Atti Soc. tosc. Sci. nat., Mem., Serie B, 118 (2011)
pagg. 75-80, figg. 4; *doi: 10.2424/ASTSN.M.2011.25*

S. Farina (*), S. Paganucci (**), W. Landini (*) (***)

# *DATA MATRIX* CODES: EXPERIMENTAL USE IN A MUSEUM EXHIBITION

**Abstract -** The application of the *data matrix* codes to the exhibition «Back to the past – A 500 million-year trip to Monti Pisani» is here presented. Reading these codes with the camera-equipped smartphones permits to visualize information and pictures about eight specimens that lived in the Monti Pisani 217 million-year ago (Triassic). The innovative application of this technology provides a new and exciting way to visit the Museum exhibitions through an interactive experience.

**Key words -** *Data matrix* codes, Monti Pisani, Triassic.

**Riassunto -** *Codici data matrix: uso sperimentale applicato ad una esposizione museale*. Viene presentata l'applicazione dei codici *data matrix* all'esposizione «Ritorno al passato – Un viaggio di 500 milioni di anni sui Monti Pisani». La lettura di questi codici con la fotocamera di uno smartphone permette di collegarsi ad un server locale e di visualizzare informazioni ed immagini relative ad otto esemplari di rettili e artropodi che hanno abitato i Monti Pisani 217 milioni di anni fa (Triassico) e che sono stati ricostruiti nel Museo di Storia Naturale e del Territorio (Università di Pisa) sulla base delle impronte fossili ritrovate sul territorio pisano. Inoltre, possono essere visualizzate anche delle ulteriori pagine di approfondimento collegate agli esemplari presenti nella sala. La pionieristica applicazione di questa tecnologia alle esposizioni museali rappresenta una nuova forma di linguaggio e veicolo di conoscenza che permette di trasformare le tradizionali visite in Museo in esperienze interattive.

**Parole chiave -** Codici *data matrix* - Monti Pisani – Triassico.

## Introduction

At the present time, Natural History Museums are becoming increasingly cultural centres that create innovative forms of communication through the employment of different kinds of languages and multimedia communicative tools. Therefore, the Natural History Museum has to be considered not only a place where specimens are exposed and preserved, but also a place where new ways of communication, learning, and teaching are created and experimented.
The role of the Museum is to make suitable and to convey the information contained in the specimens exposed to users; the effectiveness of this process depends on the types of communication tools adopted.
In this perspective, the intention of the Museo di Storia Naturale e del Territorio, during the last year, has been researching new forms of communication through the experimentation of innovative technologies (Dini *et al.*, 2010). Such experimentation is focussed on satisfying the requirements of the users that are becoming more culturally diversified.
The object of the present research, funded by Regione Toscana, Provincia di Pisa, and Comune di Calci (Piano Integrato Cultura, PIC), was focused on the application of the *data matrix* codes to the exhibition «Back to the past- A 500 million year trip to Monti Pisani».
The use of barcodes is increasing rapidly in many sectors as commerce, industry, technology and private. The interest in this technology has produced different standards for barcodes such as mono dimensional barcodes, Data Matrix, QR codes and Microsoft Tags.
The mono dimensional barcodes are difficult to read using mobile devices, while the other ones are easy to read and a lot of reader applications are available on online markets.
The approach followed is robust and can be agnostic with respect to the tagging technology used. This means that it is possible to replace *data matrix* codes with QR or Microsoft Tags without changing anything about the software system.
The reason of the choice of *data matrix* codes is because they are an European standard.
*Data matrix* codes are two-dimensional matrix barcode consisting of black and white «cells» or modules arranged in either a *square* or *rectangular* pattern (Fig. 1). The information to be encoded can be text or raw data. The length of the encoded data depends on the symbol dimension used. *Data Matrix* was invented by International *Data Matrix*, Inc. (ID Matrix) which was merged into *RVSI/Acuity CiMatrix* Inc. corporation (Nashua, US) and is covered today by several *ISO/IEC* standards. The *data matrix* codes are in the public domain for many applications that means it can be used free of any licensing or royalties [1].
*Data matrix* codes were developed in the 1980s and are currently used for quality management and control of industrial products (Martinez Moreno *et al.*, 2011), as well as for data collection and inventory control purposes (Chang *et al.*, 1997). Moreover, *data matrix* codes are becoming common on printed media such as *labels* and *letters*. The code can be quickly read by a *scanner* which allows the media to be tracked. Recently, their use has been extended to label archaeological material (Martinez Moreno *et al.*, 2011).
The goal of this project is to provide a computer system able to receive and process HTTP requests issued by

