基于位置服务中的隐私保护

孟小峰

近年来随着传感器和无线移动设备的飞速发展,随时随地获得个人位置成为可能。一方面,促进了新一类应用程序——基于位置服务的出现与发展;另一方面,个人隐私保护问题引起人们的广泛关注。由于移动环境中位置信息的特殊性,造成无法直接利用现有的关系数据库隐私保护技术。本文分析了位置隐私保护中存在的挑战问题,从系统结构、位置匿名技术和查询处理技术三方面归纳总结了现有的研究工作,并指出了未来的研究方向。





基于位置服务中的隐私保护

孟小峰 中国人民大学信息学院

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报告大纲

- □隐私保护问题及意义
- □隐私保护系统结构
- □隐私保护研究内容
- □隐私保护面临挑战
- □总结



基于位置服务(LBS)

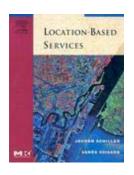




基于位置服务

☐ Services that integrate a mobile device's location or position with other information so as to provide added value to a user

(基于位置的信息服务是将一个移动设备的 **位置**或者**坐标**和其他信息整合起来,为 用户提供增值服务)



J. Schiller, Jochen, A. Voisard, Location-based Services, Elsevier Science Ltd, April 2004



基于位置服务

□ 美国著名市场研究公司ABI research日前发布预测



ABIresearch About ▼ Research ▼	Consulting ▼ Media ▼ Events Careers Contact ▼
technology market melligence Fixed Mobile - Enterprise Consumer - Infrestructure D.	evices - Serricanductors - Object Networks - Digital H
Global LBS Revenues to Reach \$2.6 Billion in	1 2009
Location Based Services Research Service Location Based Services Market	Data
	Contact: Christine Gallen
	Contact PR www.abinesearch.com
LONDON - September 3, 2009	WWW.DDT-CCCCT.CO.TT
ABI Research expects Location Based Services revenues to grow	at 156% from \$1.7 billion in 2008 to \$2.6 billion in
2009. By 2014 global LBS revenues will have surpassed \$14 billi	on.
*One of the main drivers of the strong growth in LBS is the po	pularity of an impressive number of off-deck LBS
applications available for a one-off fee on smartphone platform	s," says ABI Research practice director Dominique
Bonte. "Apple" s Phone is leading the way, followed by Blackb	
to developers' creativity in using location for functions such a	
blogging and augmented reality. Combined with the astonishing	
touch screen smartphones, this will continue to constitute the li	feblood of LBS in the coming years."
A More Open Strategy	
Many carriers in both the US and Europe are waking up to this	reality by gradually adopting a more open LBS
strategy with Verizon increasing the number of unlocked GPS $\boldsymbol{\rho}$	
software vendor Wayfinder. Both carriers are also making their	
carriers such as Sprint have opted to partner with location aggr	egators as a way to play a role in the LBS ecosystem.

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LBS应用领域

□ 军事和政府产业

■ 全球第一个位置系统GPS,最初主要用于军事和涉及国家重要利益的民用领域

□ 紧急救援服务

- 1996年,联邦通信委员会(FCC)颁布E-911法 规要求移动运营商为手机用户提供紧急救援服务 1999年FCC对E-911法进行修订
- 欧洲于2003年1月1日开始实施"US FCC"标准 ——建议使用E-OTD即"增强型观测时间差"技术

□ 商业公司

■ 定位服务(TAGGING)、追踪服务(TRACKING)、导航服务(TRACING)等







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LBS应用分类

□面向用户 LBS	□Push服务
□面向设备 LBS	□Pull服务

	Push服务	Pull服务
面向用户服务	当你进入某城市时接到欢迎 信息	请求查找最近邻餐馆
面向设备服务	在货物追踪应用中,当货物 运送偏离预计轨道时给与警 报信息	请求查找卡车现在所 在位置

