James D. Carswell
Taro Tezuka (Eds.)

Web and Wireless Geographical Information Systems

LNCS 4295

6th International Symposium, W2GIS 2006
Hong Kong, China, December 2006
Proceedings

Springer

James D. Carswell Taro Tezuka (Eds.)

Web and Wireless Geographical Information Systems

6th International Symposium, W2GIS 2006
Hong Kong, China, December 4-5, 2006
Proceedings

Springer

Volume Editors

James D. Carswell
Digital Media Centre
Dublin Institute of Technology
Dublin 2, Ireland
E-mail: jcarswell@dit.ie

Taro Tezuka
Graduate School of Informatics
Kyoto University
Yoshida-Honmachi, Sakyo
Kyoto, 606-8501, Japan
E-mail: tezuka@dl.kuis.kyoyo-u.ac.jp

Library of Congress Control Number: 2006936624

CR Subject Classification (1998): H.2, H.3, H.4, H.5, C.2

LNCS Sublibrary: SL 3 – Information Systems and Application, incl. Internet/Web and HCI

ISSN 0302-9743
ISBN-10 3-540-49466-9 Springer Berlin Heidelberg New York
ISBN-13 978-3-540-49466-9 Springer Berlin Heidelberg New York

Typesetting: Camera-ready by author, data conversion by Scientific Publishing Services, Chennai, India
Printed on acid-free paper SPIN: 11935148 06/3142 5 4 3 2 1 0

Lecture Notes in Computer Science 4295

Commenced Publication in 1973
Founding and Former Series Editors:
Gerhard Goos, Juris Hartmanis, and Jan van Leeuwen

Editorial Board

Preface

These proceedings contain the papers selected for presentation at the sixth edition of the International Symposium on Web & Wireless Geographical Information Systems held in Hong Kong during December 2006. This symposium was intended to provide an up-to-date review of advances in both theoretical and technical development of Web and Wireless Geographical Information Systems (W^2GIS). It was the sixth in a series of successful events beginning with Kyoto 2001, and alternating locations annually between East Asia and Europe. It now represents an ever-increasing spatially aware geotechnology research community.

Now in its sixth year, W2GIS has matured in name from a "workshop" to a full 2-day "symposium" – recognition by the field as a forum for quality dissemination and discussion on the latest research and development achievements in the domain. The number of papers received for this symposium demonstrates not only the growing importance of this field for researchers but also the growing impact these developments have in the daily lives of all citizens.

From well over 130 submissions, 72 papers were initially selected as being directly in scope with the symposium, and from these, 24 papers (33%) were selected for final presentation and inclusion in the proceedings. Each paper received three reviews and was ranked accordingly. The accepted papers cover a wide range of topics from the Semantic Web, Web personalization, contextual representation and mapping to querying in mobile environments, mobile networks and recent developments in location-based services and applications.

We had the privilege of having a distinguished invited talk by Yufei Tao, Department of Computer Science of the City University of Hong Kong. The best paper from the symposium was selected by the Steering Committee and invited for an extended journal publication by *Transactions in GIS*.

We wish to thank the authors that contributed to this workshop for the high quality of their papers and presentations and the support of Springer LNCS. We would also like to thank the Program Committee for the quality and timeliness of their evaluations. Finally, many thanks to the Steering Committee for providing continuous advice.

October 2006

James D. Carswell
Taro Tezuka

W2GIS 2006 Symposium Committee

Symposium Chairs

J.D. Carswell, Dublin Institute of Technology, Ireland
T. Tezuka, Kyoto University, Japan

Industrial Chair

K.J. Li, Pusan National University, Korea

Local Chair

H. Lin, The Chinese University of Hong Kong, SAR China

Steering Committee

M. Bertolotto, University College Dublin, Ireland
C. Claramunt, Naval Academy, France
B. Huang, The Chinese University of Hong Kong, SAR China
C. Vangenot, EPFL, Switzerland

