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智慧公园建设框架构建研究——以北京海淀公园智慧化改造为例

Research on the Construction Framework of Smart Park: A Case Study of Intelligent Renovation of Beijing Haidian Park

张洋 夏舫 李长霖
ZHANG Yang, XIA Fang, LI Changlin

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张洋 / 男 / 博士 / 上海交通大学设计学院讲师 / 研究方向为智慧园林、城市生物多样性
ZHANG Yang, Ph.D., is a lecturer in the School of Design, Shanghai Jiao Tong University. His research focuses on smart landscape and urban biodiversity.

夏舫 / 女 / 硕士 / 海淀公园管理处主任 / 研究方向为智慧公园、互动景观、公园精细化管理
XIA Fang, Master, is the director at Beijing Haidian Park Administration. Her research focuses on smart park, interactive landscape and park delicacy management.

李长霖 / 男 / 硕士 / 北京甲板智慧科技有限公司首席执行官 / 研究方向为智慧园林
LI Changlin, Master, is the chief executive officer at Beijing Dream Deck Science and Technology Co., LTD.. His research focuses on smart landscape.

摘要：公园是城市绿地系统的重要组成部分，近年来其在城市中的重要性日益凸显。通过分析当前公园存在的管理精细化程度偏低、游客游憩体验不佳等问题，研究探索智慧公园的建设理念和技术框架，并提出其核心框架——智慧综合信息平台、智慧管理系统和智慧服务系统，其中智慧管理系统包括智慧生态监测、智慧管养、能耗管理、智慧安防等，智慧服务系统包括智慧导览、景观互动设施、智慧健身设施、智慧服务设施等方面。以北京海淀公园智慧化改造为例，结合智慧公园核心框架的 3 个层面，探讨智慧化技术在城市公园中的具体实践途径和应用场景，旨在为未来智慧公园的建设提供参考和借鉴。

关键词：风景园林；智慧公园；智慧综合信息平台；智慧管理系统；智慧服务系统

Abstract: Park is essential for urban green space system, and has become increasingly prominent in recent years. This research presented a tactful approach for smart park to illustrate its construction concept and technology framework by analyzing existing problems, such as the low degree of delicacy management and unsatisfactory visitor experience. And this essay proposed its core framework, including smart comprehensive information platform, smart management system and smart service system. The smart management system should include smart ecological monitoring, smart management and maintenance, energy management, smart security, etc.. The smart service system should include smart tour, landscape interactive device, smart fitness facilities, smart service facilities, etc.. Taking Beijing Haidian Park as an example, we implemented some specific applications on urban park with smart technology based on three layers of core framework, to provide insight reference for future urban smart park's construction.

Keywords: landscape architecture; smart park; smart comprehensive information platform; smart management system; smart service system

公园是城市绿地系统的重要组成部分，在维持城市生态环境、塑造城市景观风貌、提供公众休憩空间等方面具有重要作用。近年来中国城市人均公园绿地面积呈现不断增长的趋势，预计 2020 年，人均公园绿地面积将达到 14.6 m^2[1]，其在城市中的重要性也日益凸显。随着 5G、物联网、大数据等新一代信息技术的快速发展，公园的管理和服务需求呈现多元化发展的趋势，传统公园已经越来越难以满足新的需求，并暴露出诸多问题。对于公园而言，“智慧化”是在传统公园模式上的升级，不仅是信息技术发展的必然趋势，也是公园未来建设的重要方向。

1 智慧公园的建设背景

1.1 智慧城市兴起推动智慧公园建设

2009 年，IBM 公司首次提出“智慧城市”的理念，即以物联网为重要基础，赋予各类物品感知功能，使各类物品产生“智慧”，为人所用，实现更全面的物与物、物与人、人与人的互联互通和相互感知，更有效的数据整合，更好的业务协同和更强的创新发展能力的城市[2]。“十二五”以来，中国众多城市将建设智慧城市作为转型发展的战略选择，掀起了智慧城市的建设热潮[3]。截至 2018 年初，中国 95% 的副省级城市、83% 的地级城市，总计超过 500 个

城市均在规划或正在建设智慧城市[4]，并在交通、医疗、能源等领域得到了良好的进展，而智慧公园作为智慧城市重要的子系统（图1），应该为智慧城市提供生态环境、动植物资源、公众游憩行为等方面的专业数据，但目前来看，公园在智慧化方面的建设明显滞后于其他行业，因此，智慧城市的兴起必然会推动智慧公园的建设。

