Copula 熵的多学科应用

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Contents

Copula 熵

Jian Ma and Zengqi Sun. "Mutual Information Is Copula Entropy". In: *Tsinghua Science & Technology* 16.1 (2011). See also arXiv preprint arXiv:0808.0845 (2008), pp. 51–54

$$H_c(\mathbf{x}) = -\int_{\mathbf{u}} c(\mathbf{u}) \log c(\mathbf{u}) d\mathbf{u} \tag{1}$$

综述论文

马健. “Copula 熵：理论和应用”. In: *ChinaXiv:202105.00070* (2021)

摘要

统计独立性是统计学和机器学习领域的基础性概念，如何表示和度量统计独立性是该领域的基本问题。Copula 理论提供了统计相关关系表示的理论工具，而 Copula 熵理论则给出了度量统计独立性的概念工具。本文综述了 Copula 熵的理论和应用，概述了其基本概念定义、定理和性质，以及估计方法。介绍了 Copula 熵研究的最新进展，包括其在统计学的九个基本问题（结构学习、关联发现、变量选择、因果发现、系统辨识、时延估计、域自适应、正态性检验和双样本检验等）上的理论应用。讨论了前四个理论应用之间的关系，以及其对应的深层次的相关性和因果性概念之间的联系，并将 Copula 熵的（条件）独立性度量框架与基于核函数和距离相关的同类框架进行了理论对比，又通过仿真和实际数据实验评估验证了 Copula 熵的实际优越性。简述了 Copula 熵在理论物理学、理论化学、化学信息学、材料学、水文学、气候学、气象学、环境学、生态学、动物形态学、农学、认知神经学、运动神经学、计算神经学、心理学、系统生物学、生物信息学、临床诊断学、老年医学、精神病学、公共卫生学、经济学、管理学、社会学、教育学、计算语言学、新闻传播学、法学、政治学、军事学、情报学，以及能源工程、食品工程、土木建筑、交通运输、制造工程、可靠性工程、化学工程、航空航天、车辆工程、电子工程、通信工程、高性能计算、测绘遥感和金融工程等领域的实际应用。

理论物理学

- 相关粒子系统
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- 变构效应研究
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    - 丙氨酸二肽的 C 端和 N 端

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化学信息学

- 分子设计
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材料学

- 耐热型含能材料分子设计
  - 含能材料热分解温度预测[4]
    - 含能材料化合物分子结构和量子化学性质数据集

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水文学 I

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水文学 IV

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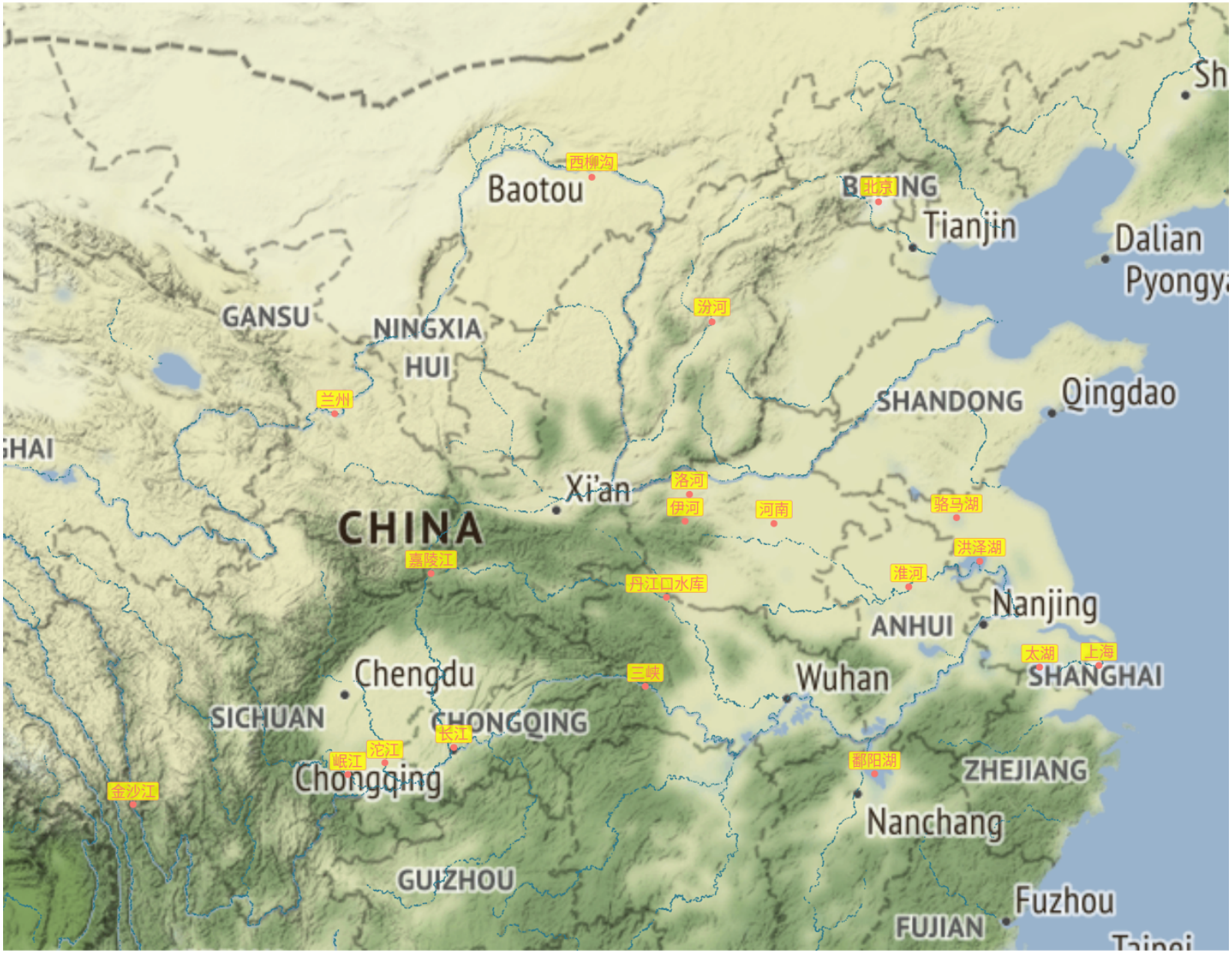
水文学-国内应用地图