Program Committee

P. Agouris, University of Maine, USA
M. Arikawa, University of Tokyo, Japan
A. Bouju, University of La Rochelle, France
T. Cheng, University College London, UK
K. Clarke,University of California, Santa Barbara, USA
N. Cullot, University of Burgundy, France
M.L. Damiani, DICO - University of Milan, Italy
R.A. de By, ITC, Netherlands
M. Duckham, University of Melbourne, Australia
M. Egenhofer, NCGIA, USA
M. Gahegan, Penn State, USA
Y. Ishikawa, Nagoya University, Japan
C.S. Jensen, Aalborg University, Denmark
M.A. Kang, University Clermont-Ferrand, France
H.A. Karimi, University of Pittsburgh, USA
B. Köbben, ITC, Netherlands

Y.J. Kwon, Hankuk Aviation University, Korea
R. Laurini, INSA Lyon, France
H. Li, Chinese Academy of Sciences, China
S. Li, Ryerson University, Canada
M. Mainguenaud, INSA Rouen, France
P. Muro-Medrano, Universidad de Zaragoza, Spain
S. Nittel, University of Maine, USA
B.C. Ooi, National University of Singapore, Singapore
D. Papadias, HKUST, Hong Kong, SAR China
G. Percivall, Open Geospatial Consortium, USA
D. Pfoser, Computer Technology Institute, Greece
M. Raubal, University of Munster, Germany
A. Rodriguez, University of Concepcion, Chile
M. Schneider, University of Florida, USA
S. Spaccapietra, EPFL, Switzerland
K. Tanaka, Kyoto University, Japan
Y. Tao, City University of Hong Kong, SAR China
G. Taylor, University of Glamorgan, UK
Y. Theodoridis, University of Piraeus, Greece
A. Voisard, Fraunhofer ISST and FU Berlin, Germany
R. Weibel, University of Zurich, Switzerland
S. Winter, The University of Melbourne, Australia
O. Wolfson, University of Illinois at Chicago, USA
S. Yi, Huazhong University of Science and Technology, China
I. Zaslavsky, San Diego Super Computer Center, USA
A. Zipf, Mainz University of Applied Sciences, Germany

External Reviewers

Keith Gardiner, Dublin Institute of Technology, Ireland
Elias Frentzos, University of Piraeus, Greece
Kostas Gratsias, University of Piraeus, Greece
P. Álvarez, University of Zaragoza, Spain
J. Nogueras, University of Zaragoza, Spain
J. Lacasta, University of Zaragoza, Spain
S. Martínez, University of Zaragoza, Spain

Sponsors

K.C.Wong Education Foundation, Hong Kong
PointI.com, Korea
Research Support Unit, Dublin Institute of Technology, Ireland

Lecture Notes in Computer Science

For information about Vols. 1–4216

please contact your bookseller or Springer

Vol. 4313: T. Margaria, B. Steffen (Eds.), Leveraging Applications of Formal Methods. IX, 197 pages. 2006.

Vol. 4312: S. Sugimoto, J. Hunter, A. Rauber, A. Morishima (Eds.), Digital Libraries: Achievements, Challenges and Opportunities. XVIII, 571 pages. 2006.

Vol. 4311: K. Cho, P. Jacquet (Eds.), Technologies for Advanced Heterogeneous Networks II. XI, 253 pages. 2006.

Vol. 4306: Y. Avrithis, Y. Kompatsiaris, S. Staab, N.E. O'Connor (Eds.), Semantic Multimedia. XII, 241 pages. 2006.

Vol. 4302: J. Domingo-Ferrer, L. Franconi (Eds.), Privacy in Statistical Databases. XI, 383 pages. 2006.

Vol. 4300: Y.Q. Shi (Ed.), Transactions on Data Hiding and Multimedia Security I. IX, 139 pages. 2006.

Vol. 4296: M.S. Rhee, B. Lee (Eds.), Information Security and Cryptology – ICISC. XIII, 358 pages. 2006.

Vol. 4295: J.D. Carswell, T. Tezuka (Eds.), Web and Wireless Geographical Information Systems. XI, 269 pages. 2006.

Vol. 4293: A. Gelbukh, C.A. Reyes-Garcia (Eds.), MICAI 2006: Advances in Artificial Intelligence. XXVIII, 1232 pages. 2006. (Sublibrary LNAI).