1.2 传统公园在管理和服务方面存在的问题

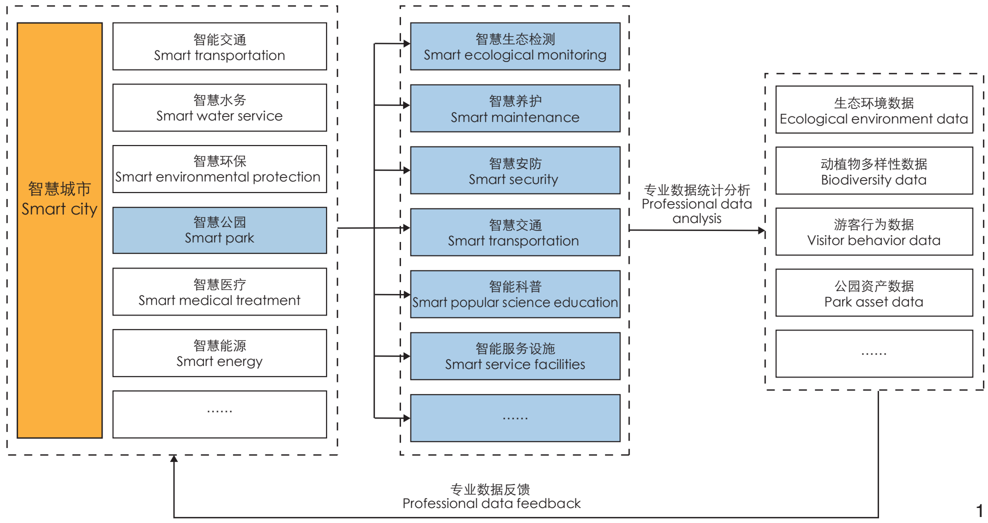
1）以人工为主的粗放式管理模式，精细化程度偏低。传统公园在灌溉、照明、养护、安防等方面的管理，主要依赖于管理者的主观经验，而不是基于客观数据，容易造成管理的实时性和准确性不高。例如公园中植物的日常灌溉主要根据管理者经验，进行定期定量浇灌，往往会忽视土壤的实际干湿度以及不同植物类型的真实需水量，这种模式既不利于植物的生长，也易造成水资源的浪费；而且，传统管理方式中，数据的手工统计方式已不能满足园林绿化日常管理的需求，手工数据查询难度大、更新困难、不便于共享[5]，也无法有效应用；另外，有些公园的管理团队由于管理经验不足，出现管理目标不清晰、任务分工不明确、考核机制不完善等问题，无法实现高效集约化管理。

2）景观服务设施缺乏互动性，游憩体验不佳。传统公园设计偏重于通过景观空间的营建，为游客提供欣赏自然风景的场所，人们的活动也随之被限制在所提供的现有景观空间当中，变成一种相对“静态”的游园方式，无法与公园中的景观要素进行互动，不能获得深度游园的体验。同时，现有服务设施的智能化程度偏低，无法提供人性化的服务。例如公园中大多数的导览系统采用平面标识牌的形式，功能较为单一，只能提供园内道路的基础信息，无法为游客提供实时定位、个性化游园线路规划和公园景点信息介绍等必要的导览服务功能。

1.3 智慧化技术在公园中的应用

在一些发达国家，信息化、集成化管理正应用于公园的设计、建造、运营维护、服务等各个阶段。例如，德国公园绿地管理数据库系统，基于公园自然生态要素的动态发展以及社会功能的弹性更新，通过多层级的数据更新、录入和维护，实现多端口的更新和统计分析功能，直接支持公园自然要素及其设施生态效能管理与保护的决策操作，也进一步作为养护与公共经费投入的决策依据[6]。英国伦敦奥林匹克公园从综合集成系统的开发、免费wifi建设、生物多样性保护、应用程序（App）开发等几个方面，实现公园的智慧化管理服务[7]。

近年来，中国城市公园建设中也开始尝试引入一些智慧化的理念和技术，如北京朝阳公园引进智能停车管理系统，增设收费数据实时核算、实时统计、实时分析、电子支付、线上线下和客户端多渠道交易等功能，提高停车收费过程和财务管理的自动化程度，同时开通线上购票服务，为游客提供了便利。上海植物园于2019年开展安保技防设施升级完善项目（一期），基于数字化技术搭建视频监控系统，并在园区布置覆盖重要景点、设施和建筑的光纤数据传输网络，推进公园的科学化管理[8]。深圳香蜜公园通过空间分析技术、4G移动网络、物联网技术，探索园区视频监控、智能照明、停车管理等多项智能系统的集成管理[9]。总体而言，智慧化技术在中国公园中的应用还处于起步摸索阶段，缺乏整体性和系统性建设。



1 智慧城市与智慧公园关系
The relationship between smart city and smart park

2 智慧公园建设框架

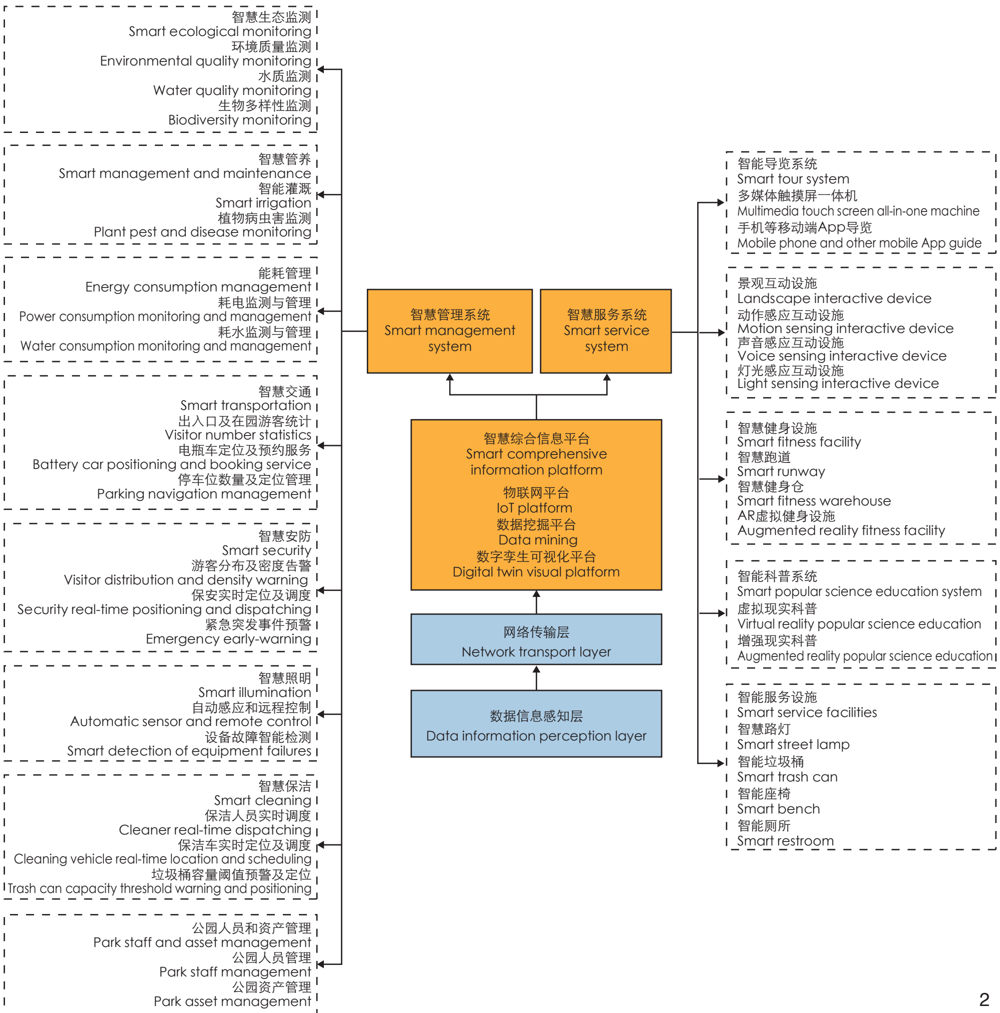
智慧公园是指在公园中运用“互联网+”的思维和物联网、大数据云计算、移动互联网、信息智能终端等新一代信息技术，对服务、管理、养护过程进行数字化表达、智能化控制和管理，实现与游人互感、互知、互动的公园[10]。从公园服务对象层面划分，智慧公园建设的核心构架应该包括1个平台——智慧综合信息平台，2个子系统——智慧管理系统和智慧服务系统（图2）。