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LBS与隐私

□ 欧洲委员会

Directive 2002/58/EC 条款9

- Location data may only be processed when it is made anonymous OR with the consent of the user for the duration necessary for the provision of a service(位置数据只有在匿名或用户同意的前提下为有效并必要的服务使用).
- □ Vodafone UK制定了一套隐私管理业务 条例(privacy management code of practice),要求所有为Vodafone客户提 供服务的第三方必须遵守

A CONTRACTOR OF THE CONTRACTOR
001,009
Desires 2003/65/C of the European Performent and of the Council of 22 July 2003, concerning the processing of present data and the profession of privacy in the electro- communications settler (Direction on privacy and electronic communications)
Official Insurant 2012, \$1,477,2002,9,4007 - \$007
Divisite 2002/0800 of the European Federates and at the Council of 12 July 2002
concerning the processing of personal data and the processing of privacy in the electronic communications sector Cifective on privacy and electronic communications that is decreased whether work the Colonics Of the Colonics (MCON).
Having regard to the Treaty establishing the Sunness Connecting, and In particular Artists MS thereof. Having regard to the process of time the Connection CE.
Having regard to the contain of the European and Social Committee(II). Having consolate the Committee of the Eastern.
Acting in scordance with the procedure led driver in Article (St. of the Treas(d)). Whereact
(i) Directive 19,144,01 of the European Performent and all the Council of 14 Counties 1995 on this processed on the Additional with respect to the processing of processed datas and on the in- momentation dust thinking the processed of the European Additional Counties and the Additional Counties Additional
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SET to be rect to controlling traditional market structures by providing a converse, global infrastructure for the delivery of a valid is range of viscossic communications services. Adults and other communications services cover the internet agree new possibilities for cover full along which for their parametrists and privace.
(i) in the case of public communications retentin, specific legal, requisitory and technical provisions should be made in order to protest fundamental rights and therefore of material persons and diagetimes interests of single persons, in particular with request to the increasing capacity for automated carrage and processing of data reliability to calculations and cares.
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CDD for electronic communication rector. Decide 934455 applies in period and instant comments protection of fundamental rights and featings, which we not specified converting the positions of this Direction, including the obligations on the constaller and the right or individual, Direction 65/4555 applies on communication reviews.
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LBS中的隐私泄露

- □位置隐私泄露
 - 位置,包括用户过去或现在的位置
- □查询隐私泄露
 - 查询内容,例如查询距离我最近的艾滋 医院

行为模式、兴趣爱好、健康状况和政治倾向等 个人隐私信息

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LBS中隐私保护

- □ 位置隐私保护
 - 避免用户与某一精确位置匹配
- □查询隐私保护
 - 避免用户与某一敏感查询匹配



位置服务 VS 隐私保护





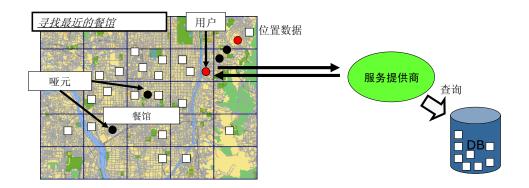
隐私保护的方法

- □ 假位置(Dummy)
- □ 时空匿名(Spatio-temporal Cloaking)
- □ 空间加密(Space Encryption)



