

Mapping with GIS and Cartographic Software

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1 Mapping with GIS and Cartographic Software

Cartography predates the invention of Geographic Information System (GIS) by thousands of years. Up to 10 years ago, maps were made by professional cartographers, who had the time and the need to carefully plan where each map feature would be placed and consider the visual impact of the map. Nowadays, progression in GIS and Cartography software technology have converged in a suite of truly open and flexible tools which reduce time for map and chart production from days to hours, including for non-cartographic specialists. We will see in this lesson, why the map outputs from GIS are not always optimal, and learn the main advantages and disadvantages of Computer Aided Cartography and Geographic Information System for mapping purposes.

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Figure 1: map source: student work at IKA, ETH Zurich

Learning Objectives

- Learn the differences between the various kinds of existing digital cartographic software.
- Learn which software is right for specific purposes.
- Know the capacity and limitations of GIS for cartographic presentation.

1.1 GIS versus Cartography Systems

GIS and Cartography

Many recorded aspects of human activity need to be analysed and integrated in a geographical context in terms of maps.

The main task of cartography is to define the aim of a map and to visualise geo-data on paper or electronically. As a result of technological efforts, Geographic Information Systems (GIS) and Computer Aided Cartography (CAC) have been subject to huge advances during the last two decades. Due to high costs of computer technology and unsatisfactory solutions in earlier years, the breakthrough of both GIS desktop software and cartographic software occurred during the early 1990s. Since then, GIS and cartography software have simultaneously competed and complemented one another in some way.

Today, however, neither of them is to be ignored in its importance for the visualisation of spatial objects and phenomena.

In this learning unit, you will have an overview of Geographic Information System and Cartographic Software main objectives, as well as their differences. But you will above all learn why they complement each other.

1.1.1 Geographic Information System (GIS) versus Cartographic Software (CAC)

We can roughly sub-divide the software relevant for cartography into two groups:

- 'Geographic Information Systems' (GIS) and
- 'Computer Aided Cartography' software (CAC)

GIS programs generally provide a huge potential to store, manage and analyse referenced and interconnected data. In contrast to GIS, CAC software is mainly used for high quality visualisation of given spatial information. To achieve this, CAC users work with user-friendly graphic software with a large number of special functions and tools.

GIS and CAC visualisation of spatial information example

Discover the difference between GIS and CAC visualisation of spatial information by rolling over the following example with your mouse.

- A. GIS visualisation of spatial information (Land use in Rafzerfeld).
- B. CAC visualisation of the same information.

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Figure 2: map source: student work IKA, ETH Zurich

1.1.2 Overview of CAC and GIS products

The number of computer programs for spatial data analysis and visualisation have increased during the last decade. Within this learning unit, we will analyse the relationship and the differences between GIS standard packages, GIS desktop software, desktop publishing software (DTP), Computer Aided Design (CAD) and specialised mapping programs.

Overview of some CAC and GIS Software Products.

The following table gives a short overview of the main CAC and GIS Software Products.

Push Control + Right Mouse click to enlarge.

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Figure 3: Overview of some CAC and GIS Software products [?]

Desktop Publishing Programs (DTP)

Since the late 1980's, several graphic programs have been developed independently of GIS desktop software. They are suitable for an aesthetical graphic presentation. In contrast to GIS desktop software, desktop publishing programs (DTP) are not designed for spatial analysis as objects have no attached thematic attributes and no database for geographical position information. The most popular DTP programs are

- Adobe Illustrator
- Macromedia FreeHand
- CorelDraw

DTP programs generally work with stacked data layers, instead of a topological relation between attached element attributes. Therefore, the user has to identify and select identical objects in order to put them on a common separated layer. Thus, we can create different kinds of thematic maps by selecting certain layers.

In Desktop Publishing Programs (DTP), maps are created with layers. On each layer we put identical element groups which, can be switched on or off according to the user's needs.

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Figure 4: Data source: Vector 200 Dataset reproduced with the permission of swisstopo (BA057224), www.swisstopo.ch

When we import a map that has been prepared and presented in ArcView into the DTP program FreeHand, we lose the attached data attributes. It is possible to use a software extension (e.g. MAPublisher) in order to retain the attached data attributes. Using the attached database information we can attribute colours to the different land use zones on the map automatically. These different adaptation steps from the ArcView map up to the final cartographic presentation in FreeHand are shown in the following three views.



Figure 5: ArcViewHiddenAttributes.jpg

ArcView - hidden attributes.

This figure shows the contour lines of a land use map hiding the data set of attached attributes. The map has been created in ArcView (Desktop GIS).

FreeHand - initial cartographic representation.