2.1 智慧综合信息平台

智慧综合信息平台相当于公园的“大脑”，主要将感知层采集到的海量数据信息，通过网络传输层传输至智慧综合信息平台，进行数据的储存、分析和可视化，将以往分散的各类数据整合到一个“底图”上，打破传统公园中各系统之间的“信息孤岛”和“孤立状态”，实现多源、多尺度、多维度的数据信息资源共享和联动，为公园的智慧管理系统和智慧服务系统提供数据支撑。

2.2 数据驱动的精细化智慧管理系统

智慧管理系统主要面向公园管理者，应用于公园的日常管理和维护，包括智慧生态监测、智慧管养、能耗管理、智慧交通、智能照明、智慧安防、智慧保洁、公园人员和资产管理等方面。智慧管理系统可以使管理



2 智慧公园建设总体框架

The construction framework of smart park

不再拘泥于管理者的主观经验，而是利用大数据信息、智能算法、人工智能等手段，对公园的各项数据进行深层次的动态挖掘处理，自动计算生成智能化的管理策略，为公园的日常管理和突发事件决策提供信息和技术支持，有助于实现管理的精准化、精细化、科学化，以提升公园的生态效益和经济效益。

2.3 以人为本的参与性智慧服务系统

智慧服务系统主要面向游客，应用于游客游憩过程中的服务，包括智能导览、景观互动设施、智慧健身、智能科普、智能服务设施等方面。智慧服务系统可以有效提升公园的服务质量，基于物联网将公园中的物与物、人与物、人与人相互连接，并通过赋予物体“感知”功能，形成交叉性的互感、互知、互动网络，增强游客对公园中景观要素的感知体验，拓展游客对公园物理空间甚至虚拟空间的感知范围，提高游客的参与性和互动性，激发游客潜在的户外活动方式和社交行为。同时，智慧化的服务设施可以为游客提供更加友好、便捷、人性化的服务，提高游客的幸福感和满足感，提升公园的社会效益。

3 北京海淀公园智慧化改造

北京海淀公园建于2003年，位于北京市西北四环万泉河立交桥的西北角，占地面积约34 hm^2，其前身是昔日皇家园林“三山五园”之一的畅春园。与其他建成时间较久的公园一样，面临管理和服务方式提升的问题。公园于2018年11月完成第一轮智慧化改造，2019年9月完成第二轮智慧化改造，经过两轮提升改造，系统性构建了公园的智慧化系统，基本实现公园的自我感知和智慧化控制。

3.1 智慧综合管理平台

公园搭建了智慧综合管理平台——“公园之芯”，其作为全园的“智慧大脑”，可以对采集的环境数据、人流量数据、动植物数据等各类数据进行分析，并反馈给公园中的智慧化设施，如智慧生态监测设施、智慧交通设施、智能灌溉设施等，进行智能管理与联动，而且管理者也可以通过“公园之芯”的可视化管理平台，实时监控公园的动态数据指标，进行公园智慧化设施的远程管理。

3.2 智慧管理系统

公园主要从智慧生态监测、智慧管养、智慧能耗管理、智慧照明管理、智慧交通、智慧安防6个层面，构建了智慧管理系统。

1）智慧生态监测。公园通过在中心草坪等区域安装环境监测设备，在水体的上、中、下游分别安装水质监测设备，实时采集空气质量、温湿度、水位水质等环境数据（图3），形成公园的环境感知网络。例如，环境监测设备可监测各区域空气中$PM_{2.5}$、CO_2、NO_2、负氧离子浓度等数据，自动对空气质量进行综合评价，并通过公众平台、APP、官方网站等途径发布信息，引导游客适宜的活动时间和区域[11]；水质监测设备可监测水体的酸碱度、溶解氧量、浊度等数据，对水质情况进行判断和实时告警，并根据污染程度提供不同的解决措施，当水质浊度较高时，平台会预警并建议开启水循环系统进行水质净化。