隐私保护的基本方法--假位置

□ 通过制造假位置,达到以假乱真的效果

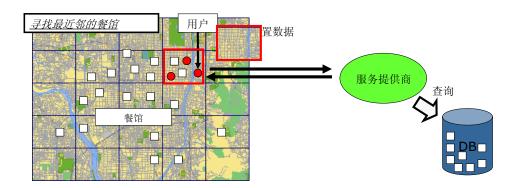


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隐私保护的基本方法--时空匿名

□ 将一个用户的位置通过扩展变成时空区域,达到匿名的 效果

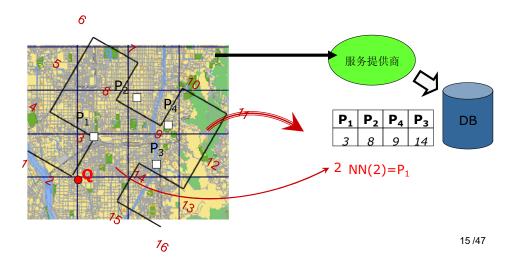


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隐私保护的基本方法一空间加密

□ 通过对位置加密从而达到匿名的效果





感知隐私保护的查询处理

假数据

• 移动对象数据库中的查询处理器无需作任何修改

时空匿名

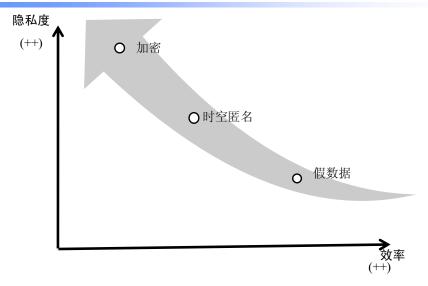
• 设计基于区域位置的查询处理技术;查询结果是一个包含真实结果的超集

空间加密

• 查询方法与使用的加密协议有关



隐私度与效率对比



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存在的挑战



保护隐私与位置服务是一对矛盾



位置匿名的即时性



位置频繁更新以及位置依赖性



隐私需求个性化



报告大纲

- □隐私保护问题及意义
- □隐私保护系统结构
- □隐私保护研究内容
- □隐私保护面临挑战
- □总结

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隐私保护系统结构

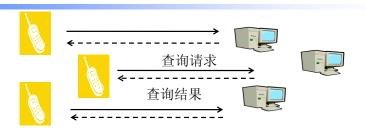




- □ 独立式结构
- □ 中心服务器结构
- □ 分布式结构
- □ 点对点结构



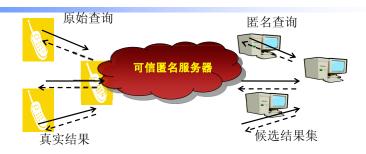
隐私保护系统结构-独立式结构



- □ 优点
 - 结构简单,易于配置
- □ 缺点
 - 增加客户端负担
 - 缺乏全局信息,隐蔽性弱

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‴隐私保护系统结构-中心服务器结构



- □ 优点
 - 具有全局信息,隐私保护效果好
- □ 缺点
 - 可能成为系统瓶颈
 - 唯一攻击点



隐私保护系统结构-主从分布式结构

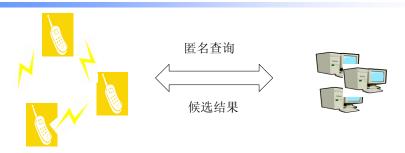


- □ 优点
 - 拥有全局信息,隐私效果好
 - 消除了系统瓶颈
- □ 缺点
 - 网络通讯代价高

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隐私保护系统结构-移动点对点结构



- □ 优点
 - 拥有全局信息,隐私效果好
 - 消除唯一攻击点
- □ 缺点
 - 网络通讯代价高



报告大纲

- □隐私保护问题及意义
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- □隐私保护研究内容
- □隐私保护面临挑战
- □总结

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隐私保护研究内容

- □ 隐私保护方法
 - 位置隐私保护方法
 - 查询隐私保护方法
- □感知隐私的查询处理
 - 基于区域位置的查询处理技术
 - 基于加密位置的查询处理技术



隐私保护模型

隐私保护方法

一位置隐私方法 查询隐私方法 感知隐私的查询处理 基于区域位置

□ 位置 k-匿名

□ 当且仅当一个用户的位置与其他(*k*-1)个用户的位置 无法区别时,称该用户满足*位置k-匿名*





原始查询

位置	查询
(1, 6)	Q_1
(1, 5)	Q_2
(2,9)	Q_3

	匿名位置	查询
	[(1,2)-(5,9)]	Q_1
┨	[(1,2)-(5,9)]	Q_2
l	[(1,2)-(5,9)]	Q_3
•		

匿名后查询

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基于四分树的隐私保护方法 (Quadtree based Cloaking)