Vol. 4292: G. Bebis, R. Boyle, B. Parvin, D. Koracin, P. Remagnino, A. Nefian, G. Meenakshisundaram, V. Pascucci, J. Zara, J. Molineros, H. Theisel, T. Malzbender (Eds.), Advances in Visual Computing, Part II. XXXII, 906 pages. 2006.

Vol. 4291: G. Bebis, R. Boyle, B. Parvin, D. Koracin, P. Remagnino, A. Nefian, G. Meenakshisundaram, V. Pascucci, J. Zara, J. Molineros, H. Theisel, T. Malzbender (Eds.), Advances in Visual Computing, Part I. XXXI, 916 pages. 2006.

Vol. 4290: M. van Steen, M. Henning (Eds.), Middleware 2006. XIII, 425 pages. 2006.

Vol. 4284: X. Lai, K. Chen (Eds.), Advances in Cryptology – ASIACRYPT 2006. XIV, 468 pages. 2006.

Vol. 4283: Y.Q. Shi, B. Jeon (Eds.), Digital Watermarking. XII, 474 pages. 2006.

Vol. 4281: K. Barkaoui, A. Cavalcanti, A. Cerone (Eds.), Theoretical Aspects of Computing - ICTAC 2006. XV, 371 pages. 2006.

Vol. 4280: A.K. Datta, M. Gradinariu (Eds.), Stabilization, Safety, and Security of Distributed Systems. XVII, 590 pages. 2006.

Vol. 4279: N. Kobayashi (Ed.), Programming Languages and Systems. XI, 423 pages. 2006.

Vol. 4278: R. Meersman, Z. Tari, P. Herrero (Eds.), On the Move to Meaningful Internet Systems 2006: OTM 2006 Workshops, Part II. XLV, 1004 pages. 2006.

Vol. 4277: R. Meersman, Z. Tari, P. Herrero (Eds.), On the Move to Meaningful Internet Systems 2006: OTM 2006 Workshops, Part I. XLV, 1009 pages. 2006.

Vol. 4276: R. Meersman, Z. Tari (Eds.), On the Move to Meaningful Internet Systems 2006: CoopIS, DOA, GADA, and ODBASE, Part II. XXXII, 752 pages. 2006.

Vol. 4275: R. Meersman, Z. Tari (Eds.), On the Move to Meaningful Internet Systems 2006: CoopIS, DOA, GADA, and ODBASE, Part I. XXXI, 1115 pages. 2006.

Vol. 4273: I. Cruz, S. Decker, D. Allemang, C. Preist, D. Schwabe, P. Mika, M. Uschold, L. Aroyo (Eds.), The Semantic Web - ISWC 2006. XXIV, 1001 pages. 2006.

Vol. 4272: P. Havinga, M. Lijding, N. Meratnia, M. Wegdam (Eds.), Smart Sensing and Context. XI, 267 pages. 2006.

Vol. 4271: F.V. Fomin (Ed.), Graph-Theoretic Concepts in Computer Science. XIII, 358 pages. 2006.

Vol. 4270: H. Zha, Z. Pan, H. Thwaites, A.C. Addison, M. Forte (Eds.), Interactive Technologies and Sociotechnical Systems. XVI, 547 pages. 2006.

Vol. 4269: R. State, S. van der Meer, D. O'Sullivan, T. Pfeifer (Eds.), Large Scale Management of Distributed Systems. XIII, 282 pages. 2006.

Vol. 4268: G. Parr, D. Malone, M. Ó Foghlú (Eds.), Autonomic Principles of IP Operations and Management. XIII, 237 pages. 2006.

Vol. 4267: A. Helmy, B. Jennings, L. Murphy, T. Pfeifer (Eds.), Autonomic Management of Mobile Multimedia Services. XIII, 257 pages. 2006.

Vol. 4266: H. Yoshiura, K. Sakurai, K. Rannenberg, Y. Murayama, S. Kawamura (Eds.), Advances in Information and Computer Security. XIII, 438 pages. 2006.