By using the extension MAPublisher, we can import the map from ArcView into FreeHand. Thanks to such extensions, we do not lose attached at-

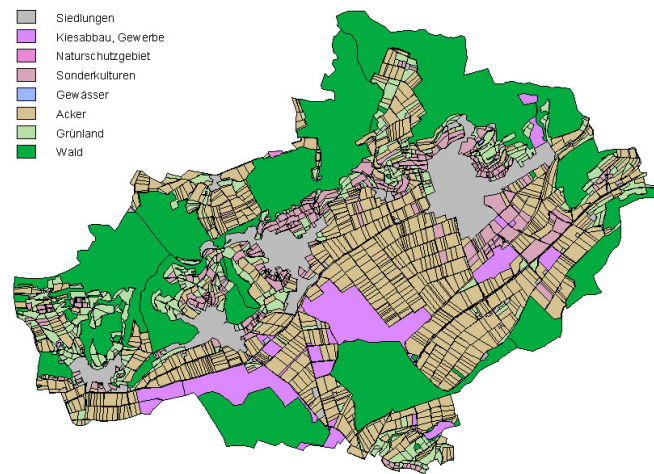


Figure 6: FreehandCartoPres.jpg

tributes during the data import. This is important for the identification of elements with identical attributes (e.g. forest). Once identical elements have been identified, they are grouped automatically, coloured and put on separate layers. Furthermore, FreeHand allows a selected area to be viewed.

FreeHand - with base map and transparent layers.

For the final cartographic presentation, the following adaptations have been made:

- Colours have been chosen according to the final presentation.
- A new digitised and generalised base-map layer has been attached to the thematic map.
- Relevant map elements have been symbolised. More complex symbols such as dashed lines, double outlines and asymmetric symbols have been adjusted.
- Adaptations for a consistent legend and layout have been made.

Computer Aided Design Programs (CAD)

Computer Aided Design Programs (CADs) are overall mapping toolboxes that fill the gap between the more simple Desktop Publishing Programs DTP complex Geographic Information Systems GIS. In a strict sense CAD programs process lines by modification of their graphic properties (such as line

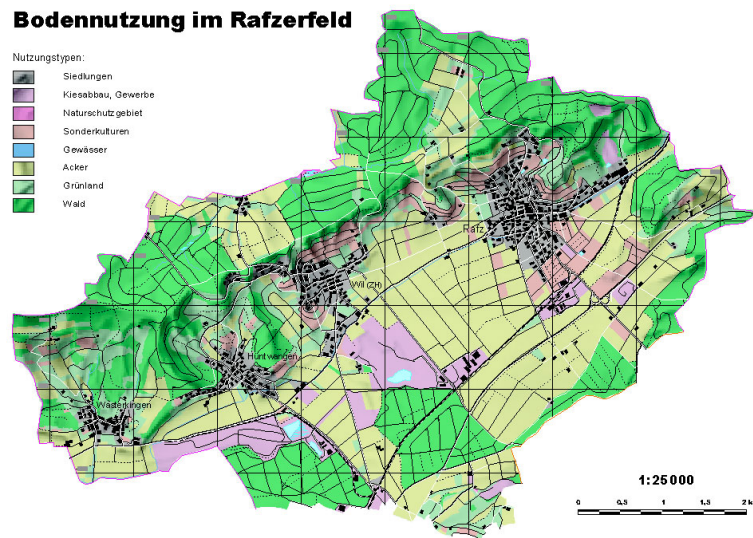


Figure 7: FreehandGoodPres.jpg

width and line character). Such line elements can be modified individually on different layers. The program combines standards of data visualisation overall database interfaces with a powerful spatial analysis engine and with object attributes. If spatial information are available, CAD programs are with georeferenced data. Options for data import, data management, data and data visualisation are integrated in CAD. Furthermore, they have combined vector data with layers of raster data or non-spatial attributes. Two well-known CAD programs are:

- Microstation
- AutoCAD

Initially, the CAD programs Microstation and AutoCAD were conceived for mechanical engineering, but the options have been expanded for other sectors and are often used for digital cartography. CAD programs are difficult to learn for beginners, which is a major disadvantage of this software. For this reason, CAD programs are not as user-friendly as other cartographic software (e.g. mapping programs, which are more convenient for cartographic purposes) [?]. The following examples show the different ways of visualisation of vector and raster data in Microstation:

Vector Data (Microstation) Usual visualisation of vector data in Microstation (symbolised and non-symbolised elements, grouped on different layers) [?]. Source: Planning and Information Research Centre GeoPlan

