The Unique Grid Cell Identification (UGCI) system was created using the Croatian cartographic map grid system as a basis for development. A short description of the Croatian map grid system is therefore provided. Cartographic map nomenclature is used to uniquely identify map sheets; e.g. grid cells. Nonetheless, because such nomenclature uses alpha-numeric and special characters and complex coding/decoding systems, it is not well suited for use with GIS, databases, internet services and other Information and Communications Technologies applications. UGCI has been developed to uniquely identify all spatial grid cells, no matter their scale. It should enable easy connections with spatial grid cell identifier systems of other Spatial Data Infrastructure communities, such as ecology, geology, meteorology, etc. Easier identification and use of spatial grid cells contributes to the interoperability of maps and other spatial data. Map is covering Croatian grid area in the scale 1:1 800,000. It is representing grids scales from 1:250,000 to 1:5000.

Keywords: grid cell identification; map series numbering and naming system; map sheet identification; spatial data infrastructure

1. Introduction

Different types of spatial grid systems can be developed for different purposes. They can vary from grids on an ellipsoid, sphere, or in a projection plane, to grids with different resolutions and scales, different grid shapes and so on. Regardless, identification of the grid cells should be as easy as possible to ensure the interoperability of spatial data. According to the authors’ knowledge, only a few other authors (Larsen, Holmern, Prager, Maliti, & Røskaft, 2009) have published articles concerning grid cell identification methods. It is important to emphasize that those methods are not applicable to the territory of the Republic of Croatia.

The EU INfrastructure for SPatial Information (INSPIRE) Directive defines the geographical grid systems as a referent annex I data theme that constitutes a spatial frame for linking other information (INSPIRE, 2010). The geographical grid system data theme is one of the fundamental data themes in Spatial Data Infrastructures (SDI). The main principles of the INSPIRE specification on geographical grid systems are to develop unambiguous referencing and identification of a grid cell. The INSPIRE coding system identify the cell size and the position of the lower left corner. A country is spatially divided according to administrative units and grid systems.
A cartography map sheet grid system is one of the main national grid systems. This work develops a grid cell identifier with a strong connection to the cartographic grid system (map sheet nomenclature). The goal is to develop a Universal Grid Cell Identifier (UGCI) system suitable for other communities: ecological, geological, meteorological, etc.

Development of new Croatian terrestrial reference system, cartographic projection as well official map grids is initiated by State Geodetic Administration of Croatia and development was done by Faculty of Geodesy University of Zagreb and Croatian Geodetic Institute.

Official cartography in Croatia uses the Croatian Terrestrial Reference System 1996, Transverse Mercator projection (hrv. Hrvatski terestički referentni sustav 1996, poprečne Merkatorove projekcije, HTRS96/TM) (Official Gazette, 2004a, 2004b). HTRS96/TM is based on the projection of the Geodetic Reference System 1980 (GRS80) ellipsoid. The Croatian territory is projected in one zone of the 600km × 600km defining grid area (Figure 1). The prime meridian is 16° 30′ (from Greenwich). It divides the grid area in two symmetric parts. The value of its linear scale is

![Figure 1. Croatian cartography reference system HTRS96/TM.](image)
0.9999. In order to avoid negative coordinates, E 500,000 m is assigned to the prime meridian. The origin of the grid system is in the upper-left corner of the grid area and has the HTRS96/TM coordinates E 200,000 m, N 5,170,000 m.

Official Croatian cartography uses grids in the scales: 1:250,000 (250k), 1:100,000 (100k), 1:50,000 (50k), 1:25,000 (25k), 1:10,000 (10k), 1:5000 (5k), 1:2000 (2k), 1:1000 (1k) and 1:500 (0.5k). More concerning the official Croatian cartographic projection system and grid systems can be found in Lapaine (2006a, 2006b, 2007a, 2007b).

Grid cell identification is made by considering a map scale hierarchy system (Figure 2).

![Figure 2. Hierarchy of grid identification.](image)

The grid area of the scales 250k, 100k and 50k is directly divided into grid cells. All other grids are divided inside the grid cells of the 50k grid (State Geodetic Administration, 2009). Where grid cells are hierarchically connected, the cell identifier contains information about all hierarchically connected grid cells (Croatian Geodetic Institute, 2004; Hećimović & Bakalbašić, 2009; Hećimović, Jakir, & Bašić, 2009; Hećimović & Jakir, 2010; State Geodetic Administration, 2013). The grid in the scale 1:500 hierarchy depends on the most grid scales; e.g. grid cell identifier 1:500 should contain the identifier of the grid cells of the scales 1k, 2k and 50k.