2）智慧管养。公园从智能灌溉和病虫害监测2个方面，对植物的生长环境和健康程度进行精准化管理。以往植物灌溉采用自动喷灌结合人工漫灌的方式，改造后的智能灌溉通过将土壤墒情传感器与灌溉系统联动，实时监测土壤干湿度、周边环境小气候等数据，并结合不同植物预先设定的需水指标，自动或远程控制灌溉（图4），而且可以选择夜间灌溉，减少蒸发量的同时也避免影响游

表 1 北京海淀公园传统灌溉方式与智能灌溉对比

Tab. 1 Comparison of traditional irrigation and smart irrigation in Beijing Haidian Park

灌溉方式 Irrigation method	工作模式 Working mode	灌溉时间 Irrigation time	后期维护方式 Post-maintenance mode
人工漫灌 Manual irrigation	1）人工控制灌溉 Manual controlled；2）大量劳动力成本 Significant labour costs	日间 Daytime	人工故障排查 Manual troubleshooting
自动灌溉 Automatic irrigation	1）定时控制灌溉 Timed control；2）人工开关 Manual switched	日间 Daytime	人工故障排查 Manual troubleshooting
智能喷灌 Smart irrigation	1）按需分区灌溉 On-demand zone；2）自动或远程控制灌溉 Programmed or remote-control	日间或夜间 Daytime or nighttime	平台故障报警和精准定位 Platform fault alarm and accurate positioning

表 2 北京海淀公园传统路灯与智慧路灯对比

Tab. 2 Comparison of traditional street lamp and smart street lamp in Beijing Haidian Park

路灯类型 Street lamp type	灯具 Bulb	功率 Power/W	照明方式 Lighting method	主要功能 Main function	管理方式 Management mode	后期维护方式 Post-maintenance mode
原有路灯 Traditional street lamp	高能耗 LED 灯 High-energy consumption LED bulb	45	定时照明 Timing lighting	照明 Illumination	定时器控制 Timer control	人工故障排查 Manual troubleshooting
智能路灯 Smart street lamp	低能耗 LED 节能灯 Low-energy consumption LED bulb	30	按需照明 On-demand lighting	照明、Wifi、环境监测、紧急呼叫、信息发布等 Illumination, Wifi, environmental monitoring, emergency call, broadcast, etc.	自动感应和远程控制 Automatic induced and remote control	平台故障报警和精准定位 Platform fault alarm and accurate positioning

3 智慧生态监测数据
Smart ecological monitoring data

4 智慧灌溉数据
Smart irrigation data

5 智慧能耗管理数据
Smart energy management data

客的日间活动（表 1）。既实现了植物的精细化管养，又提高了水资源的利用率。在病虫害监测方面，主要通过遥感和视频监测技术，结合图像识别，将采样点植物枝叶的变化情况与数据库储存的植物样本进行比对，并配合人工巡检锁定病虫害的发生区域，及时采取病虫害防治措施。

3）智慧能耗管理。主要对公园各种设备设施的耗水、耗电情况进行监测和管理。通过安装智能电表和智能水表，对道路照明、水景、办公区、厕所等区域的能耗数据进行分析和统计，实现能耗的合理调配和故障报警，并通过加装感应设备和网络控制模块，实现园区水、电设备的智能开关和远程控制（图 5）。例如，当用水量监控发现异常，会自动启动故障报警，可快速定位跑水、冒水、滴水、漏水点，节省人工成本。通过监测用电设备的实时功率，可以快速找到照明故障点并及时进行处理，方便后期管理维护。

4）智慧照明管理。普通路灯存在耗电量大、开关控制方式单一、故障排查困难等问题。公园将普通路灯换为低能耗、多途径控制、亮度可调节的智能路灯。智能路灯采用阶梯递减的照明模式，可依据光照强度按需开启照明，借助红外感应装置根据人流密度调节照明亮度，在游客量较大的时段自动启用高亮度照明，在游人量较少的时段自动启用低亮度照明，在没有游客经过时，亮度则自动降为正常亮度的 10%。智能路灯的开关控制方式由原来的定时器控制，变为自动感应光照控制和远程控制（管理平台或手机移动端）结合的方式，方便管理的同时达到节能的目的。另外，当路灯出现故障会自动报警并精准定位，缩短维护人员故障排查周期，节省人工成本（表 2）。

5）智慧交通。公园的智慧交通包括自动驾驶无人巴士和智能停车。无人巴士预设的运行线路在海淀公园西门至儿童乐园之间，巴士借助车身的激光雷达、单目和双目摄像头以及多种传感器，结合 AI 技术可精确识别路况、车辆、周边行人，保障其在不同的路况条件下安全运行。而且巴士的往返频率和时间，可以根据游客情况实时调度。智能停车是利用 GPS 定位技术、视频监控系统，对停车场的使用情况进行实时监控（图 6），具备自动计费收费、剩余停车位数量统计和定位，各时段和历史数据统计对比等功能，实现停车场的无人化管理，提高停车场的使用率。

6 智慧交通数据
Smart traffic data

7 智慧安防数据
Smart security data

6）智慧安防。利用游客手机移动信号捕捉和高清摄像机等监控设备，对公园游客分布和安全进行实时监控（图7），对可能出现的突发事件和安全隐患进行及时预警，加强公园安防的实效性和精准性。例如，当公园某一区域的游客密度超过预设值时，平台会自动预警，管理人员可以及时调度安保人员进行人流疏导，减少和避免危险的发生。