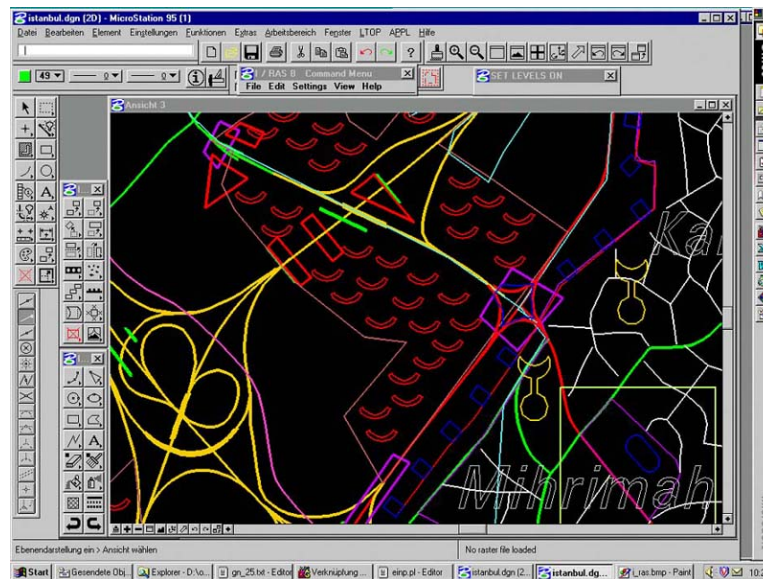


Figure 8: Vector Data (Microstation)

Raster Data (Microstation with additional Raster Tool “I/RAS B) Visualisation of symbolised raster data. For this raster option a special raster tool (I / RAS B) had to be downloaded [?] . Source: Planning and Information Research Centre GeoPlan

Mapping Programs

Mapping programs are suitable for users who work with a limited number of base maps. The main focus of mapping programs lies more in the visualisation of modelled spatial data than in the generation of geometric objects (see CAD programs). In contrast to DTP and some CAD programs, mapping systems (such as OCAD and Dry/Nuages) assign symbols, texture, and colours to a chosen object group. Furthermore, it is possible to georeference data. In addition, objects on the map are connected with a database, so that thematic aspects can be analysed. In this manner, thematic information can be attached to geometric objects. The following outline gives a short software overview of some selected mapping programs:

- OCAD
- Dry / Nuage
- RegioGraph
- Map Viewer

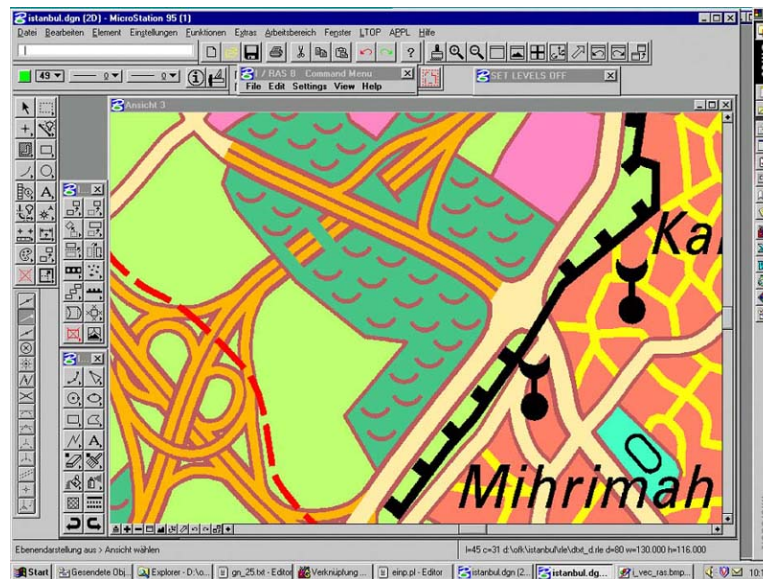


Figure 9: Raster Data (Microstation with additional Raster Tool “I/RAS B)

- THEMAK.2
- MERCATOR
- EASYMAP

Compared to GIS, mapping programs are easier and more user-friendly. A special layout mode allows aesthetic map adaptations for different map elements, map size, title, legend, colours, scale and map orientation. The ease of use of mapping programs, however, may lead to an unprofessional application of tools. Imprecise and skewed maps may be a result of this. The market for mapping programs has been growing continuously. Generally, the prices and the number of licences sold are not necessarily an indication of the suitability of a mapping program for a user’s needs. A simpler and cheaper program may be more suitable than an expensive, GIS-like program. The more individually applicable options a user requires, the better it is to buy an expensive mapping system [?] .