2. Grid cell identification

Grid cells can be identified in multiple ways. Nomenclature is the traditional system of cartographic map sheet identification. Simple natural (nonzero) numbers, however, are also used in practice.

2.1. Identifying grid cells using map nomenclature

Nomenclature, the traditional system to identify map sheets (grid cells), is composed of alphanumeric and special characters. Character coding/decoding in digital form is a demanding
process, and map nomenclature is not the most suitable for use in GIS, databases, services, and the other ICT applications that request SDI.

An overview of the nomenclature structure of all Croatian official maps is given in Table 1. Generally, it consists of a scale identifier and identifiers of grid rows and columns, as well as hierarchical relations to other grids.

Table 1. Nomenclature structure of official Croatian maps.

| Scale | Nomenclature structure of official Croatian maps |
|-------|--------------------------------------------------|
| 250k  | 2 5 0 250k-row 250k-column                      |
| 100k  | 1 0 0 100k-row 100k-row 100k-column 100k-column |
| 50k   | 5 0 50k-row 50k-row 50k-column 50k-column       |
| 25k   | 2 5 25k 50k-row 50k-row 50k-column 50k-column   |
| 10k   | 1 0 10k 50k-row 50k-row 50k-column 50k-column   |
| 5k    | 5 5k 5k 25k 50k-row 50k-column 50k-column       |
| 2k    | 2 2k 2k 2k 50k-row 50k-row 50k-column 50k-column |
| 1k    | 1 1k 2k 2k 50k-row 50k-row 50k-column 50k-column |
| 0,5k  | 3 0,5k 1k 2k 2k 2k 50k-row 50k-column 50k-column |

2.2. Identifying grid cells using natural numbers

To avoid problems caused by complex map nomenclature structure, grid cell identification with natural (nonzero) numbers is also used in practice. The most common approach of using natural numbers as grid cell identifiers is to label each grid cell with a natural number starting from the origin of grid (top left corner of the grid area) and beginning with the number one from left to right. The disadvantages of this kind of grid cell identification are:

- the identifier does not contain information regarding the scale of the grid cell;
- if only cells that cover national territory are labelled, because of the irregular (not rectangular) shape of the country’s borders the logical order of grid cell identifiers will be lost, and if grid cells are dropped or added at the border area, the identification system becomes more complicated;
- at larger scales, there are many grid cells, making it difficult to orient a grid cell in space according to a simple natural number;
- additional problems arise when printed maps are made and smaller pieces of land (e.g. a small, isolated island in the Adriatic Sea) are not present on the original, individual map sheet, but are presented separately on other map sheets to reduce costs.

2.3. Unique grid cell identification

Considering past experience using map nomenclature and natural numbers as grid cell identifiers, the principles how grid cell identifiers should be structured are defined below:

- the identifier should uniquely define each grid cell regardless of the scale;
- the identifier should be an integer data type to allow easier use in ICT systems;
the identifier should be as short as possible, but the unique identification of the grid cell should be preserved;
the identifier should be easily convertible to map nomenclature and other grid cell identifying systems.

To ensure connectivity with cartographic nomenclatures, the following rules are used as the starting point to define the structure of UGCI:
- integers are preferred as a data type;
- the map nomenclature with the most digits is used as the basis to develop UGCI, and this is the last grid cell in the grid (lower-right corner of the grid);
- scale information should be preserved.

Multiple forms of integer data types can be used (e.g. from 8 to 64 bit). The most commonly used integer data types (Java, C#, VB.Net, SQL, VBScript, C99 and others) can be found in Cheever (2013). A 32-bit integer is used to ensure native compatibility, taking into consideration operating systems, software frameworks, programming languages, application development platforms, databases, Internet services and other ICT applications. This means that the integer identifier of grid cells can have up to 10 digits and cannot be greater than 4,294,967,295 (Microsoft, 2013; MySQL, 2013; Oracle, 2011).