(*) Museo di Storia Naturale e del Territorio dell'Università di Pisa, via Roma 79, 56011 Calci, Italy, Italy. E-mail: simonefarina@inwind.it
(**) Dipartimento di Informatica, Università di Pisa, largo B. Pontecorvo 3, 56127 Pisa, Italy. E-mail: paganucc@di.unipi.it
(***) Dipartimento di Scienze della Terra, Università di Pisa, via S. Maria 53, 50126 Pisa, Italy. E-mail: landini@dst.unipi.it

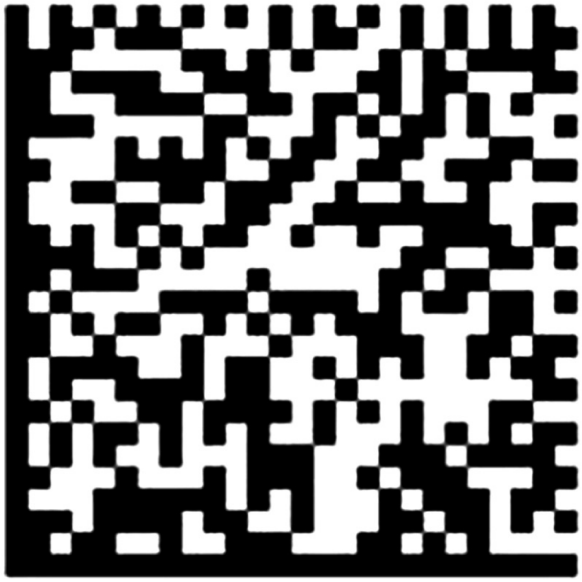

Fig. 1 - Example of *data matrix* code relative to *Herrerasaurus*.

mobile devices and to respond to these requests with HTML pages containing information about the specimens of the museum. Therefore, the project gives a new and more exciting tool to visit the Museum exhibitions through an interactive experience by exploiting some emerging information technologies such as *data matrix* codes and camera-equipped smartphones.

## The exhibition «Back to the past - a 500 million-year trip to Monti Pisani»

The exhibition, opened in 2006, represents a 500 million-year time trip through the geologic and paleontologic history of Monti Pisani (Tuscany, Italy). The exhibition consists in three rooms where natural size models are placed in the paleontological settings showing the areas around Pisa.
The first room is referred to Carboniferous period (300 million years ago); at that time the Monti Pisani area was latitudinally close to the equator and was represented by an intricate rainforest of giant club mosses, horsetails, and ferns. The second room is referred to the Triassic period (217 million years ago) and the third room is referred to the Pliocene period (three million years ago). During the last period, around the Monti Pisani region there was a deep sea area where huge sharks attacked species of dolphins and seals (Bianucci *et al.*, 2006).
Concerning the second room, the area of Monti Pisani was geographically located above the equator and characterized by warm and dry climate. Moreover, the area was placed on the border line between land and sea. Many animals, both marine and terrestrial, left their tracks on the mud drying along the coast (Bianucci *et al.*, 2006).
The finding and the scientific study of these fossil footprints (Bianucci & Landini, 2005; Fucini, 1910; Huene von, 1940a, 1940b, 1941; Leonardi & Lockley, 1995; Leonardi, 2000; Lotti, 1881; Rau & Tongiorgi, 1974; Sirigu & Tongiorgi, 1997; Tommasi, 1886; Tongiorgi, 1980) permitted to reconstruct the models of the animals that left the tracks. The labels with the *data matrix* codes have been placed close to the specimens.
The Triassic room hosts eight specimens (Fig. 2). The *Herrerasaurus* (Fig. 2G) was one of the most ancient dinosaurs which lived on the earth. It was three meters long, one meter and half tall, with long teeth and sharp claw. It was a very efficient predator, and one of its favourite prey was *Scaphonyx* (Fig. 2F), a reptile belonging to the order of Rhynchosauria. The other animals exposed in the room are the thecodonts (ancestors of dinosaurs) *Ticinosuchus* (Fig. 2C), *Lagosuchus* (Fig. 2E) and *Euparkeria* (Fig. 2D), *Macrocnemus* (Fig. 2B) (an ancestor of the modern lizards), *Thrinaxodon* (Fig. 2H) (a reptile ancestor of mammals) and the living fossil *Limulus* (Fig. 2A), a distant relative of spiders and scorpions.