3.3 智慧服务系统

公园主要从智能导览、景观互动设施、智慧跑道、智能科普、智能设施5个层面，构建了智慧服务系统。

1）智能导览。公园在东门和西门分别设置了智能多媒体触摸屏，基于公园的真实信息数据建立互动性的虚拟场景。游客可以通过语音或手势交互的方式，查询公园的精细化地图、主要景点和服务设施介绍等内容，还可以规划个性化的游览线路。同时游客结合手机等移动端设备，可以进行AR虚拟游园导览，通过AR实景导航前往目的地，游览过程中导览系统提供实时定位、路径规划、信息推送等服务，获得定制化的游览体验，实现人—机之间交互性的智慧导览。

2）景观互动设施。公园设计了多种类型的景观互动设施，通过对游客行为的及时反馈，形成人与景观之间有趣的互动，提升场地的活力。雨水花园展示区设置感应交互水景装置（图8），游客可以通过手势动态感应的方式，控制喷泉的高度。随着游客手势高度的上升，喷泉的高度也会随之上升。儿童乐园区的互动自行车装置，根据游客骑行的速度转换为不同频率的电信号，控制景观水景的高度。互动钢琴装置则通过感应设备实时感应游客的位置，当踩踏钢琴键时，对应琴键的灯光就会亮起并发出声音，游客可以以互动的方式演奏音乐。

3）智慧跑道。公园将围绕中心草坪的跑道改造为智慧跑道（图9），在跑道的起点、中间和终点3个位置设置了人脸识别器，实时记录游客跑步的单圈速度、最快速度、累计运动时长、累计运动里程以及卡路里消耗等数据，而且跑道设置了博尔特速度、大学生速度、小学生速度等竞速模式，游客可以根据需要选择不同的竞速模式，跑道两侧的互动灯带会感应位置进行竞速引导，提高跑步的科学性和趣味性。

4）智能科普系统。海淀公园建于“三山五园”之一的畅春园遗址上，在未来空间展厅中，基于虚拟现实（Virtual Reality）技术对畅春园进行虚拟重建，使游客身临其境地沉浸在历史场景中虚拟漫游（图10）。借助古建筑交互式搭建互动体验，科普古建筑榫卯结构的构造原理，并植入畅春园交互式的历史文化信息，增加历史文化科普的丰富性和可读性。后期还会开发基于增强现实（Augmented Reality）技术的植物科普系统，游客使用手机扫描植物标本，三维交互式的观察植物生长的整个过程，提高自然科普的趣味性。

5）智能服务设施。公园利用信息技术对传统服务设施进行迭代更新，通过传感器和其他智能设备，赋予其人性化的服务功能，如智能路灯、智能座椅、智能垃圾桶等。智能路灯除了传统的照明功能外，还集成了环境监测、广播信息发布、高清视频监控、一键报警等多种功能，实现智慧化一灯多用。公园对憩心亭的座椅也进行智慧化改造，可以为游客提供手机无线充电、蓝牙音箱、自动加热等功能（图11），所需的电能来源于太阳能板和电力风车。公园还在主要出入口等位置安置了智能垃圾桶，通过感应装置控制垃圾投放口的自动开闭，干垃圾的自动压缩，当垃圾超出容量阈值时，会远程预警并定位引导管理人员及时清理，后期还会开发AI智能升级，增加语音问答功能协助垃圾分类。

4 结语

智慧公园是未来公园建设和发展的重要方向，针对当前城市公园在建设管理中面临的问题，笔者对智慧公园的建设框架和可能的应用场景进行了初步探索，但应用场景仍是以点状应用为主。未来智慧公园在完善信息化基础设施建设的基础上，应加强数据的集成化，将更多的管理和服务设施纳入公园智慧系统中，实现全面化的智慧管理，提高公园的管理效率和服务质量，建设可持续性的城市公园。而且，智慧公园应该进一步对

8 雨水花园展示区的景观互动喷泉
Landscape interactive fountain in the rainwater garden

9 海淀公园的智慧跑道
Smart runway in Beijing Haidian Park

10 畅春园 VR 虚拟漫游
Virtual reality tour of Garden of Everlasting Spring

11 具有加热功能的海淀公园智能座椅
Smart seat with heating function in Beijing Haidian Park

接和服务于智慧城市建设，打通与其他领域之间的数据应用途径，实现智慧城市各子系统的协同运行，加快智慧城市的建设进程。

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图表来源：
图 1~2 由作者绘制；图 3~11 由北京海淀公园管理处和北京甲板智慧科技有限公司共同提供；表 1~2 由作者绘制。

（编辑 / 逄羽静）

Research on the Construction Framework of Smart Park: A Case Study of Intelligent Renovation of Beijing Haidian Park

Park is essential for urban green space system, as they play an essential role in maintaining the urban ecological environment, shaping the urban landscape and providing public open space. In recent years, the per capita green area of urban parks has been increasing and is expected to reach 14.6 m^2[1] by 2020, which demonstrates an increasingly prominent position of parks in the urban areas. With the rapid development of new-generation information technologies including 5G, internet of things (IoT) and big data, the management and service demands of parks are showing a trend of diversified development, as traditional parks are falling short of meeting new demands with many problems exposed. As far as parks are concerned, “smart” development implies an upgrade of the traditional park concept, which represents not only an inevitable trend of information technology development, but also an important direction for future park construction.