UGCI provides unique grid cell identification, such as map nomenclature, but also uses the advantages of natural numbers to provide for easier use by ICT applications. UGCI creates a standardization basis for the grid data themes of the INSPIRE and Spatial Data Infrastructure (SDI) systems in Croatia.

Following the established grid cell identifier principles and rules, UGCI can be defined for Croatian grids on every scale.

3. Unique grid cell identification of Croatian official map grids

The grid cells of the 250k grid are obtained by directly dividing the grid area into six rows and four columns (Figure 2). The UGCI of the 250k grid uses three digits to identify the scale, one digit to identify the 250k-row and one digit to identify the 250k-column (Table 2).

The grid cells of the 100k grid are obtained by directly dividing the grid area into 15 rows and 10 columns. The UGCI uses three digits to identify the scale, two digits to identify the 100k-row and two digits to identify the 100k-column (Table 2).

The grid cells of the 50k grid are obtained by directly dividing the grid area into 30 rows and 20 columns. The UGCI uses two digits to identify the scale, two digits as the 50k cell identifier within the 50k cell, two digits to identify the 50k-row and two digits to identify the 50k-column (Table 2).

The grid cells of the 25k grid are identified inside the 50k grid. A 50k grid cell is divided to form the 2 rows and 2 columns of the 25k grid. The UGCI uses two digits to identify the scale, one digit as the 25k cell identifier within the 50k cell, two digits to identify the 50k-row and two digits to identify the 50k-column (Table 2).

The grid cells of the 10k grid are identified inside the 50k grid. A 50k grid cell is divided to form the five rows and five columns of the 10k grid. The UGCI uses two digits to identify the scale, two digits as the 10k cell identifier within the 50k cell, two digits to identify the 50k-row and two digits to identify the 50k-column (Table 2).

The grid cells of the 5k grid are identified inside the 25k grid, and are defined inside 50k grid cell. The UGCI uses one digit to identify the scale, two digits as the 5k cell identifier within the 25k grid cell, one digit as the 25k grid cell identifier within the 50k grid cell, two digits to identify the 50k-row and two digits to identify the 50k-column (Table 2).
The grid cells of the 2k grid are identified inside the 50k grid. A 50k grid cell is divided to form the 625 grid cells of the 2k grid. The UGCI uses one digit to identify the scale, three digits as the 2k cell identifier within the 50k cell, two digits to identify the 50k-row and two digits to identify the 50k-column (Table 2).

The grid cells of the 1k grid are identified inside the 2k grid, and are defined inside 50k grid cell. A 2k grid cell is divided to form the 2 rows and 2 columns of the 1k grid. The UGCI uses one digit to identify the scale, one digit as the 1k grid cell identifier within the 2k grid cell, three digits as the 2k grid cell identifier within the 50k grid cell, two digits to identify the 50k-row and two digits to identify the 50k-column (Table 2).

The grid cells of the 0.5k grid are identified inside the 1k grid, and are defined inside the grid cells of the 2k and 50k grids. The 0.5k grid contains identifiers of the grid cells of the 1k, 2k and 50k grids, and its UGCI has the most digits. If the UGCI integer started with the scale number ‘5’, it would be greater than maximum allowed 32-bit integer 4,294,967,295. To keep the integer inside the allowed limits, the numbers 1, 2 or 3 could be chosen as the first digit. The number 3 is used because there is no scale that starts with this number, which makes conversion between grid cell identification systems easier. The UGCI of the 0.5k scale uses one digit as identifier of the scale ‘3’, one digit as the 0.5k cell identifier within the 1k cell, one digit as the 1k cell identifier within the 2k cell, three digits as 2k cell identifier within the 50k cell, two digits to identify the 50k-row and two digits to identify the 50k-column (Table 2).

The UGCI of the first grid cells in the grid area (upper-left corner of the grid area) and of the last grid cells in the grid area (lowest-right corner of the grid area) are given in Table 2.

4. Discerning map nomenclature from UGCI

UGCI should preserve easier connections with other grid cell identification systems, such as cartography map sheet nomenclatures (identifiers). Converting UGCI to map nomenclature should be done in two steps: determination of the grid scale and identification of the individual grid cell inside the scale. Scale can be identified from UGCI by analyzing the first digit of the UGCI and the number of UGCI digits. Using this information the map scale can be identified from Table 3.
After the scale of the grid cell is determined, cell identification within a grid scale should be made considering the structure of the UGCI given in Table 2. This is explained in a practical example in the next chapter.