Vol. 4265: L. Todorovski, N. Lavrač, K.P. Jantke (Eds.), Discovery Science. XIV, 384 pages. 2006. (Sublibrary LNAI).

Vol. 4264: J.L. Balcázar, P.M. Long, F. Stephan (Eds.), Algorithmic Learning Theory. XIII, 393 pages. 2006. (Sublibrary LNAI).

Vol. 4263: A. Levi, E. Savas, H. Yenigün, S. Balcisoy, Y. Saygin (Eds.), Computer and Information Sciences – ISCIS 2006. XXIII, 1084 pages. 2006.

Vol. 4261: Y. Zhuang, S. Yang, Y. Rui, Q. He (Eds.), Advances in Multimedia Information Processing - PCM 2006. XXII, 1040 pages. 2006.

Vol. 4260: Z. Liu, J. He (Eds.), Formal Methods and Software Engineering. XII, 778 pages. 2006.

Vol. 4259: S. Greco, Y. Hata, S. Hirano, M. Inuiguchi, S. Miyamoto, H.S. Nguyen, R. Słowiński (Eds.), Rough Sets and Current Trends in Computing. XXII, 951 pages. 2006. (Sublibrary LNAI).

Vol. 4257: I. Richardson, P. Runeson, R. Messnarz (Eds.), Software Process Improvement. XI, 219 pages. 2006.

Vol. 4256: L. Feng, G. Wang, C. Zeng, R. Huang (Eds.), Web Information Systems – WISE 2006 Workshops. XIV, 320 pages. 2006.

Vol. 4255: K. Aberer, Z. Peng, E.A. Rundensteiner, Y. Zhang, X. Li (Eds.), Web Information Systems – WISE 2006. XIV, 563 pages. 2006.

Vol. 4254: T. Grust, H. Höpfner, A. Illarramendi, S. Jablonski, M. Mesiti, S. Müller, P.-L. Patranjan, K.-U. Sattler, M. Spiliopoulou, J. Wijsen (Eds.), Current Trends in Database Technology – EDBT 2006. XXXI, 932 pages. 2006.

Vol. 4253: B. Gabrys, R.J. Howlett, L.C. Jain (Eds.), Knowledge-Based Intelligent Information and Engineering Systems, Part III. XXXII, 1301 pages. 2006. (Sublibrary LNAI).

Vol. 4252: B. Gabrys, R.J. Howlett, L.C. Jain (Eds.), Knowledge-Based Intelligent Information and Engineering Systems, Part II. XXXIII, 1335 pages. 2006. (Sublibrary LNAI).

Vol. 4251: B. Gabrys, R.J. Howlett, L.C. Jain (Eds.), Knowledge-Based Intelligent Information and Engineering Systems, Part I. LXVI, 1297 pages. 2006. (Sublibrary LNAI).

Vol. 4249: L. Goubin, M. Matsui (Eds.), Cryptographic Hardware and Embedded Systems - CHES 2006. XII, 462 pages. 2006.

Vol. 4248: S. Staab, V. Svátek (Eds.), Managing Knowledge in a World of Networks. XIV, 400 pages. 2006. (Sublibrary LNAI).

Vol. 4247: T.-D. Wang, X. Li, S.-H. Chen, X. Wang, H. Abbass, H. Iba, G. Chen, X. Yao (Eds.), Simulated Evolution and Learning. XXI, 940 pages. 2006.

Vol. 4246: M. Hermann, A. Voronkov (Eds.), Logic for Programming, Artificial Intelligence, and Reasoning. XIII, 588 pages. 2006. (Sublibrary LNAI).

Vol. 4245: A. Kuba, L.G. Nyúl, K. Palágyi (Eds.), Discrete Geometry for Computer Imagery. XIII, 688 pages. 2006.

Vol. 4244: S. Spaccapietra (Ed.), Journal on Data Semantics VII. XI, 267 pages. 2006.

Vol. 4243: T. Yakhno, E.J. Neuhold (Eds.), Advances in Information Systems. XIII, 420 pages. 2006.