Baotou
西柳沟
Tianjin
北京
Dalian
GANSU
NINGXIA
HUI
兰州
汾河
SHANDONG
Qingdao
Xi'an
洛河
伊河
河南
CHINA
骆马湖
洪泽湖
嘉陵江
丹江口水库
淮河
Nanjing
ANHUI
Chengdu
三峡
Wuhan
太湖
上海
SHANGHAI
SICHUAN
CHONGQING
长江
沱江
岷江
Chongqing
金沙江
鄱阳湖
ZHEJIANG
Nanchang
GUIZHOU
Fuzhou
FUJIAN

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    - 欧洲 25 座城市气温和降水数据

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    - UCI 鲍鱼数据集

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心理学

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医学 I

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    - 美国 Health Facts 糖尿病救治网络数据
  - 癌症预后[48]
    - UCI 肺癌数据
  - 乳腺癌预后[49]
    - SEER 数据库乳腺癌临床数据
  - 白内障术后角膜水肿风险预测[50]
    - 临床白内障超声乳化手术患者数据
  - 主动脉瓣置换手术射血分数分析[51]
    - 临床主动脉瓣置换手术前后射血分数数据

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医学 II

- 认知医学
  - 认知能力评估 / 痴呆症筛查[52]
    - 北京和天津痴呆症老年人数据
- 运动医学
  - 运动能力评估 / 跌倒风险预测[53]
    - 天津和成都跌倒人群老年人数据
  - 重复经颅磁刺激对帕金森病改善神经机制分析[54]
    - 帕金森患者经颅磁刺激前后 EEG 数据
- 精神病学
  - 抑郁症患者识别[55]
    - 江苏常州抑郁症青少年患者 EEG 数据

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公共卫生学

- 新冠肺炎流行病 (COVID19)
  - 发热症状疑似病人筛查诊断[56]
    - 新冠临床数据
- 高血压
  - 高血压关联基因研究[57]
    - ELEMENT 数据集

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- 经济学
  - 扶贫政策效果评估，用于政策目标人口鉴别[58]
    - 2018 年政府贫困家庭状况普查数据（四川省）
  - 议价机制中的互惠行为和时间效应[59]
    - eBay 的 Best Offer 平台数据
  - 产业链内部相关性分析[60]
    - 国内畜禽养殖产业链主要上市企业股票价格数据
  - 投资者情绪分析
    - 中国新能源汽车上市公司的百度搜索数据

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- 管理学
  - 商品期货价格预测[61]
    - 国家统计局猪肉价格数据和大连商品交易所大豆期货价格数据
  - 单周期库存管理[62]
    - 大众朗逸汽车销售数据
- 社会学
  - 分析教育、职业和收入上的性别不平等问题[63]
    - 美国国家成年人收入调查数据（1994 年）
- 教育学
  - 高中数学成绩与其他学科成绩相关性分析[64]
    - 某市 2013 级理科学生高一、高二期末成绩和高三两次模考成绩

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- 计算语言学
  - 城市热线派单系统知识图谱构建[65]
    - 济南市民热线数据
- 新闻传播学
  - 上海新冠疫情下的公众情绪变化[66]
    - 微博平台“上海疫情”主题数据
- 法学
  - 社区属性与社区犯罪关系分析[67]
    - 美国社区与犯罪数据集

