# The Future of Coordinate Reference Systems - *Stefan A. Voser*

## Introduction

The European Commission has already organised two workshops on coordinate reference systems. The first one held in November 1999 dealt with geodetic reference systems, the second one held in December 2000 dealt with map projections. This shows the importance of the topic not only for scientists, engineers, technologists, but also for users and politicians.
Coordinate reference systems are the mathematical fundamentals for geospatial management. Their integration into digital geomatic tools such as GIS and remote sensing tasks, navigation applications and computer-aided cartography is a must. And there is also an ongoing process on harmonisation, normalisation and coordination. [see e.g. Voser 1998, Voser 2000].

In the past, most of the different types of coordinate reference systems were treated separately, and only few experts were aware of the complexity of their handling and the relationships among them. A user of geospatial information was only confronted with the topic when making measurements from maps.

Nowadays, every user of digital geospatial information should be aware of coordinate reference systems, their importance for understanding coordinates describing geospatial locations as well as the handling of the coordinate reference system management. Here still is a big deficiency, and also its integration into geospatial tools is insufficient or not user-friendly, or the knowledge to identify the correct coordinate reference system instance makes problems due to missing information or knowledge.

## Digital Geospatial Management (DGM)

Modern technologies have an increasing large influence into our daily life. It affects our (tele)communication as well as our focus, the geospatial management: navigation on the water, in the air and on land, the digital compilation of inventories about the landscape or the biodiveristy, environmental data, social and economic patterns. Some overview about the wide spectrum is also found by the list of EC projects presented in [Annoni 2002]. All these geospatial management tasks require a large amount of models, knowledge, experience and tools.

The growing discipline of geomatics is covering more and more different, specifically traditional disciplines such as geodesy, cartography, geography, informatics, ecological and social disciplines as well as economic marketing strategies. Because of that, a lot of interdisciplinary teamwork is required to build up compatible national and international geodata infrastructures[19]. In summary, this part of digital geospatial management (DGM) is a complex field, influences the workflow to solve geospatial tasks, may affect a higher efficiency, but also requires a lot of investments.

A fundamental requirement that often gets forgotten herein is the complexity of a digital coordinate reference system management (dCRSM) which is part of a general coordinate reference system management.

## Coordinate Reference System Management (CRSM)

Coordinate reference systems are an abstract construction to describe geospatial positions mathematically by coordinates. The mathematical construct is based on at least one coordinate system definition together with its geographic link to the Earth. This geographic relationship is given by the datum(s), describing the geometric fixation of the coordinate reference system on the Earth. Based on mathematical rules like the definition of metrics, different calculi to describe distances, angles, areas, volumes, directions etc. are derived by applying mathematical axioms and theorems. There exist a lot of coordinate reference system types and a much larger amount of instances. These facts make a rigorous coordinate reference system management (CRSM) indispensable.

The coordinate reference system management covers a very wide field of tasks to be solved. Its spectrum covers all topics of a general information management, including the use of digital tools and their standardisation. But

[19] a geodata infrastructure includes, data, tools, distribution of data, knowledge, education, human resources, logistics, institutions and organisations.

more over, the definition of CRS entities as well as their physical or technical implementation such as the construction and upkeep of geodetic reference frames etc. belongs to the management.

It is based on the vision, its abstraction to a theory delivering the fundamentals and methods for defining, describing and handling of coordinate reference systems. The fundamentals are found in mathematics, analytical and differential geometry, and their geospatial implementation is strongly related to geodesy, physics, and sensor techniques, but also is an important subject in astronomy and navigation and all methods for capturing geospatial information.

Hereby, coordinate reference system instances (e.g. ETRS89, a national map projection) and their physical realisations with coordinate reference frames (physically fixed points) have to be defined and implemented geospatially. Because a lot of different CRS types and instances may coexist, the relationships between them have to be described. This includes geometrical formalisms which may be very complex, and in many cases these geometric formalisms even are unknown.

## Current situation of CRSM in Europe

The current situation for the handling of coordinate reference systems still is far away of being comfortable for any user of geospatial data. There exist a lot of national systems (see e.g. [Voser 2000, Ihde et al. 2002]) and only few high-end tools currently support a CRSM based on a CRS-registry in combination with the required functionality and metadata. The user still has a CRS puzzle to solve, and one of the most current problems is the missing CRS assignment to the data. The users often do not know where to find it. Moreover, they don't understand the underlying concepts.