1 Construction Background of Smart Park

1.1 The Emergence of Smart City Drives Smart Park Construction

In 2009, the concept of “smart city” was first proposed by IBM. It is considered to be a city that holds the Internet of Things as an important foundation. It enables the perception function of everything to make them “smart” so they can be widely used to achieve more comprehensive connectivity and mutual perception between objects, between objects and humans, and between humans. This facilitates a city with more effective data integration, better business collaboration, and a stronger capacity for innovative development[2]. Since the 12th five-year plan, many cities in China have taken the construction of smart cities as their strategic choice for transformation and development, which set off the upsurge of smart cities construction[3]. As of the beginning of 2018, a total of more than 500 Chinese cities, including 95% of sub-provincial cities and 83% of prefecture-level cities, were planning or building smart cities[4], and all of those cities have achieved sound progress in fields such as transportation, medical care, and energy. Smart parks, as a major subsystem of smart cities (Fig. 1), are supposed to provide smart cities with professional data on the ecosystem, animal and plant resources, public recreation behavior and so on. However, at present, the construction of smart parks in terms of intelligence is obviously lagging behind the development of other industries. In such sense, the rise of smart cities will definitely drive the construction of smart parks.

1.2 Problems in the Management and Service of Traditional Park

Traditional parks adopt a manual-based extensive management concept with a low degree of refinement. The management of irrigation, lighting, maintenance, security and, other aspects mainly relies on the subjective experience of the managers rather than objective data, which likely to cause latency and low accuracy in management. For example, the regular quantitative irrigation of plants in the parks, is mainly based on the manager's experience and often ignores the actual humidity of the soil and the actual water requirements of different plant types. Such practice is not conducive to the growth of plants and may easily cause awaste of water resources. Moreover, manual data statistics in traditional management methods can no longer meet the needs of daily management of landscaping due to the difficulty in querying, updating and sharing of manual data[5], and data that cannot be effectively applied. In addition, the management teams of some parks are unable to realize efficient and intensive management due to lack of management experience, ambiguous management objectives, unclear division of tasks and under-developed assessment mechanisms.

Lack of interaction in landscape service facilities leads to poor recreation experience. Traditional parks are designed to provide visitors with a place to enjoy natural scenery within an existing landscape space, where the movement of visitors is restricted. Visitors can only have a relatively "static" tour of the park, which does not allow them to interact with the landscape elements and enjoy an in-depth tour experience in the park. At the same time, the existing service facilities are not smart enough to provide humanized services. For example, most guide systems in the parks use flat signage with a single function, which only provides visitors with the basic information of trails in the park rather than the necessary navigation service functions such as real-time positioning, personalized tour route planning, and park attractions introduction, etc.

1.3 Application of Smart Technologies in Park

In some developed countries, information-based and integrated management is being applied in every phase of the design, construction, operation and maintenance and services of parks. For example, the German Park Green Space Management Database System, is based on the dynamic development of the natural ecological elements of parks and the flexible update of social functions. It enables the update and statistical analysis of multiple ports through multi-level data updating, entry and maintenance. It directly supports the decision-making operations in the management and protection of natural elements of parks and the ecological efficiency of facilities, and further serves as the basis for decision-making for conservation and public funding[6]. London Olympic Park in the United Kingdom achieves the smart management services of the park through the development of integrated systems, free WiFi configuration, biodiversity protection, application (APP) development and other aspects[7].

In recent years, Chinese urban parks have also introduced some smart concepts and technologies. For instance, Beijing Chaoyang Park introduced the intelligent parking management system, which incorporated real-time accounting, real-time calculation, real-time analysis of charge data, electronic payment, and online and offline customer multi-channel transactions. The smart system has improved the automation of parking charging process and financial management, and at the same time, enabled online ticket purchase services for the convenience of tourists. In 2019, Shanghai Botanical Garden carried out the upgrade and renovation project of security technology protection facilities (Phase I). It involved building a video surveillance system based on digital technology, and deploying an optical fiber data transmission network covering key scenic spots, facilities and buildings in the park to promote the scientific management of the park[8]. Shenzhen Xiangmi Park explored the integrated management of multiple intelligent systems such as video monitoring, intelligent lighting and parking management in the park through spatial analysis technology, 4G mobile network and Internet of Things[9]. Generally speaking, the application of smart technologies in Chinese parks is still in it's initial exploration stage, which lacks holistic and systematic construction.

2 Construction Framework of Smart Park

Smart park refers to the park which facilitates mutual perception, mutual knowledge and interaction through digital expression, intelligent control and management of the service, and management and maintenance process of the park. This is achieved by employing the new generation information technologies such as the "Internet +" concept, the Internet of Things, big data and cloud computing, mobile Internet and information intelligent terminal[10]. Dividing the service object levels of the parks, the core framework of smart park construction should comprise one platform — a smart integrated information platform, and two sub-systems — the smart management system and the smart service system (Fig. 2).

2.1 Smart Comprehensive Information Platform

The smart comprehensive information platform is equivalent to the "brain" of the park. It mainly transmits the massive data and information collected by the perception layer to the smart integrated information platform through network transmission layer to store, analyze and visualize the data, and integrate scattered data into a "base map". This helps break the "information island" and "isolated state" between various systems in traditional parks, and realize the sharing and linkage of multi-source, multi-scale and multi-dimensional data and information resources, thus providing data support for the park's smart management system and smart service system.

2.2 Data-Driven Refined Smart Management System

The smart management system is mainly for park managers and is used in the daily management and maintenance of parks. It includes smart ecological monitoring, smart management, energy consumption management, smart transportation, smart lighting, smart security, smart cleaning, the management of park personnel and asset and other aspects. Supported by the smart management system, the management of parks is no longer confined to the subjective experience of the park managers. Instead, it makes use of the big data information, intelligent algorithms, artificial intelligence and other means to carry out in-depth dynamic mining and processing of the park data, automatically calculate and generate the intelligent management strategy, and provide information and technical support for the daily management and emergency decision-making of parks. This helps to achieve precise, refined, and scientific management to improve the parks' ecological and economic benefits.