Vol. 4242: A. Rashid, M. Aksit (Eds.), Transactions on Aspect-Oriented Software Development II. IX, 289 pages. 2006.

Vol. 4241: R.R. Beichel, M. Sonka (Eds.), Computer Vision Approaches to Medical Image Analysis. XI, 262 pages. 2006.

Vol. 4239: H.Y. Youn, M. Kim, H. Morikawa (Eds.), Ubiquitous Computing Systems. XVI, 548 pages. 2006.

Vol. 4238: Y.-T. Kim, M. Takano (Eds.), Management of Convergence Networks and Services. XVIII, 605 pages. 2006.

Vol. 4237: H. Leitold, E. Markatos (Eds.), Communications and Multimedia Security. XII, 253 pages. 2006.

Vol. 4236: L. Breveglieri, I. Koren, D. Naccache, J.-P. Seifert (Eds.), Fault Diagnosis and Tolerance in Cryptography. XIII, 253 pages. 2006.

Vol. 4234: I. King, J. Wang, L. Chan, D. Wang (Eds.), Neural Information Processing, Part III. XXII, 1227 pages. 2006.

Vol. 4233: I. King, J. Wang, L. Chan, D. Wang (Eds.), Neural Information Processing, Part II. XXII, 1203 pages. 2006.

Vol. 4232: I. King, J. Wang, L. Chan, D. Wang (Eds.), Neural Information Processing, Part I. XLVI, 1153 pages. 2006.

Vol. 4231: J. F. Roddick, R. Benjamins, S. Si-Saïd Cherfi, R. Chiang, C. Claramunt, R. Elmasri, F. Grandi, H. Han, M. Hepp, M. Hepp, M. Lytras, V.B. Mišić, G. Poels, I.-Y. Song, J.D. Trujillo, C. Vangenot (Eds.), Advances in Conceptual Modeling - Theory and Practice. XXII, 456 pages. 2006.

Vol. 4230: C. Priami, A. Ingólfsdóttir, B. Mishra, H.R. Nielson (Eds.), Transactions on Computational Systems Biology VII. VII, 185 pages. 2006. (Sublibrary LNBI).

Vol. 4229: E. Najm, J.F. Pradat-Peyre, V.V. Donzeau-Gouge (Eds.), Formal Techniques for Networked and Distributed Systems - FORTE 2006. X, 486 pages. 2006.

Vol. 4228: D.E. Lightfoot, C.A. Szyperski (Eds.), Modular Programming Languages. X, 415 pages. 2006.

Vol. 4227: W. Nejdl, K. Tochtermann (Eds.), Innovative Approaches for Learning and Knowledge Sharing. XVII, 721 pages. 2006.

Vol. 4226: R.T. Mittermeir (Ed.), Informatics Education – The Bridge between Using and Understanding Computers. XVII, 319 pages. 2006.

Vol. 4225: J.F. Martínez-Trinidad, J.A. Carrasco Ochoa, J. Kittler (Eds.), Progress in Pattern Recognition, Image Analysis and Applications. XIX, 995 pages. 2006.

Vol. 4224: E. Corchado, H. Yin, V. Botti, C. Fyfe (Eds.), Intelligent Data Engineering and Automated Learning – IDEAL 2006. XXVII, 1447 pages. 2006.

Vol. 4223: L. Wang, L. Jiao, G. Shi, X. Li, J. Liu (Eds.), Fuzzy Systems and Knowledge Discovery. XXVIII, 1335 pages. 2006. (Sublibrary LNAI).

Vol. 4222: L. Jiao, L. Wang, X. Gao, J. Liu, F. Wu (Eds.), Advances in Natural Computation, Part II. XLII, 998 pages. 2006.

Vol. 4221: L. Jiao, L. Wang, X. Gao, J. Liu, F. Wu (Eds.), Advances in Natural Computation, Part I. XLI, 992 pages. 2006.

Vol. 4220: C. Priami, G. Plotkin (Eds.), Transactions on Computational Systems Biology VI. VII, 247 pages. 2006. (Sublibrary LNBI).

Vol. 4219: D. Zamboni, C. Kruegel (Eds.), Recent Advances in Intrusion Detection. XII, 331 pages. 2006.