## Methods

This section presents methods and technologies exploited to create and visualize web pages about the eight selected specimens.

### Information Flow

The main steps involved in a single request process are the following (Fig. 3):

1. The visitor uses his mobile device to read the content of a *data matrix* code. *Data matrix* codes contain URLs that are links to the local server. The device sends an HTTP request to the server.
2. The server processes the incoming request and queries the local database for the selected specimen.
3. The database system responds with information about the specimen.
4. The server sends an HTML formatted page to the device that issued the request.

### Software architecture

The software system is composed by the following three elements: a relational MySQL [2] database containing information about the selected specimens (name, description, taxonomy, pictures and other media elements), an ASP.NET [3] server running on a Linux machine inside Mono (cross-platform, open source.NET development framework) [4] and listening to requests performed by mobile devices, and a Content Management System (a software tool running on a web server that simplifies the content management of a web site).
During the first stage of the project development, the requirement analysis has been performed in order to be able to identify the domain and to design a correct database structure. We recognized a simple hierarchical structure in which the class «Specimen» is the root class from which any subclass derives. For instance, the class «Fossil» is a subclass of «Specimen» from

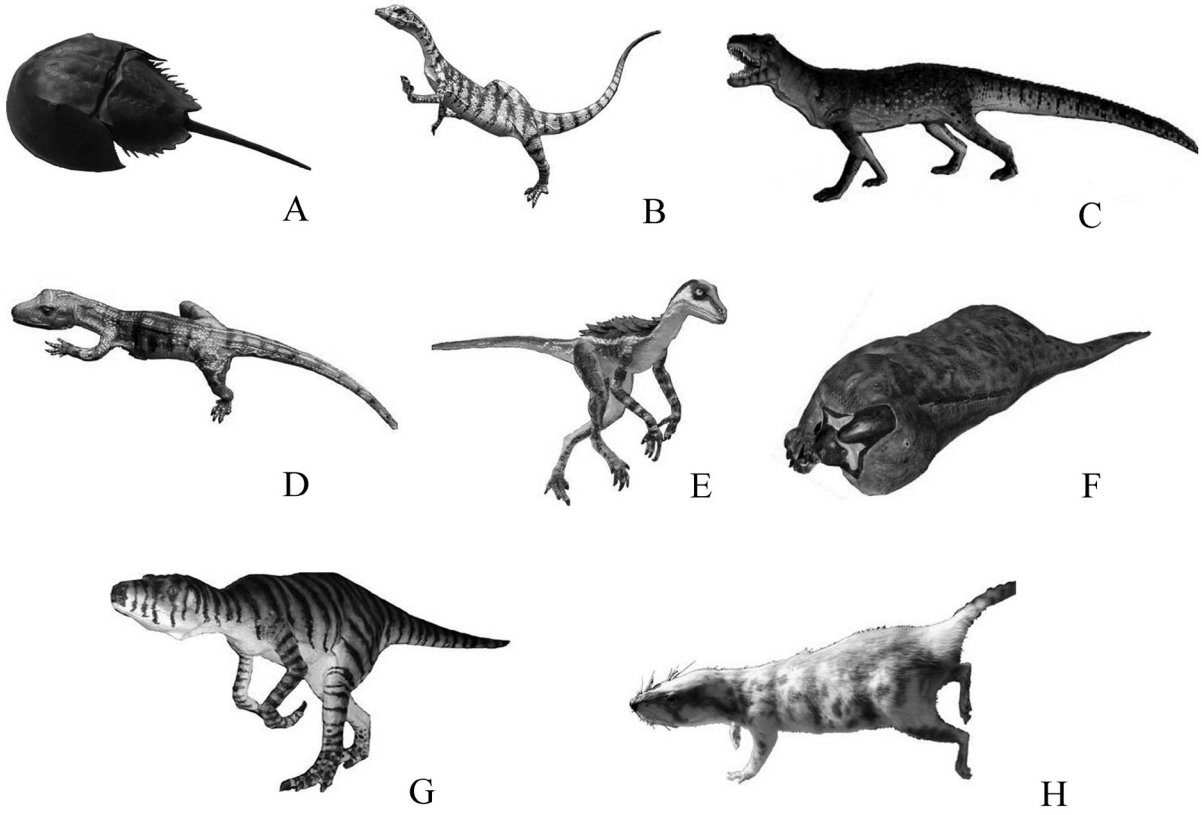


Fig. 2 - The eight animals exposed in the Triassic room. A: *Limulus*; B: *Macrocnemus*: C: *Ticinosuchus*; D: *Euparkeria*; E: *Lagosuchus*; F: *Scaphonyx*; G: *Herrerasaurus*; H: *Thrinaxodon*.

