Chapter 34
Laser Scanning for the Evaluation of Historic Structures

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ABSTRACT

In the last times, laser scanning is being massively used to perform reverse engineering of different built-up structures, both modern and historic ones, providing detailed geometry. This chapter presents an introduction to the technology so topics like the physic fundamentals of laser scanners, instrumentation (static and mobile platforms) and the advantages of each method. This chapter aims to illustrate the optimal application of laser scanning to the field of structural engineering in order to ease the adoption of the technology by engineers outside of the geomatic domain. The chapter presents a review of different case studies where laser scanning allowed very precise and very detailed geometric characterization of historic structures in order to obtain an objective diagnosis of their current state. Also, methodologies that permit the implementation of laser scanning products in structural calculation will be shown. Finally, up-to-date trends, mainly related to automatic and intelligent processing, of laser scanning data in historic structures are discussed.

INTRODUCTION

In this section a general perspective of laser scanning technology is presented. During the last decade this technology has experienced an important evolution, and nowadays it is more and more in demand in order to perform detailed and accurate geometric characterizations of finished constructions. This surveying method was also successfully applied to other different fields, such as archaeological and architectural documentation (Pesci et al., 2012; González-Aguilera et al., 2008), civil engineering (Lovas & Berényi, 2009; González-Jorge et al., 2012), or the as-built mod-

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elling of industrial plants (Rabbani et al., 2007), among others. Particular applications to historic structures can be seen in Riveiro et al. (2011a), who developed a methodology that allowed the converting point clouds acquired by terrestrial laser scanning into metric images that were subsequently used for stability analyses of masonry arches; Armesto et al. (2010a) used a dense set of points combined with statistical methods to perform accurate an geometric diagnosis of masonry arches in the Roman Bridge; McInerney et al. (2012) and Milani et al. (2013) used the technique to automatically create geometric block models of masonry walls; Armesto et al. (2010b) used a combination of geometry and intensity data for detecting and quantifying the presence of superficial pathologies in masonry buildings; Solla et al. (2014) developed integrated approaches using laser scanning and ground penetrating radar (GPR) to create synthetic models of masonry arch bridges to assist the interpretation of the GPR data.

These experiences and many others have validated the potential of laser scanning in the field of structural engineering, particularly when tackling the evaluation of historic structures where detailed design plans are not usually available. Also, the actual geometry of the structure plays a crucial role in an objective and accurate assessment of their structural behaviour. Laser scanning has gained popularity because it fulfils the requirements mentioned above, but also because it is a remote, non-destructive method that ensures the safe survey of historic structures. Nowadays, the advances in automatic data processing are allowing the implementation of laser scanning to more particular applications, also by enabling access to the technology by non-experts in geomatics.

This chapter is organized in order to demonstrate the state-of-the-art of laser scanning technology; additionally, an overview of the principles of the operation of laser scanners is presented in the background section. Two main typologies of land platforms are described: static scanners, also known as Terrestrial Laser Scanners (TLS) and Mobile Laser Scanners (MLS). Later, the advantages and disadvantages of each typology will be discussed.

Then, a series of methodologies focusing on the usage of laser scanning towards its implementation in structural applications will be summarized. First, it will be shown how laser scanning was successfully applied to the evaluation of historic masonry arch bridges in Spain. Some approaches to performing dimensional analyses of historical buildings using dense point clouds will be presented. Also, integral methodologies using laser scanning data together with other surveying techniques such as Ground Penetrating Radar are also presented. Finally, not only were the geometric data captured by scanners used, but also the radiometric attributes of materials through the "intensity" value resulted in their being useful for detecting the superficial pathologies of historic structures. The chapter finishes with an outlook towards the ultimate advances in laser scanning related to the automation of data processing, which is more and more customized for particular structural applications.

BACKGROUND

Motivation for the Use of Geomatics in Structural Engineering

The conservation of cultural heritage is one of the fundamental concerns of modern society, and historical constructions present a cultural legacy that needs to be preserved (UNESCO, 2007). This generic term includes a wide range of constructions such as residential buildings, religious, or even civil structures such as bridges, which are normally built of masonry. However, when these constructions need to be evaluated from the point of view of engineering, many restrictions make it difficult to obtain accurate and realistic analyses