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- 政治学
  - 分析政权领导力因素和政权危机之间关系[68]
    - 雪城大学莫伊尼汉全球事务研究所国际政治领导力数据集
- 军事学
  - 目标意图识别[69]
    - 空中飞行目标示例
- 情报学
  - 颠覆性技术科学-技术-产业互动模式分析[70]
    - 再生医学（干细胞）和白血病治疗相关资料数据

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- 能源工程
  - 能源网络管理，研究天气因素与能源网络的耦合[71]
    - 北方某地区能源系统运行数据
  - 光伏发电功率预测[72]
    - 澳大利亚 Yulara 地区光伏电站数据
  - 风电机组工况划分[73]
    - 广东某海上风电场 SCADA 数据
  - 电力负荷预测[74]
    - 摩洛哥缔头万城电力消费数据
  - 风光储协同规划[75]
    - 某工业园区风光火储联合发电系统

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- 能源工程
  - 电网频率稳定性预测[76]
    - 贵州电网数据
  - 用户线损贡献分析[77]
    - 辽宁电网数据
  - 电价预测[78]
    - 2017 年美国 PJM 电力市场电价数据
  - 锂电池容量估计[79]
    - NASA 锂电池退化数据
  - 电力系统宽频振荡影响因素和传播路径分析[80]

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- 食品工程
  - 葡萄酒质量与理化成分关系分析[81]
    - 葡萄牙绿酒葡萄酒理化成分与质量评价数据
- 土木建筑
  - 建筑能源系统节能技术[82]
    - 大连某教学楼供热监测数据
  - 工程变形监测[83]
    - 某隧道工程施工段围堰监测数据

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工程学 IV

- 交通工程
  - 大件货物运输方案制定[84]
    - 大件货物运输案例数据
  - 航空和高铁票价影响因素分析[85]
    - 京沪高铁和航空票价数据
  - 城市轨道交通客流分析和预测[86]
    - 苏州市轨道交通系统客流时序数据

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工程学 V

- 制造工程
  - 制造质量管理，研究优化制造过程参数，预测产品质量[87]
    - 富士康生产线制造过程数据
  - 装配质量控制[88]
    - 江淮汽车某型汽油发动机关键零部件装配过程数据
  - 工业过程故障监测[89]
    - 鞍钢热轧带钢工艺过程数据
  - 钢铁工艺过程碳排放预测[90]
    - 某钢铁厂烧结过程数据
  - 液晶显示器质量预测[91]
    - 薄膜晶体管液晶显示器生产数据

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工程学 VI

- 可靠性工程
  - 系统退化过程建模[92]
    - 微波电子组件数据
  - 风电机组健康状态评估[93]
    - 内蒙古某风场的风机 SCADA 数据
- 化学工程
  - 化学过程故障监测和诊断[94]
    - Tennessee Eastman 过程数据
  - 化工过程因果网络构建[95]
    - 连续搅拌槽式反应器数据和 Tennessee Eastman 过程数据

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- 航空航天
  - 飞行器总体参数分析和优化[96]
    - 美国喷气战斗机总体设计参数数据
  - 卫星在轨健康状态监测[97]
    - 真实卫星遥测数据
    - NASA 公开的 SMAP 和 MSL 数据集
  - 涡扇发动机健康状态监测[98]
    - NASA 格林中心引擎性能退化模拟数据
  - 机场间航班延误因果关系分析[99]
- 车辆工程
  - CAN 总线入侵检测[100]
    - 现代汽车 YF 索纳塔 CAN 数据

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工程学 VIII

- 电子工程
  - 集成电路封装材料物理性能预测[101]
    - CuNi 合金体系材料强度和稳定性计算数据
- 通信工程
  - 通讯网络加密技术研究[102]
  - 6G 网络语义通信技术研究[103]
    - ImageNet-1k 数据集和 VOC2012 数据集
- 高性能计算
  - 高性能计算能源效率优化[104]
- 测绘遥感
  - 高光谱遥感数据分析[105]
    - 美国印第安纳 Indian Pine 高光谱遥感数据

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金融工程 I

- 投资组合优化
  - 股票资产相关性网络分析[106]
    - 沪深 A 股指数、沪深 300 指数数据
  - ST 股票分类[107]
    - A 股市场 ST 股票数据
- 金融问题建模
  - Copula 函数模型选择[108]
    - 标普 500 指数数据
- 股票相关性建模
  - R-vine copula 结构建模[109]
    - 德国 DAX 指数数据
    - 中证五大行业指数数据

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金融工程 II

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    - 国际主要金融指数、能源期货价格和农产品价格数据

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