2.3 Human-Centric and Participation-Based Participatory Smart Service System

The smart service system is mainly applied in the services delivered to visitors in the course of recreation, including smart guides, landscape interactive facilities, smart fitness, smart science and smart service facilities and so on. The smart service system can effectively improve the service quality of a park, interconnect the objects and people in the park based on the Internet of Things, and form a crossed mutual perception, mutual knowledge and interaction through the attached "sensing" function of objects. This help to enhance the tourists' perception of the landscape elements in the park, expand their perception range of the physical and virtual space of the park, increase the participation and interaction of tourists, and stimulate the potential outdoor activities and social behaviors of visitors. At the same time, the intelligent service facilities can provide visitors with more friendly, convenient and humanized services, improve their happiness and satisfaction, and enhance the social benefits of the park.

3 Intelligent Renovation of Beijing Haidian Park

Founded in 2003, Beijing Haidian Park is located in the northwest corner of Wanquan River overpass on the northwest fourth ring road of Beijing. Covering an area of about 34 hm^2, the park was formerly known as the Changchun Garden, one of the imperial gardens of "three mountains and five gardens". Like other parks that was built a long time ago, it faced problems of management and services improvement. The park completed the first round of intelligent renovation in November 2018, and the second round in September 2019. After two rounds of upgrading and renovation, it has systematically constructed the smart system of the park, and basically realized the self-perception and smart control of the park.

3.1 Smart Comprehensive Management Platform

The park has built a smart comprehensive management platform: "The core of the park", which serves as the "smart brain" of the park. The platform can analyze various collected data such as environmental data, visitors flow data, animal and plant data, and feedback such data to the intelligent facilities in the park, such as smart ecological monitoring facilities, smart transportation facilities, and smart irrigation facilities to conduct smart management and interconnection of the data. In addition, the park manager can monitor in real-time the dynamic data index of the park through "the core of the park" visual management platform, and carry out remote management of the intelligent facilities in the park.

3.2 Smart Management System

The park has constructed the smart management system mainly from six levels: Smart ecological monitoring, smart management and maintainance, smart energy consumption management, smart lighting management, smart transportation, and smart security.

1) Smart Ecological Monitoring. Based on the environmental monitoring equipment installed on the central lawn and other areas, the park collects environmental data such as air quality, temperature and humidity, water level and water quality in real-time with the water quality monitoring equipment installed in the upper, middle and lower reaches of the water body respectively (Fig. 3), thus forming an environment perception network of the park. For instance, the environmental monitoring equipment can detect $PM_{2.5}$, CO_2, NO_2, negative oxygen ion concentration and other data in the air of each region, automatically conduct a comprehensive evaluation the air quality, and release information through the public platform, APP, official website and other channels to guide the tourists to the appropriate time and area of activities[11]. The water quality monitoring equipment can detect the PH value, dissolved oxygen amount, turbidity and other data of the water body, evaluate the water quality, send alarm in real-time, and provide different solutions according to the pollution level. When the water quality reaches a high turbidity level, the platform will forewarn and suggest activating the water circulation system for water purification.

2) Smart management and maintenance. The park accurately manages the growth environment and health of plants through intelligent irrigation and pest monitoring. In the past, the automatic sprinkling irrigation and artificial flooding irrigation are combined for plant irrigation. Now, the smart irrigation can monitor the data of soil humidity and the surrounding environment microclimate in real-time by linking the soil moisture sensor with the irrigation system and automatically or remotely control irrigation by considering the pre-set water demand indicators for different plants (Fig. 4). Furthermore, night irrigation can be applied to reduce evaporation and avoid affecting daytime activities of visitors (Tab. 1). Therefore, it not only realizes the refined management of plants, but also improves the utilization rate of water resources.

As for disease and pest monitoring, the change of plant branches and leaves at the sample point is compared with the plant sample stored in the database through remote sensing, video detection technology, and image recognition. Then, the area where disease and pest occurs can be identified with the help of manual inspection, so that timely measures can be taken to control pests and diseases.

3) Smart energy consumption management. It mainly monitors and manages the water consumption and power consumption of various equipment and facilities in the park. The energy consumption data of road lighting, water features, office area, toilets, and other areas are analyzed and calculated using the installed smart electricity meter and smart water meter. This helps establish a reasonable allocation of energy consumption and energy consumption fault alarm, and enable the smart switch and remote control of the water and electric equipment in the park through the installation of the inductive equipment and network control module (Fig. 5). For example, when water consumption monitoring detects an abnormality, the fault alarm will be automatically set off, so that the water running, emitting, dripping and leaking points can be quickly positioned, and labor cost can be saved. By monitoring the real-time power of the electric equipment, the lighting fault point can be quickly identified and dealt with in time, so as to facilitate the subsequent management and maintenance.

4) Smart lighting management. Ordinary street lights are characterized by great power consumption, single switch control mode, and difficulty in troubleshooting. The parks will replace ordinary lights with smart street lights with low energy consumption, multi-channel control, and adjustable brightness. Smart street light adopts a step-decreasing illumination mode, which turns on lighting as needed according to light intensity and adjusts the brightness according to the crowd density by means of an infrared sensing device. For instance, it automatically turns on high-brightness lighting during periods of high tourist volume, enables low-brightness lighting when there are fever visitors, and reduces to 10% of normal brightness when no visitor passes. The switch control mode of smart street lights has changed from the original timer control to a combination of automatic induction lighting control and remote control (management platform or mobile phone), so as to facilitate management and achieve energy saving (Tab. 2).