隐私保护方法

一**位置隐私方法** 一查询隐私方法

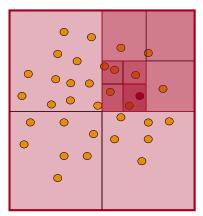
查询隐私方法 感知隐私的查询处理

□ 问题

■ 面对大量移动用户,如何快速 高效的为移动用户寻找匿名集

□ 解决方法

■ 递归式的划分空间,直至在某一子空间内的用户数小于k,则返回其上一级的子空间作为位置匿名区域



K=3

M .Gruteser,D. Grunwald. Anonymous usage of location-based services through spatial and temporal cloaking. Proceedings of the International Conference on Mobile Systems, Applications, and Services (MobiSys'03), Scan Francisco, USA, 2003:163–168.



个性化隐私需求匿名方法 (CliqueCloak)

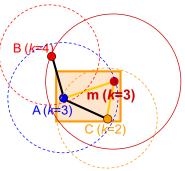
隐私保护方法
- 位置隐私方法
- 查询隐私方法
- 查询隐私方法
- 感知隐私的查询处理
- 基于区域位置

□问题

■ 如何为每一个用户提供满足个性化隐私需求的 匿名

□ 解决方法

■ 利用图模型形式化的定义此问题,并把寻找匿名集转化为在图中寻找k-点团的问题



Gedik B, Liu L. Location privacy in mobile systems: a personalized anonymization model. Proceeding of the International Conference on Distributed Computing Systems(ICDCS'05), Columbus, OH, USA, 2005: 620–629

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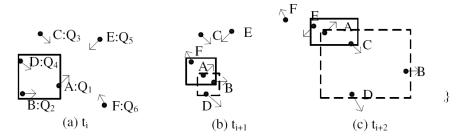
连续查询隐私保护技术

(C.Chow and M. F. Mokbel, 2007) Latroxida

隐私保护方法
— 位置隐私方法
— 查询隐私方法
成知隐私的查询处理

□ 问题

■ 位置服务中现有的隐私保护工作均针对snapshot查询类型



□ 解决方法

■ 连续查询的用户在最初时刻形成的匿名集在其查询有效期内均有 效。

C. Chow and M. F. Mokbel. Enabling privacy continuous queries for revealed user locations. In $Proceedings \ of \ SSTD$, 2007



感知查询差异性的隐私保护 (p-sensitive)

□ 问题

- 位置*k*-匿名只能防止用户与查询间的关联,但不能切断用 户与查询内容的关联
- 缺少语义的匿名,将产生查询隐私泄露的现象

Location	Query	
[(1,2)-(5,9)]	Hospital	
[(1,2)-(5,9)]	Clinic	
[(1,2)-(5,9)]	Hospital	
[(2,5)-(4,7)]	Gas Station	
[(2,5)-(4,7)]	Gas Station	
[(2,5)-(4,7)]	School	

Location	Ouery	
[(1,2)-(4,7)]	** Club A	
[(1,2)-(4,7)]	Gas Station	
[(1,2)-(4,7)]	Gas Station	
[(5,2)-(7,9)]	Restaurant	
[(5,2)-(7,9)]	Clinic	
[(5,2)-(7,9)]	School	

□ 解决方法

- 考虑查询语义
- 一个匿名集中所包含的敏感查询不能超过p%

 $X.Zhen,\,J.\,Xu,\,and\,\,X.\,\,Meng.\,\,A\,Semantic\,\,Privacy-Protection\,\,Model\,\,for\,\,Location-based\,\,Services.\,\,In\,proceeding\,\,of\,\,MDM-PALM,2008$

