: 10.1016/j.buildenv.2012.01.003.
- [16] B. Cao, Q. Ouyang, Y. Zhu, L. Huang, H. Hu, and G. Deng, "Development of a multivariate regression model for overall satisfaction in public buildings based on field studies in Beijing and Shanghai," *Build. Environ.*, vol. 47, no. 1, pp. 394–399, Jan. 2012, doi: 10.1016/j.buildenv.2011.06.022.
- [17] C. M. Chiang and C. M. Lai, "A study on the comprehensive indicator of indoor environment assessment for occupants' health in Taiwan," *Build. Environ.*, vol. 37, no. 4, pp. 387–392, Apr. 2002, doi: 10.1016/S0360-1323(01)00034-8.
- [18] C. M. Chiang, P. C. Chou, C. M. Lai, and Y. Y. Li, "A methodology to assess the indoor environment in care centers for senior citizens," *Build. Environ.*, vol. 36, no. 4, pp. 561–568, May 2001, doi: 10.1016/S0360-1323(00)00024-X.
- [19] L. T. Wong, K. W. Mui, and P. S. Hui, "A multivariate-logistic model for acceptance of indoor environmental quality (IEQ) in offices," *Build. Environ.*, vol. 43, no. 1, pp. 1–6, Jan. 2008, doi: 10.1016/j.buildenv.2007.01.001.
- [20] A. C. K. Lai, K. W. Mui, L. T. Wong, and L. Y. Law, "An evaluation model for indoor environmental quality (IEQ) acceptance in residential buildings," *Energy Build.*, vol. 41, no. 9, pp. 930–936, Sep. 2009, doi: 10.1016/j.enbuild.2009.03.016.
- [21] C. A. Roulet *et al.*, "ORME: A multicriteria rating methodology for buildings," *Build. Environ.*, vol. 37, no. 6, pp. 579–586, Jun. 2002, doi: 10.1016/S0360-1323(02)00005-7.
- [22] K. W. Mui and W. T. Chan, "A new indoor environmental quality equation for air-conditioned buildings," *Archit. Sci. Rev.*, vol. 48, no. 1, pp. 41–46, 2005, doi: 10.3763/asre.2005.4806.
- [23] R. Cohen, M. Standeven, B. Bordass, and A. Leaman, "Assessing building performance in use 1: The Probe process," *Build. Res. Inf.*, vol. 29, no. 2, pp. 85–102, 2001, doi: 10.1080/09613210010008018.
- [24] "Occupant Indoor Environmental Quality Survey and Building Benchmarking." [Online]. Available: <https://cbe.berkeley.edu/research/occupant-survey-and-building-benchmarking/>. [Accessed: 02-Feb-2020].
- [25] T. Parkinson, A. Parkinson, and R. de Dear, "Continuous IEQ monitoring system: Performance specifications and thermal comfort classification," *Build. Environ.*, vol. 149, no. February, pp. 241–252, 2019, doi: 10.1016/j.buildenv.2018.12.016.
- [26] P. Jayathissa, M. Quintana, T. Sood, N. Nazarian, and C. Miller, "Is your clock-face cozie? A smartwatch methodology for the in-situ collection of occupant comfort data," in *Journal of Physics: Conference Series*, 2019, vol. 1343, no. 1, doi: 10.1088/1742-6596/1343/1/012145.

- [27] J. F. Nicol and M. Wilson, "A critique of European Standard EN 15251: Strengths, weaknesses and lessons for future standards," *Build. Res. Inf.*, vol. 39, no. 2, pp. 183–193, Mar. 2011, doi: 10.1080/09613218.2011.556824.
- [28] S. R. Porter, M. E. Whitcomb, and W. H. Weitzer, "Multiple surveys of students and survey fatigue," *New Dir. Institutional Res.*, vol. 2004, no. 121, pp. 63–73, 2004, doi: 10.1002/ir.101.
- [29] C. Benton, F. Bauman, and U. Fountain, M., "A Field Measurement System for the Study of Thermal Comfort," *ASHRAE Trans.*, vol. 96, no. 1, pp. 623–633, 1990.
- [30] J. H. Choi, V. Loftness, and A. Aziz, "Post-occupancy evaluation of 20 office buildings as basis for future IEQ standards and guidelines," in *Energy and Buildings*, 2012, vol. 46, pp. 167–175, doi: 10.1016/j.enbuild.2011.08.009.
- [31] P. Jayathissa, M. Quintana, M. Abdelrahman, and C. Miller, "Indoor Comfort Personalities: Scalable Occupant Preference Capture Using Micro Ecological Momentary Assessments," *Preprint*, no. January, 2020, doi: 10.13140/RG.2.2.24901.60644.
- [32] O. US EPA, "Indoor Air Quality (IAQ)."
- [33] J. S. H. Hyweldaviesb, R. Owens, and B. Hunn, "ASHRAE'S NEW PERFORMANCE MEASUREMENT PROTOCOLS FOR COMMERCIAL BUILDINGS."
- [34] C. de N.-T. Environment, L. and Acoustics, undefined CEN, and undefined 2007, "EN 15251: indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal."
- [35] T. Parkinson, A. Parkinson, and R. de Dear, "Continuous IEQ monitoring system: Context and development," *Build. Environ.*, vol. 149, no. February, pp. 15–25, 2019, doi: 10.1016/j.buildenv.2018.12.010.
- [36] T. Parkinson, A. Parkinson, and R. de Dear, "Continuous IEQ monitoring system: Performance specifications and thermal comfort classification," *Build. Environ.*, vol. 149, pp. 241–252, Feb. 2019, doi: 10.1016/j.buildenv.2018.12.016.
- [37] H. Kim, "Methodology for Rating a Building's Overall Performance based on the ASHRAE/CIBSE/USGBC Performance Measurement Protocols for Commercial Buildings," *J. Chem. Inf. Model.*, vol. 53, no. 9, pp. 1689–1699, 2013, doi: 10.1017/CBO9781107415324.004.
- [38] T. Webster, F. Bauman, G. Anwar, T. Webster, and F. Bauman, "UC Berkeley HVAC Systems Title CBE Portable Wireless Monitoring System (PWMS): UFAD Systems Commissioning Cart Design Specifications and Operating Manual Publication Date CBE PORTABLE WIRELESS MONITORING SYSTEM (PWMS): UFAD SYSTEMS COMMISSIONING CART DESIGN SPECIFICATIONS AND OPERATING MANUAL," 2012.
- [39] J. Y. Lee, P. Wargocki, Y. H. Chan, L. Chen, and K. W. Tham, "How does indoor environmental quality in green refurbished office buildings compare with the one in new certified buildings?," *Build. Environ.*, vol. 171, no. October 2019, p. 106677, 2020, doi: 10.1016/j.buildenv.2020.106677.
- [40] K. W. Tham, P. Wargocki, and Y. F. Tan, "Indoor environmental quality, occupant perception, prevalence of sick building syndrome symptoms, and sick leave in a Green Mark Platinum-rated versus a non-Green Mark-rated building: A case study," *Sci. Technol. Built Environ.*, vol. 21, no. 1, pp. 35–44, 2015, doi: 10.1080/10789669.2014.967164.
- [41] A. Mahdavi and M. Taheri, "An ontology for building monitoring," *J. Build. Perform. Simul.*,