Vol. 4218: S. Graf, W. Zhang (Eds.), Automated Technology for Verification and Analysis. XIV, 540 pages. 2006.

Vol. 4217: P. Cuenca, L. Orozco-Barbosa (Eds.), Personal Wireless Communications. XV, 532 pages. 2006.

Table of Contents

Session 1 - Location-Based Services

Session 2 - W2GIS Applications and Prototypes

Session 3 - Wayfinding, Mobile and Wireless GIS

Session 4 - W2GIS Personalization and Agent

Session 5 - Data Management and Data Retrieval Methods

Session 6 - Semantic Geo-spatial Web and Ubiquitous W2GIS

Putting Location-Based Services on the Map

Michael Grossniklaus, Moira C. Norrie, Beat Signer, and Nadir Weibel

Institute for Information Systems
ETH Zurich
8092 Zurich, Switzerland
{grossniklaus, norrie, signer, weibel}@inf.ethz.ch

Abstract. Location-based services for users on the move provide a convenient means of filtering information based on current geographical position. However users also often want to retrieve or capture information associated with past or future locations. We show how new technologies for interactive paper can be used to augment conventional paper maps with location-based services using a combination of user tracking and pointing to the map to specify location.

1 Introduction

Location-awareness is an important aspect of context-awareness and can thus be exploited to reduce the information bandwidth in mobile systems by delivering only information relevant to the current user situation. This is important due to not only limitations of mobile devices, but also the fact that users may be involved in parallel activities or need to react quickly to a given situation. However, users in mobile environments often want to retrieve or capture information relevant to a particular location either before or after the visit, possibly as part of a planning or decision-making process. For example, tourists may use time in a cafe to enquire about restaurants near the next location that they plan to visit or to write entries in their travel journal.

Tasks that involve the planning and reviewing of routes and visits within a city require an overview of the spatial layout of a city rather than just localised maps, together with the ability to easily view areas other than the current location. A well-known disadvantage of current mobile devices is the fact that the small screen size makes it awkward to perform such tasks. While some projects have used Tablet PCs to increase available screen size, this clearly restricts mobility. Conventional paper maps, on the other hand, satisfy the requirements of mobility as well as providing the required spatial overview. In addition, they have advantages in terms of readability in outdoor environments, especially by users collaborating, and can be easily annotated.

We show how digital pen and paper solutions can be used to provide a range of location-based services based on interactions with a paper map and audio feedback delivered via a text-to-speech engine. Our system offers flexible positioning modes as locations can be specified either *implicitly* based on current user

J.D. Carswell and T. Tezuka (Eds.): W2GIS 2006, LNCS 4295, pp. 1–11, 2006.

location obtained from a position sensor, *explicitly* by having the user point to the map with the pen or by using coordinates *stored* in an application database.

In previous work, we have developed a general framework that enables digital pen and paper solutions to be used not only for the digital capture of handwriting, but also for real-time interaction with a vast range of digital services. In this paper, we show how the resulting concept of interactive paper can be used to augment a paper map with four well-known types of location-based services that provide information about places of interest, events and also help the user find locations on the map. As an additional location-based service, handwritten information can be captured and associated with either the user's current location or a location pointed to on the map. For each of these services we will examine in detail the kinds of positioning modes that they support by describing the functioning of selected tasks a user can accomplish with our system.

In Sect. 2, we motivate the use of interactive paper maps as an interface to location-based services in mobile environments and discuss related work. Section 3 presents the underlying technologies for interactive paper and Sect. 4 then describes the location-based services accessible through the map. Details of the system implementation are presented in Sect. 5 and concluding remarks are given in Sect. 6.

2 Motivation and Related Work

Tourists make extensive use of maps before, during and after city visits. Tasks performed during a visit have been categorised as *locator*, *proximity*, *navigation* and *event* tasks [1]. Locator tasks are concerned with questions such as *"Where am I?"* and *"Where is X?"*. Proximity tasks deal with finding objects or people located near to the user's current location. Navigation tasks involve route finding either from the user's current location to a given location or object, or between any pair of specified objects/locations independent of the current location. Event tasks deal with finding information about what happens at a given place.