which it inherits some common attributes like name, description, classification, taxonomy etc. Each subclass of «Specimen» defines its own attributes like, in the case of «Fossil», posture, footprint or length. Each of these classes has been mapped to a table of the MySQL database.
The interaction between the ASP.NET server instance and the MySQL database is obtained through an Object Relational Mapping software called NHibernate [5]. This solution guarantees portability and code simplification since most of the database interactions is managed by NHibernate.
NHibernate provides an object-oriented abstraction layer over the DBMS (Data-Base Management System) mapping tables to C# classes and columns to class attributes.

**The Content Management System**
Since the database structure is very simple and we needed few administration features, the Content Management System has been implemented from scratch. The benefits of having a CMS are the following:
– Allowing for a large number of people to contribute to and share stored data.
– Controlling access to data, based on user roles (defining which information users or user groups can view, edit, publish, etc.).
– Aiding in easy storage and retrieval of data.
– Reducing repetitive duplicate input.
– Improving the ease of report writing.
– Improving communication between users.

The basic idea is that each domain class inherits from a common super class. The main method of this class constructs a web form for the editing of the attributes of any subclass.
The CMS provides the main management functionalities of data elements:
– creation;
– deletion;
– editing;
– listing;
– inspection.

**Creation and printing of data matrix labels**
The system also provides a tool for labels management. In particular, the system administrator is able to create data matrix labels that are bound to the specimens stored in the database. Once created, labels can be