Since 1996, the MapRef-internet collection [Voser 2000] publishes a lot of required CRS information. The MapRef collection is built up individually by the author of this article, but the spirit was born by a project which was funded by the German Federal Agency for Nature Conservation (BfN) from 1994-1996 where the geometric homogenisation of various European geodata sets had to be solved (see e.g. [Voser 1995, Voser 1996]).

Based on the idealistic vision, MapRef became a very broadly and frequently used source to match already many of the European users' needs. It still needs that the software industry provides the required harmonised CRS infrastructure, and this not only for high end tools.

The European coordination for CRSM began to become public with the first EC Workshop in November 1999. Before, the topic was dealt only within expert circles like the geodetic initiatives on the establishment of the European Terrestrial Reference System 1989 (ETRS89) or the European Vertical GPS Reference Network (EUVN) [Annoni, Luzet 2000, p. 50f]. In the late nineties, various European countries began to adopt ETRS89 as their new geodetic reference system.

At the 1999 EC workshop [Annoni, Luzet 2000], it was recommended to adopt ETRS89 as the geodetic reference systems for projects within the EC and also to establish a public domain list of CRS parameters which isn't available yet. In the 2000 EC workshop [Annoni et al 2002], a set of new European projection instances are recommended at least for the EC needs.

Map Projections and spheroids are used to describe primarily horizontal position, whereas the height often is treated within different CRS systems. A connecting effort is also done by the geodetic community [Ihde et al. 2002, Ihde/Augath 2002a].

At a technical level, various efforts have already been made to include the CRS assignment to the datasets. Various high-end geomatic tools support this requirement; some data formats support such system assignments as well. Best known therefore is the raster format GeoTIFF in which the CRS identity codes are based on the EPSG database. At standardisation level, the OpenGIS Consortium as well as ISO TC211 works on a semantical, technical and functional level to reach interoperability for CRSM. But an overall coordination is missing.

## The User's need of CRSM

There is always a big gap between the experts and the users of spatial data. By the information technology and the increasing use of automated navigation and positioning tools as well as the increasing market for geospatial data, also coordinate reference systems and its management came into focus by public interests. In many cases, the user's needs for solving his problems can't be satisfied by the information or infrastructure the user has access to. In this case, the user's problems can mostly be solved by at least one of the following services:

- a centralised source for getting the missing information (e.g. the MapRef-Collection [Voser2000])
- a tool that manages the referencing problems
- a service he can request
- experts solving the referencing problems.

## Coordinating CRSM Activities

The recent activities for a CRSM were embedded very little into an interdisciplinary network, and in many cases, these different efforts didn't neither know nor learn from each other. The CRSM network has to connect geodesy, cartography, GIS, geophysics, mathematics, geometry and application sciences (e.g. navigation, informatics...).

This network needs an information channel for all activities (science, education, industry, standardisation, authority bodies, service providers ...). These concepts e.g. may be found at the MapRef-Collection [Voser 2000], but it has to be embedded into a newly founded organisation. This organisation should become the regulatory and coordination body for the wide range of CRSM. It has to be discussed if this organisation only covers the European interest or already the world-wide interests. Next to the already discussed requirements, the following tasks and services should be covered:

- a library of historic and actual coordinate reference systems
  - definitions, metadata, responsibility etc.
  - identifying relations and their parameters between the different systems (including description of geodetic networks)
- a registry for coordinate reference systems
  - unique identifiers including harmonised naming conventions for CRS entities as well as for transformation methods and transformation parameters
  - quality controlling routines for CRS-services
- coordinating activities in research, science, tool development, user requirements and further more ...

Therefore a strong regulatory rule set has to be developed and the current developments at international standardisation level should be considered as well.

## Conclusions

Coordinate reference systems are the mathematical and physical fundament to describe geospatial positions. In future, an even more intensive interdisciplinary coordination in the field of this topic is required to reach technical and automated interoperability.

An urgent need therefore is as next steps:

- designing & building up a CRS registry
- publication of and easy access to the collected CRS entities and their relations
- coordination of research, education and development
- Establishing platforms for education.

To follow these steps, the currently available solutions should be developed further on. One aim may be to expand the MapRef Collection in order to meet the user community quickly.

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