Early digital maps tended to focus on navigation, but recent ethnographic studies on the use of maps by tourists emphasise the need to support a much wider range of tasks [2]. Large maps provide a tourist with an overview of the features of a city and the spatial relationships that help tourists locate themselves, identify potential areas of interest and keep track of places visited. Various forms of annotation are often used to highlight locations and routes and note names of facilities such as restaurants.

Tourism is a domain with considerable potential for the use of mobile technologies and a number of projects have developed PDA-based tourist guides, with Cyberguide [3] and GUIDE [4] among the earlier examples. While some projects have focussed on navigation, others have addressed issues such as context-awareness, interaction, visualisation or collaboration. Studies show that tourists spend a lot of time comparing and combining information, but it is difficult to support these activities on small digital mobile devices. Also interaction is often awkward as it is tedious to input large amounts of information. For this reason,

some projects have opted for the use of Tablet PCs [4, 5], enabling them to provide much richer information displays and services to the user. Clearly the problem with these devices based on current technologies is that they are relatively large and heavy. Another approach is to investigate means for accessing supplementary and dynamic information as well as advanced digital services in a more natural way. The use of pen and paper as an interface can be seen as a *natural interaction* and various projects have investigated the use of paper maps either for accessing digital information [6, 7] or for the capturing of information [8]. Digital pen and paper functionality offered by the Swedish company Anoto [9] provides an easy-to-use solution for the digital capture of handwriting on paper and several projects have used these to build annotation systems, such as for example in ButterflyNet [10]. These systems are much more convenient for users than inputting annotations digitally, even when using handwriting on digital devices.

For all four categories of map-based tasks defined at the beginning of this section, location plays a key role and hence location-awareness based on user tracking is an important feature of many mobile tourist information systems. Some systems allow tourists to specify an arbitrary location on the map [11], or to select a location from a list of the last recorded positions [4, 12]. However, in many cases, the specification of the location is only meant to be used as a fallback solution if no other positioning system is available and is not supported as a real feature of the system. Other systems such as Rasa [13] or NISMap [8] support explicit positioning on a map, but they do not provide implicit tracking of positions, since they are not meant to be used in a mobile environment. Nevertheless, pointing to map positions is a very convenient way of specifying, not only where one wishes to go in seeking directions, but also past and future locations. For example, in planning activities for the evening ahead, a tourist may want navigation information from their hotel to a restaurant or information about events close to the hotel without them actually being located at the hotel. It is therefore important that user location can be specified either explicitly, implicitly or through coordinates stored in an application database. If implicit positions from a location sensor are used, it has to be possible to use several alternative tracking technologies that are combined seamlessly.

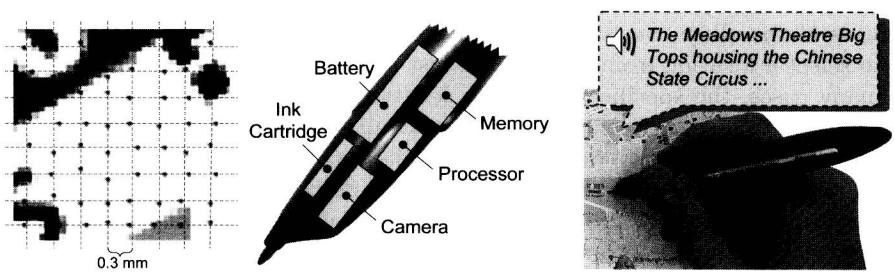
Another desirable feature of mobile tourist information systems is the possibility to capture information. The Graffiti system [14], for instance, allows tourists on the move to create electronic notes and associate them with a location. In [15], mobile phones equipped with RFID receivers were used to track user positions and publish location-based pictures, videos or annotations.

Our goal was to develop a complete solution that could support all four categories of map-based tourist tasks, exploiting the advantages of the combination of implicit, explicit and database-driven position tracking, as well as providing means for tourists to record their travel experiences. In the next sections, we describe how this can be achieved through the implementation of interactive paper maps based on a general cross-media content publishing system that we have developed.