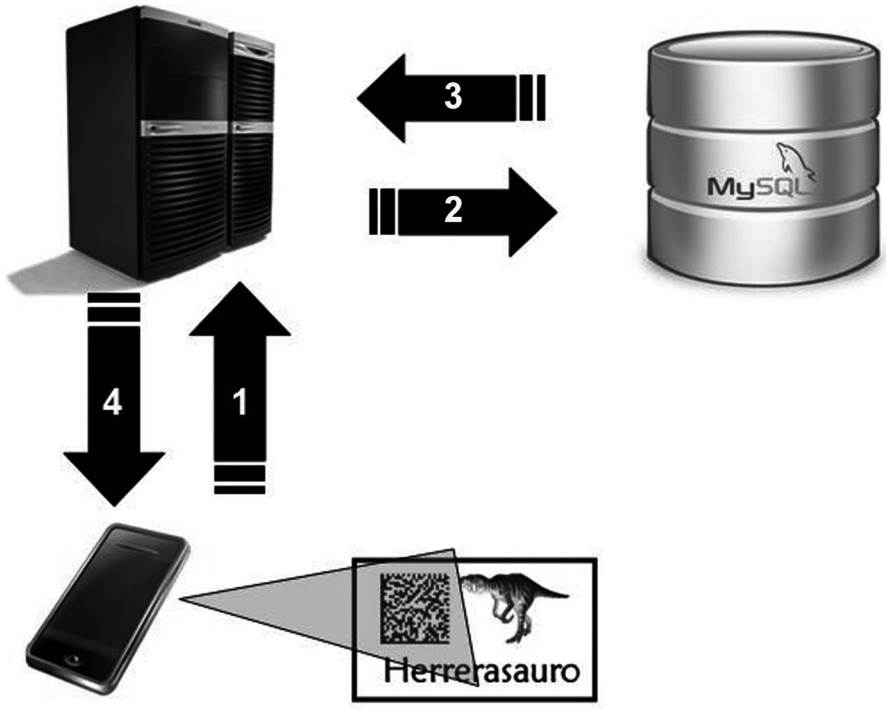


Fig. 3 - Illustration of the four steps involved in a single request process. 1: the device sends an HTTP request to the server; 2: the server processes the request and queries the local database; 3: the database system responds with information; 4: the server sends to the device an HTML page.

downloaded and printed in order to be placed inside the museum. The server stores and maintains all the created labels in order to easily change their content and print them more than just once.

## The use of the *data matrix* codes

Reading the *data matrix* codes with the camera of the smartphone permits to obtain information about the eight specimens exposed in the Triassic room. In fact, the user can visualize a main screen with pictures and general information relative to the selected specimen such as morphological description, locomotion habits, diet, and environment. Moreover, the screen presents also an identity card with the main characteristics of the specimen and the taxonomic classification of the animal (Fig. 4).
From this main screen it is also possible (by selecting the specific link) to gain further information and pictures about the footprints of the selected specimen discovered in the Monti Pisani and the environment where the animal lived.
Furthermore, at the bottom of the main screen, there are two links that permit the user to widen its knowledge and visualize two pages concerning the presence of dinosaurs in Italy during the Triassic (251-199 million years ago) and the life on the earth during that period. Additionally, from these pages it is possible to click on specific words and visualize pictures and short information about the cited animals.
This new technology is not restricted only to the Museum exhibition. In fact, the project gives the possibility to export to scholar classes the use of such technology named «educational bag». The bag contains a sectional scene that permits to assemble in the classroom a reproduction of the Triassic exhibition, the 3D-model of the eight animals, the labels with the data matrix codes, a smartphone, a video projector, and a notebook with a copy of the Museum server, including all the information about the specimens.
The «educational bag» makes possible to travel *back to the past - in a 500 million-year trip to Monti Pisani* and to discover the history of our region and the animals that lived here during the Triassic: a trip that scholars can do directly in their classrooms.

## Conclusion

The application of this innovative technology to the Museum exhibition «Back to the past – A 500 million year trip to Monti Pisani» was successfully experimented with the visitors.