5) Smart transportation. Smart transportation in parks includes automatic pilot driverless buses and smart parking. With the preset operating route from the West Gate of Haidian Park to the Children's Park, the driverless buses can accurately identify the road condition, vehicle and the surrounding pedestrians with the help of the laser radar, monocular and binocular camera and a variety of sensors equipped on the buses. It is combined with AI technology to ensure safe running under different road conditions. Besides, the frequency and time of the buses can be adjusted in real-time according to the needs of tourists. Smart parking enables real-time monitoring of the parking lots usage by employing the GPS positioning technology and video monitoring system (Fig. 6). It features automatic charging, statistics, and positioning of remaining parking spaces, statistics comparison of various time periods, and historical data. It enables the unmanned management of parking lot and improves the utilization rate of parking lot.

6) Smart security. It enables real-time monitoring of the distribution and safety of visitors in the park through monitoring devices such as mobile signal capture and high-definition camera (Fig. 7). The smart security can send a timely alarm for possible emergencies and potential safety hazards, hence strengthening the effectiveness and precision of park security. For example, when the density of tourists in a certain area of the park exceeds the preset value, the platform will automatically send an alarm, so that the management personnel can dispatch the security personnel to conduct traffic diversion in a timely manner, thus reduce and avoid the occurrence of danger.

3.3 Smart Service System

The park has built the smart service system mainly from five levels: smart guide, landscape interaction facility, smart runway, smart popular science education, and smart facility.

1) Smart guide. The park has set up intelligent multimedia touch screens in the East gate and West gate respectively and built the interactive virtual scenes based on the park's real information and data. Visitors can consult the refined map, main scenic spots, and service facilities of the park through voice or gesture interaction, and plan their individualized tour route accordingly. In addition, visitors can also tour around the park with an AR virtual guide enabled on their mobile phones or other mobile devices, and travel to a destination with the help of an AR real-time guide. It provides real-time positioning, route plan, information push, and other services in the course of the tour, so that visitors can enjoy a customized sightseeing experience with a smart guide characterized by the interaction between human and computer.

2) Landscape interaction facility. The park has designed various kinds of landscape interaction facilities, which form an interesting interplay between visitors and landscape based on the timely feedback of the tourists' behaviors, thus enhancing the vitality of the site. The rain garden display area is equipped with a sensing interactive water scene device (Fig. 8), through which visitors can control the height of the fountain by dynamic sensing gestures. For instance, when a visitor raises his gesture, the height of the fountain will also be raised. The interactive bicycle device in the children's park can convert the electric signals of different frequencies based on the riding speed of visitors to control the height of the landscape water feature. The interactive piano device senses

the position of visitors in real-time through the sensing device, and when a piano key is stepped on, the lights corresponding to the keys will light up and make a sound, thus enabling the visitors to play music in an interactive manner.

3) Smart runway. The park has transformed the track around the central lawn into a smart runway (Fig. 9), with facial recognition devices equipped at three locations including the starting point, the middle point and the end point of the runway. These devices record in real time data such as the single-lap speed, the fastest speed, the cumulative duration of movement, the cumulative distance of movement, and calorie consumption. In addition, the runaway has also set a number of different race speed modes such as Bolt speed, speed for college student and primary school student, so that visitors can choose different speed mode according to their needs. Speed guidance is given by the interactive light belts on both sides of the runways which can sense the position of the runners, thus making the running experience more scientific and lots of fun.

4) Smart popular science education. Haidian Park is built on the site of Changchun Garden, one of the "three mountains and five gardens". In the future space exhibition hall, Changchun Garden is reconstructed virtually based on the VR (virtual reality) technology, so that visitors can immerse in a historical scene and enjoy a virtual tour (Fig. 10). An interactive tour experience is built based on the ancient architecture to popularize the construction principle of the mortise structure of the ancient architecture. The embedded interactive historical and cultural information of Changchun Garden increases the richness and readability of the popular science on history and culture. At a later stage, a plant popular science system will be developed based on Augmented Reality technology which allows visitors to scan plant specimens using their mobile phones and observe the whole process of plant growth in a three-dimensional and interactive manner, to improve the interest of natural popular science.

5) Smart service facility. The park has updated the traditional service facilities with information technology, and introduced sensors and other intelligent devices to add humanized service functions such as smart street lights, smart seats, smart garbage bins and so on. In addition to its traditional lighting function, smart street lights also integrate multiple functions such as environmental monitoring, broadcast information release, high-definition video monitoring, and one-click alarm. The park has also made smart changes to the seats of Qixin Pavilion, providing visitors with functions such as wireless charging of mobile phones, Bluetooth speakers and automatic heating (Fig. 11), which are powered by the solar panels and electric windmills. In addition, the main entrances and exits of the park are equipped with smart garbage bins which uses an induction device to control the automatic opening and closing of the garbage inlets and automatically compress dry waste. When the waste exceeds the capacity threshold, a remote alert will be sent and the garbage bin will be positioned to guide the administrator to clean up in time. At a later stage, the AI intelligent upgrade of garbage bins will be developed to incorporate a voice query function to help garbage classification.

4 Conclusion

Considering that smart park is an important direction for the construction and development of future parks, the author makes a preliminary exploration of the construction framework and the possible application scenarios of smart parks based on the current problems faced during the construction and management of urban parks. However, the said application scenarios still mainly based on theorical applications. The integration of data should be strengthened on the basis of improving the information infrastructure construction of future smart parks, and more management and service facilities shall be incorporated into the smart park system. This will help to achieve all-round smart management, improve the management efficiency and service quality of parks, and build more sustainable urban parks. Moreover, smart parks should be further connected with and serve the construction of smart cities, in a bid to open up data application channels with other fields, achieve coordinated operation of all subsystems of smart cities, and speed up the construction process of the smart cities.

Sources of Figures and Tables:

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