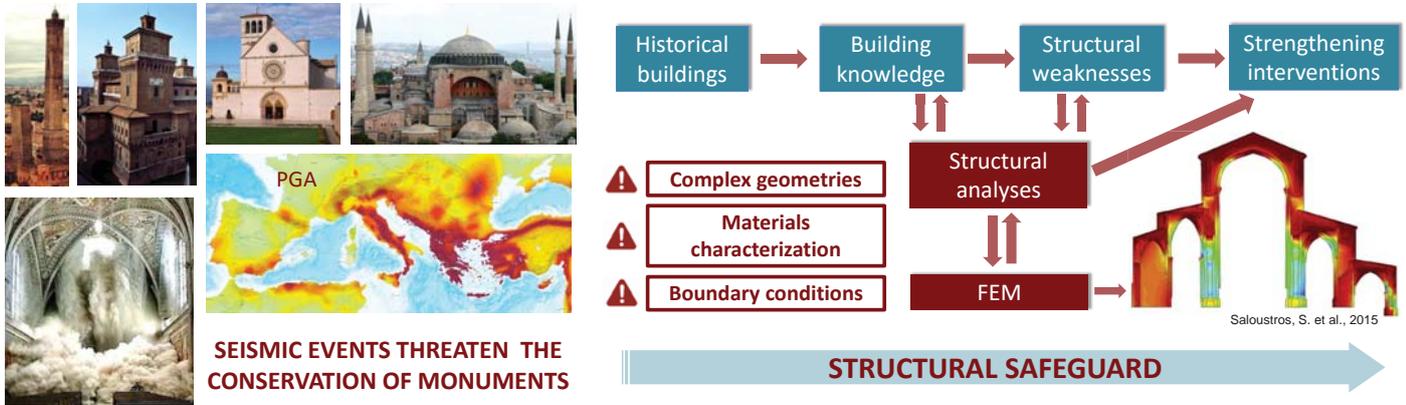


# ADVANCED NUMERICAL MODELING OF HISTORICAL MONUMENTAL BUILDINGS

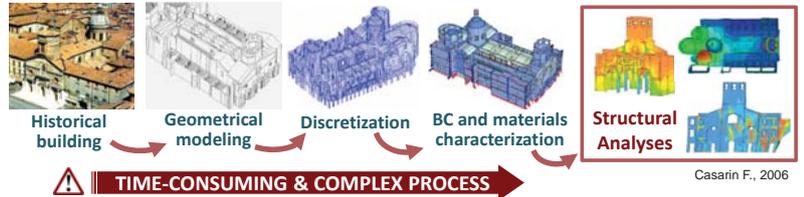
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## CONSERVATION OF HISTORICAL BUILDINGS

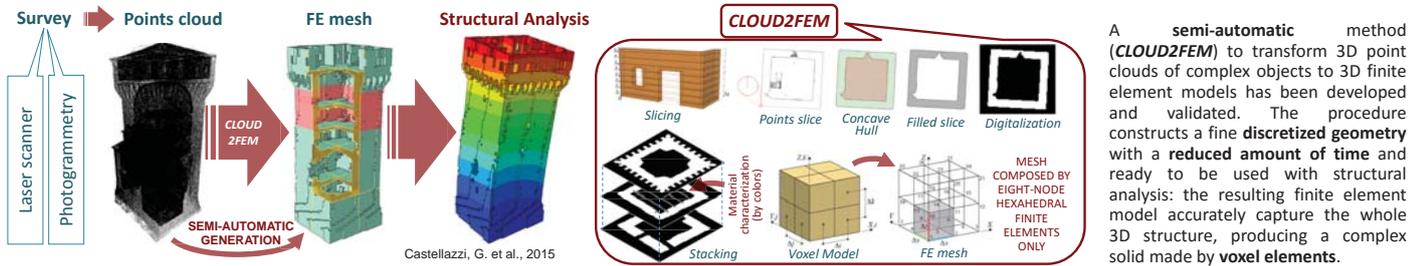


## NUMERICAL MODELING: TRADITIONAL APPROACH

The numerical modeling of historical monumental buildings is a challenging task for contemporary civil engineers. One of the main reasons for this is that, due to the **complex geometry** of such historic structures, the use of traditional simplified structural schemes is inadequate. Thereby, it is unavoidable to resort to a **fully 3D modeling** that often is performed using the CAD. In general, **CAD based modeling is an expensive and complex process**, often manually carried out by the user, which inevitably leads to the introduction of geometric simplifications (*Defeaturing*) or interpretations.



## A NEW NUMERICAL MODELING STRATEGY



## A CASE STUDY: THE SAN FELICE SUL PANARO (MO) FORTRESS

**San Felice sul Panaro Fortress**

Hit by Emilia Earthquake (2012)

**Linear static**

Comparison between linear static analysis results relative to a East directed force and the crack pattern suffered by the structure during the Emilia Earthquake, South front. Segments AB, CD, EF and GH correspond to the major cracks.

**Nonlinear static**

Nonlinear static analysis for a horizontal East directed force, North front. The computed damaged zones are highlighted in red.

**Points cloud** -> **FE mesh**

CONNECTIONS BETWEEN ADJACENT MACRO-ELEMENTS OF THE FORTRESS: SPECIALIZED ELEMENTS

**Nonlinear response history analyses**

Emilia Earthquake (May 29th 2012) Station: SANO (San Felice sul Panaro)

Constitutive model: Concrete Damage Plasticity (Lee, J. et al, 1998). Analysis type: Dynamic Explicit (Abaqus® 6.11). Plots refer to the tensile damage variable (DAMAGE\_T).

**Surveyed crack pattern**

**DAMAGE\_T**

At time

In order to show the potential of the proposed strategy, the application to the case study of the **San Felice sul Panaro (Italy) fortress**, hit by the Emilia earthquake in 2012, has been performed. This application aims at validating the numerical strategy according to the requirements of the Italian standards and guidelines about monumental historical buildings. Several **linear and nonlinear static** analyses under vertical and horizontal loads, as well as several **nonlinear Response History Analyses (RHA)** using natural accelerograms have been performed. Much attention has been paid to the modeling of the **connections** between adjacent macro-elements of the fortress. A comparison between structural analyses results and the crack pattern experienced by the structure during the Emilia Earthquake has been carried out.

Castellazzi, G. et al., 2016

**References**

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