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感知隐私保护的查询处理

隐私保护方法

一位置隐私方法
一查询隐私方法
整知隐私的查询处理
一基于区域位置

- □ 如何在位置被区域匿名后提供令用户满意的服务
- □ 两种位置数据类型:
 - 公开位置数据. 如加油站、旅馆和警车
 - 隐私位置数据. 如个人位置

查询类型		被查询点	
T. WALL		公开数据	隐私数据
查询点	公开 数据	基于公开数据的公开查询 如:在某电影院200m内所 有餐馆 →	基于隐私数据的公开查询 如:某加油站500米内所 有出租车
	隐私 数据	基于公开数据的隐私查询 如:距离我最近的加油站	基于隐私数据的隐私查询 如: 离我最近的朋友



基于隐私数据的公开查询

隐私保护方法

一位置隐私方法

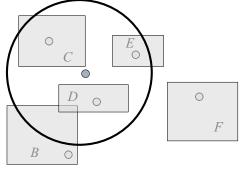
一查询隐私方法

感知隐私的查询处理

基于区域位置

- □ "某加油站500米内所有出租车" ◎→■
- □ 将所有与查询范围相交的匿名区域都作为候选集。

A \circ



查询结果:

 \blacksquare (B, 50%), (C, 90%), (D,1), (E,60%)

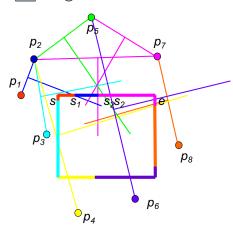
O. Wolfson, P.A. Sistla, S. Chamberlain, and Y. Yesha, Updating and Querying Databases that Track Mobile Units, Distributed and Parallel Databases, vol. 7, no. 3, pp. 257-387, 1999.

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基于公开数据的隐私查询

- □ "距离我最近的加油站"
- □ 查找匿名区域中任意一 个位置的最近邻
 - 查找匿名框所覆盖的 对象
 - 查找基于每一条边上 的任意点的最近邻
 - 二者的并作为最终的 查询结果返回



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报告大纲

- □隐私保护问题及意义
- □隐私保护系统结构
- □隐私保护研究内容
- □隐私保护面临挑战
- □总结

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隐私保护技术面临的问题

- □多技术混合的隐私保护
- □ 移动对象轨迹的隐私保护
- □ 室内位置隐私保护



多技术混合的隐私保护

- □ 问题
 - 加密安全但查询代价高,时 空匿名高效但不够安全
- □ 研究结合加密算法高隐私 保护度,空间匿名算法的 高效率的混合匿名模型和 算法
- □ 研究基于混合匿名的感知 隐私的查询处理算法

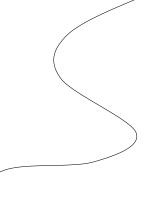


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移动轨迹的隐私保护

- □问题
 - 轨迹发布而产生的隐私泄 露
- □ 研究基于时空匿名的轨迹 匿名模型和算法
- □ 研究在线轨迹匿名模型和 算法





室内位置隐私

□问题

- 室内安装无限传感器收集用 户位置用于安全控制、资源 管理等
- 室内提出的查询多位密度查 询或聚类查询



□ 研究基于室内位置隐私的攻击模型、匿名 模型、匿名算法和查询处理算法

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可能的解决方法





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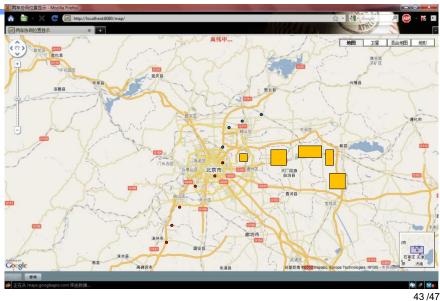


在研课题-隐私保护技术

- □ 国家863计划重点项目
- "普适计算基础软硬件关键技术及系统"项目中" 隐私保护技术"课题
- □ 研究目标
 - 在普适计算以人为中心的理念下,针对个人信息隐私、位置隐私和查询隐私等问题从模型、算法和评价等方面展开研究,开发可配置的分级隐私保护模块,为构建相应示范应用提供支持



在研课题-隐私保护技术





在研课题-隐私保护技术

□ 系统界面





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