3 Interactive Paper

A number of digital pens are now commercially available based on Anoto functionality. These technologies are able to track the position of a pen on paper through a combination of a special dot pattern printed on paper that encodes position information and a camera inside the pen as illustrated in Fig. 1(a).

The dot pattern, which is almost invisible, encodes (x,y) positions in a vast virtual document space. Camera images are recorded and processed in real-time giving up to 100 (x,y) positions per second. The technology was originally developed for the digital capture of handwriting and several pages of handwriting can be captured and stored within the pen before being transferred to a PC via a Bluetooth or USB connection. Hitachi Maxell and Logitech have recently released pens based on Anoto functionality that can also be used in streaming mode where position information is transmitted continuously. This enables the pens to be used for real-time interaction as well as writing capture.



(a) Anoto technology (b) Pointing to the map

Fig. 1. Interactive paper maps

We have developed a general link service for interactive paper [16, 17], which enables active areas to be defined on paper and bound to digital resources such as images, videos or web pages, or to services such as a text-to-speech engine, a database system or an application such as Microsoft PowerPoint. Thus, the digital pen on paper can be used in much the same way as a mouse would be used during web browsing to activate links to static documents as well as trigger specific application calls.

Using these technologies, we have developed interactive paper maps to support tourists on the move based on a text-to-speech output channel. Interaction with the map provides access to a range of location-aware services and users can also annotate the map or link annotations written in a separate document to positions on the map. Maps have been developed both for general tourist information in the city of Zurich and, specifically, to support visitors to the Edinburgh Festivals based on a map showing festival venues as presented in Fig. 1(b). We use the latter example in the rest of this paper to describe the functionality, operation and implementation of the system in detail.

4 Location-Based Services

In this section, we detail the various types of location-based services and interactions that can be supported by interactive maps. Figure 2 shows part of a map developed for visitors to a festival, where services can be accessed by touching the pictograms at the top. In addition, certain services may be accessed by directly pointing to a location on the map. For example, in the case of the festival system, pointing to a location anywhere on the map accesses information about the venue closest to that location.

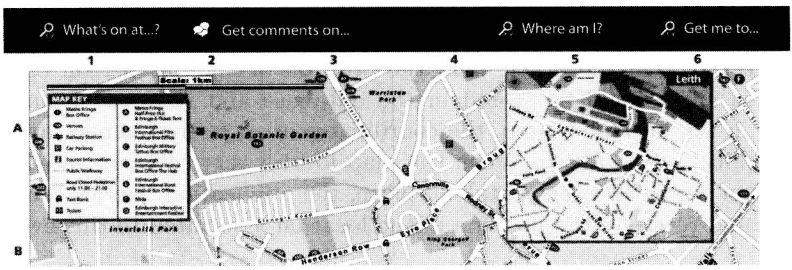


Fig. 2. Accessing location-based services on the map

Table 1 shows the services offered by our system grouped under the four categories described earlier. In addition to these services we added annotation functionality that will be described later in this section. A main contribution of our system is its support to acquire positional context information in different ways and the seamless transition between these input modalities. A first method to provide input for a location-based service involves real-time positional information provided by a sensor such as a Global Position System (GPS) device. This *implicit* tracking of positional information and its application for accessing location-based services represents the most common input form in existing location-aware applications. However, in our system a user can also provide location information *explicitly* by pointing with the digital pen to a specific location on the interactive map. Finally, positions that are *stored* in the application database can be used. Note that our architecture not only supports these three positioning modes for providing location information, but based on the actual service, the user can also freely combine them. To give an example, let us have a look a the navigation service *Get me (from X) to Y* shown in Tab. 1. If a user does not explicitly provide information about X, the current GPS position is taken as input parameter. However, the user can also specify X by pointing to the map with the digital pen or it can be derived from information currently accessed from the application database. The same mechanism can be applied to define the target Y for this specific navigation service. We will now examine in more detail the positioning modes used in the services our system offers.

Locator tasks enable tourists to find the current position of people or objects on the map. To find their own position, location is specified implicitly by a