Chapter 1

Optimization Algorithms in Local and Global Positioning

Jean-Philippe Montillet
Central Washington University, USA

Lukasz Kosma Bonenberg
The University of Nottingham, UK

Kegen Yu
Wuhan University, China

Gethin Wyn Roberts
The University of Nottingham – Ningbo, China

ABSTRACT

With the rise of large city and the need of large civil engineering structures and city planning, surveying industry improves continuously their instruments/software in order to get cm accuracy position anywhere. Moreover, since the boom of mobile phones in the late 90s, location has become very valuable information for security, emergency and commercial applications. Depending of the application, the location technologies vary based on the accuracy of the location and the price of the system, which delivers the location information to the user. For outdoor applications, Global Navigation Satellite System is the main candidate, whereas if the user/mobile node is indoors or in a narrow street other technologies will be preferred such as the ones based on Wi-Fi or radio-frequency signal.This chapter provides an overview of different positioning technologies used in geo-location together with their limits/advantages. This chapter studies also a number of algorithms developed to estimate the position coordinates of a static or mobile user or target.

INTRODUCTION

Location and tracking plays an increasingly important role in civilian, military applications and services (e.g. location based services, surveying, and car navigation). Global Navigation Satellite Systems (GNSS) typically can provide satisfactory positioning, navigation and timing services in an open outdoor environment. However, conventional GNSS receivers do not work well in an indoor environment (e.g. office and warehouse) or in a built-up area (e.g. urban canyons) because the satellite signals are blocked by roofs, walls or nearby buildings. To overcome this indoor positioning problem a number of ground-based positioning systems have been developed by researchers and engineers such as those based on Wi-Fi, ultra-wideband (UWB), radio frequency identification (RFID), and inertial measurement unit

DOI: 10.4018/978-1-4666-9644-0.ch001

(IMU). For example, some systems are dedicated to locate a user in a building at a particular floor and room (e.g. PLUS - Precision Location Ultra-wideband System, MIT Cricket indoor positioning system - e.g. (Kolodziej & Hjelm, 2006)). Also, to enhance satellite-based positioning performance in harsh propagation environments, assisted-GNSS, RTK GNSS, and data fusion methods can be employed. In particular, many optimization algorithms have been used to solve local and global positioning problems to achieve superior positioning performance in severe multipath and Non-Line-Of-Sight (NLOS) environments (Wang, Groves & Ziebart, 2013).

This chapter deals with both local and global positioning, especially with a focus on algorithms. Since there are so many positioning and localization algorithms reported in the literature, either iterative or non-iterative algorithms (Yu et al., 2006), it is impractical to provide a thorough study on this issue. In particular, mathematical descriptions are provided for a number of algorithms including the optimization theory for localization in centralized networks (e.g. Levenberg-Marquadt, Broyden family of algorithms), convex optimization in sensor ad-hoc networks, or the (nonlinear) least-squares theory for satellite positioning. Note that interested readers in localization, navigation and tracking can refer to Kolodziej and Hjelm (2006) and Yu, Sharp and Guo (2009) for more background information related to local and global positioning.

The remainder of the chapter is organized in sections, providing a short summary on the history of radio positioning and its importance. Section II is a brief introduction to local and global positioning. Section III deals with satellite positioning system and the challenges in outdoor applications (i.e. urban canyons). It also includes a comprehensive description of the theory of adjustment (i.e. least-squares), which is used to triangulate the position of GNSS receivers. The section also discusses the models used to compensate tropospheric and ionospheric delays. Latest advances include the terrestrial based positioning systems (e.g. Locata), which is currently a hot research topic for the integration with GNSS receivers in order to solve various challenges (i.e. lack of satellite availability in urban canyons). Local positioning is discussed in Section IV. Several algorithms are reviewed using least-squares, optimization theory methods and data fusion approach with a special emphasis in the NLOS scenario. This scenario is a major challenge for office localization and more generally indoor applications (i.e. consumer applications in shopping malls, locating goods in warehouses). This chapter ends with the application of adaptive filters, which are suited to integrate multiple technologies (measurements) for positioning. The role of the stochastic models is emphasized (e.g. fractional Brownian motion) in order to integrate different time series of receivers' position in multi-sensors application.

BACKGROUND

Positioning and localization has been an active and important area of research especially in electrical engineering, computer engineering and civil engineering with a particular emphasis in surveying. Galileo Galilei's work of triangulating the position of a ship using the positions of the stars in the 17th century can be seen as a pioneering work in this area (Singer, 1941). Large efforts were focused on emerging radio navigation with the first antennas manufactured in the late 1800. Subsequent improvements in radio communications and the discovery of radar systems in the 1930's accentuated further the need to locate ships and planes (Balanis, 2012). In 1978, a second revolution started with the advent of Global Positioning System (GPS) motivated by the US army to get a position of military vehicles and ships anywhere at anytime on Earth thanks to the emerging satellite technology (Strang & Borre, 1997).