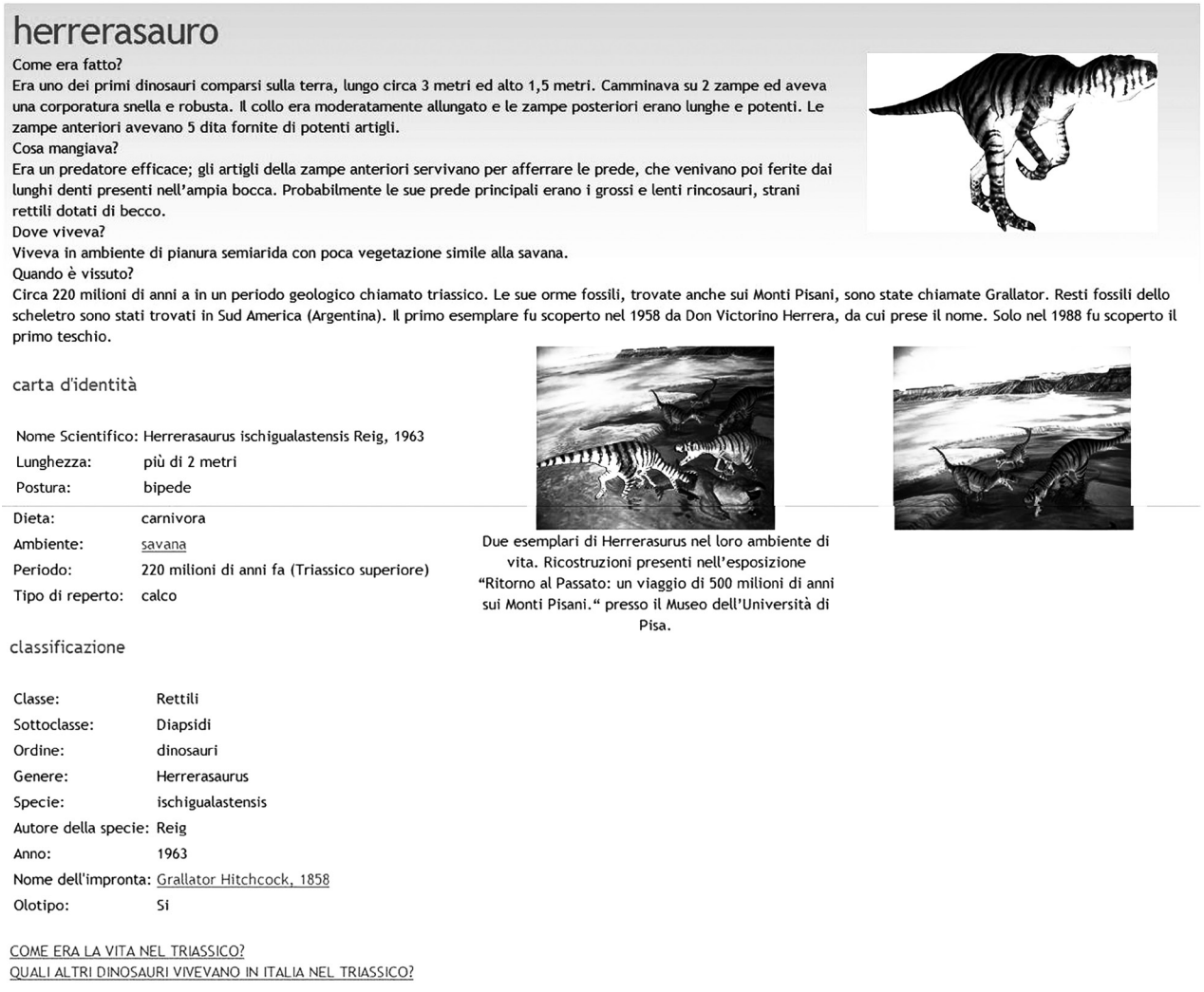


Fig. 4 - Example of the main screen (relative to *Herrerasaurus*) that the user can visualize on the smartphone. The database system is now set in Italian language only.

The positive outcome expressed by the users emphasizes the great potentiality of this technology as a new form of scientific and interactive divulgation. In fact, the user can choose to gain additional pieces of information to read on the smartphone on the basis of the time available and of the interest towards the exposed specimens.

Finally, in order to improve the use of this technology in the Museo di Storia Naturale e del Territorio, the *data matrix* codes are currently applied to a representative sample of the ornithological collection hosted at the Museum. This will permit, alongside the visualization of the main screen, to download the birdsong of the selected specimen thus giving the users the opportunity to travel in a multisensory dimension.