vol. 10, no. 5–6, pp. 499–508, Nov. 2017, doi: 10.1080/19401493.2016.1243730.

- [42] Y. Goldberg and O. Levy, “word2vec Explained: deriving Mikolov et al.’s negative-sampling word-embedding method,” Feb. 2014.
- [43] P. Ristoski and H. Paulheim, “RDF2Vec: RDF graph embeddings for data mining,” in *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 2016, vol. 9981 LNCS, pp. 498–514, doi: 10.1007/978-3-319-46523-4_30.
- [44] T. Trouillon and M. Nickel, “Complex and Holographic Embeddings of Knowledge Graphs: A Comparison,” Jul. 2017.
- [45] H. Cai, V. W. Zheng, and K. Chen-Chuan Chang, “A Comprehensive Survey of Graph Embedding: Problems, Techniques and Applications,” 2017.
- [46] A. Grover, J. L.-P. of the 22nd A. SIGKDD, and undefined 2016, “node2vec: Scalable feature learning for networks,” *dl.acm.org*.
- [47] D. Xu, W. Cheng, D. Luo, X. Liu, and X. Zhang, “Spatio-Temporal Attentive RNN for Node Classification in Temporal Attributed Graphs,” 2019.
- [48] J. Zhang, X. Shi, J. Xie, H. Ma, I. King, and D. Y. Yeung, “GaAN: Gated attention networks for learning on large and spatiotemporal graphs,” *34th Conf. Uncertain. Artif. Intell. 2018, UAI 2018*, vol. 1, pp. 339–349, 2018.
- [49] F. Wilcoxon, “Individual Comparisons by Ranking Methods,” 1945.
- [50] F. C. Lam and M. T. Longnecker, “A Modified Wilcoxon Rank Sum Test for Paired Data,” *Biometrika*, vol. 70, no. 2, p. 510, 1983, doi: 10.2307/2335570.
- [51] I. C. Anaene Oyeka and G. U. Ebu, “Modified Wilcoxon Signed-Rank Test,” *Open J. Stat.*, vol. 02, no. 02, pp. 172–176, 2012, doi: 10.4236/ojs.2012.22019.
- [52] S. Daya, “Paired t-test,” *Evidence-based Obstet. Gynecol.*, vol. 5, no. 3, pp. 105–106, 2003, doi: 10.1016/j.ebobgyn.2003.09.001.
- [53] M Stone, “Cross-validatory Choice and Assessment of Statistical Predictions,” *J. R. Stat. Soc. Ser. B*, vol. 36, no. 2, pp. 111–147, 1974.
- [54] C. Geuzaine and J. F. Remacle, “Gmsh: A 3-D finite element mesh generator with built-in pre- and post-processing facilities,” *Int. J. Numer. Methods Eng.*, vol. 79, no. 11, pp. 1309–1331, 2009, doi: 10.1002/nme.2579.
- [55] T. G. Dietterich, “Approximate Statistical Tests for Comparing Supervised Classification Learning Algorithms,” *Neural Comput.*, vol. 10, no. 7, pp. 1895–1924, 1998.
- [56] B. Perozzi, R. Al-Rfou, and S. Skiena, “DeepWalk: Online learning of social representations,” *Proc. ACM SIGKDD Int. Conf. Knowl. Discov. Data Min.*, pp. 701–710, 2014, doi: 10.1145/2623330.2623732.