4.1. Example of the nomenclature revealed by UGCI

The following practical example should illustrate the simplicity of revealing map nomenclature from UGCI. In this example, map nomenclature should be discernable for 51721911 UGCI.

The grid scale is identified in Table 3: the first UGCI digit is a 5, and the number of digits is 8; the grid is therefore on the 5k scale (Table 3). Because different ranges of UGCIs integers for different scales, the scale can be reviled from checking the range of UGCI integer. The grid cell within the 5k grid scale can be identified by knowing the UGCI structure for the 5k scale (Table 2); it is the:

| Map scale | The first UGCI digit | Number of UGCI digits |
|-----------|----------------------|-----------------------|
| 100k      | 1                    | 7                     |
| 10k       | 1                    | 8                     |
| 1k        | 1                    | 9                     |
| 250k      | 2                    | 5                     |
| 25k       | 2                    | 7                     |
| 2k        | 2                    | 8                     |
| 0.5k      | 3                    | 10                    |
| 50k       | 5                    | 6                     |
| 5k        | 5                    | 8                     |

After the scale of the grid cell is determined, cell identification within a grid scale should be made considering the structure of the UGCI given in Table 2. This is explained in a practical example in the next chapter.
• 17th cell of the 5k grid in the 25k grid,
• 2nd cell of the 25k grid in the 50k grid,
• 119th row of the 50k grid,
• 11th column of the 50k grid.

Map sheet nomenclature for UGCI 51721911 is:

```
5 - 1 7 - 2 - 1 1 9 - 1 1
```

Figure 3 shows the map sheet of the 50k scale divided into the grid cells of the 25k scale and
the cells of the 25k scale divided into the 25 map sheets of the 5k scale.
The map sheets for the scales 25k and 50k that contain the map sheet of the 5k scale are:

- 50-119-11 Brač (map sheet nomenclature of the 50k scale),
- 25-2-119-11 Pučišća (map sheet nomenclature of the 25k scale).

5. Conclusion
Spatial grid cell identification systems play an important role in spatial data interoperability and in
the development of Spatial Data Infrastructure (SDI). This work outlines the system of Unique Grid
Cell Identification (UGCI). The Croatian official cartographic map grid system, as one of the most
important grid systems, is used as the basis for its development. It uniquely identifies grid cells
regardless of their scale and relationship to other grid cells. The cartographic map sheet nomencla-
ture (cartographic grid system) contains alpha-numeric and special characters, and UGCI is an
integer data type. This makes UGCI more usable with respect to ICT applications and SDI needs.
A relationship between UGCI and cartographic nomenclature is preserved and can be easily oper-
ated. UGCI should enable easy connections with the grid cell identifier systems of other Spatial Data
Infrastructure (SDI) communities, such as ecology, hydrology, geology, meteorology, etc. It is the
defining standardization basis for using spatial grids in Spatial Data Infrastructure.

In future work, UGCI can be used as a basis to develop mathematical relationships between
grid cells, to use simple algebra operations to identify grid cells overlapping in different scales or
find neighbouring grid cells, etc. The UGCI development presented here could serve as a useful
tool in the development of other grid cell identifiers systems for different SDI communities.

Software
AutoCAD was used to draw the grids at different scales. The final map was designed using the Swiss carto-
graphic software OCAD and prepared for publishing in A0 format.

References
Cheever, E. (2013). Representation of numbers. Swarthmore College. Retrieved November 10, 2013, from
http://www.swarthmore.edu/NatSci/echeeve1/Ref/BinaryMath/NumSys.html
Croatian Geodetic Institute. (2004). Proposal for the map sheet grids of the official map scales from 1:250000
to 1:500 in the projection reference system HTRS96/TM, version 3.1, Zagreb [in Croatian].
Hecimović, Ž., & Bakalbašić, A. (2009). Proposal of the nomenclatures of the new official map sheets.
Geodetski list, 3, 199–214. [in Croatian].
Hecimovic, Ž., & Jakir, Ž. (2010). Nomenclatures of the new cadastre map sheets. Proceedings of the Fourth
Croatian Congress on Cadastre. 15.-17.2. 2010. Zagreb [in Croatian].