## Acknowledgments

We wish to thank Elisabetta Palagi for the critical comments on an early version of the manuscript.

## References

Bianucci G., Landini W., 2005. I paleositi a vertebrati fossili della provincia di Pisa. *Atti Soc. Tosc. Sc. Nat., Mem., Ser. A* 110:1-21.

Bianucci G., Tongiorgi M., Sorbini C., Nocchi C., 2006. Ritorno al passato - Un viaggio di 500 milioni di anni sui Monti Pisani. Museo di Storia Naturale e del Territorio dell'Università di Pisa. Ed. Plus, Pisa, pp. 1-40.

Chang C.A., Lo C., Hsieh K., 1997. Neural networks and fouriers descriptors for part positioning using barcode features in material handling systems. *Comput. Ind. Eng.* 32 (2): 467-476.

Dini A., Farina S., Landini W., 2010. Un Museo per tutti: la tecnologia al servizio della conoscenza. *Musei dell'Università di Pisa*. 21: 4.

Fucini A., 1910. Sull'età e sulla posizione del Verrucano in Toscana. *Atti Soc. Tosc. Sc. Nat., Proc. Verb.* 19: 25-30.

Huene von F., 1940a. Das alter des Verrucano auf grundzahl reicher reptilfahrten. *Ecl. Geol. Helv.* 32 (2): 184-185.

Huene von F., 1940b. Saurierfahrten aus dem Verrucano des Monte pisano. *Zentr. F. Min. Geol. U. Pal., Ser. B* 11: 349-352.

Huene von F., 1941. Die tetrapoden-fahrten im Toskanischen Verrucano und ihre Bedeutung. *N. Jahr. F. Min. Geol. U. Pal., Ser. B* 86: 1-34.

Leonardi G., 2000. I dinosauri d'Italia e delle aree adiacenti. In: Leonardi G., Mietto P. (Eds.). Dinosauri in Italia. Le orme dei Lavini di Marco (Trentino) e gli altri resti fossili italiani. Accademia Editoriale, Pisa-Roma, pp. 275-295.

Leonardi G., Lockley M.G., 1995. A proposal to abandone the ichnogenus *Coelurosaurichnus* Huene, 1941. A junior synonym of *Grallator* E. Hitchcock, 1858. *J. Vert. Paleont., Abstract*. 15 (3): 40 (A).

Lotti B., 1881. Fossili del Verrucano. *Atti Soc. Tosc. Sc. Nat., Proc. Verb*. 3: 94-101.

Martinez Moreno J., Gonzalez Marcen P., Mora Torcal R., 2011. Data matrix (DM) codes: A technological process for the management of the archaeological record. *J. Cult. Herit*. 12 (2): 134-139

Rau A., Tongiorgi M., 1974. Geologia dei Monti Pisani a Sud-Est della valle del Guappero. *Mem. Soc. Geol*. It. 13: 227-408.

Sirigu I., Tongiorgi M., 1997. Nuove impronte dinosauriane nel Triassico superiore dei Monti Pisani. *Atti Soc. Tosc. Sc. Nat., Mem., Ser. A* 103: 223-229.

Tommasi A., 1886. I fossili degli strati più antichi della Verruca. In: Tommasi A., Note paleontologiche. *Boll. Soc. Geol. It.* 4: 199-222.

Tongiorgi M., 1980. Orme di tetrapodi dei Monti Pisani. In: I vertebrati fossili italiani. Catalogo della mostra di Verona, 1980: 77-94.

## Web references

[1] Wikipedia. Data Matrix http://en.wikipedia.org/wiki/data_matrix
[2] MySQL DataBase Management System http://www.mysql.com
[3] Microsoft ASP.NET Framework http://www.asp.net/
[4] Mono Project http://www.mono-project.com
[5] NHibernate http://nhforge.org

*(ms. pres. il 13 maggio 2011; ult. bozze il 30 luglio 2012)*