Statistical Programs and Spread Sheet Packages

In recent years, statistical programs have started to provide additional visualisation options for spatial data (‘map’ extension). From a cartographic point of view, however, these tools have a limited potential for creating high

quality maps, as they have been primarily designed for statistical purposes. The user has to pre-define the presentation setting and is not able to change them after its application [?] . Well-known Statistical Programs are:

- Microsoft Excel
- SPSS/PC+
- SAS/PC>

GIS standard packages and desktop software

Since the 1950s, several factors have changed the way in which spatial data is analysed: Improvements of computer hardware and graphic design, new theories about spatial processes in economic and social geography, increasing social and environmental awareness, education levels and mobility. As a result, in the mid 1960s the first GIS standard packages (e.g. "Canada Geographic Information System" CGIS) were created in order to process the increasing quantities of spatial data. The particularity of GIS is its topological structure, which enables the user to work with logical relations between different geometric elements and attributes. Due to this topological structure, GIS recognises elements having identical attributes (e.g. different objects with the attribute 'forest') although all elements are situated on the same level. Contrary to this, CAC software (such as DTP and CAD programs) are mainly used for data presentation. They often works with stacked data layers instead of topological relations. As there are no attached attributes, identical objects have to be grouped by putting them on a new layer. Today, GIS standard packages have reached new limits due to the infinite range of information that can be set in a geographical context. For this reason, the range of GIS applications has expanded continuously during the last decade. However, at the relatively advanced stage of development, many GIS standard packages are not very user-friendly, difficult to learn, and often rather expensive. Therefore, GIS standard packages have more and more been supplemented by GIS desktop software.

A map that has been created in desktop GIS ArcView 3 without any further extensions. The legend is pre-defined and objects cannot be changed or redrawn individually.

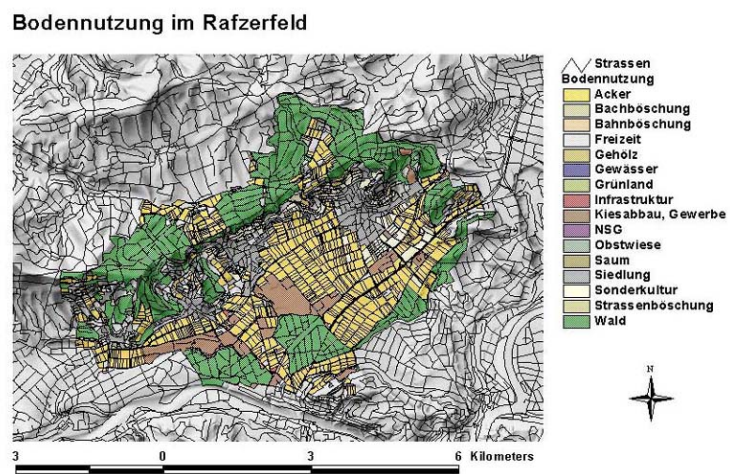


Figure 10: Comparison of Software Options

1.1.3 Summary

In this unit, you learned that GIS and CAC software cannot be ignored for the visualisation of spatial objects and phenomena, and that the main differences between GIS programs and CAC software leads to a strict division of tasks and applications.

However, to design cartographic products you should have knowledge of different computer programs and their relevance for your work.

1.2 Basic Functionalities of both Systems

Cartographic Functionalities

*Geographic Information Systems*¹ (GIS), is a rapidly growing field that incorporates knowledge from a wide number of disciplines. However, the outputs from GIS are not always optimal, particularly because the GIS software defaults often violate cartographic convention.

In this unit, you will learn the basic functionalities of GIS and Cartographic software, in order to choose the appropriate software according to your needs.

¹Geographic Information System

1.2.1 GIS Cartographic Functionalities

Advantages and disadvantages of cartography using GIS

It is true that analysing data is the real power of GIS, but analysis is wasted if you can not communicate your results. This is why more and more GIS includes some powerful cartographic tools. However, most of them are not adapted to the user and often violate cartographic convention. Furthermore, when analysing spatial data in a GIS, some temporary displays are quite often produced which are of course not intended for map communication.

Advantage of cartography using GIS

The technology of GIS mapping has evolved a lot in the last 10 years. This is why the GIS user has currently a wide range of functionalities and mapping tools at his disposal. Mapmakers which use GIS are no longer limited to simple black-and-white, letter-size pages produced on an office printer. You have now the choice of producing dazzling full-color paper maps from letter to poster size, high-quality published map products, and interactive maps with a GIS. With GIS you can easily:

- Create maps semi-automatically
- Manage layers
- Symbolise data
- Label maps with text and graphics automatically
- Layout and print maps
- Work with styles and symbols
- Look at data with graphs
- Create reports
- Query maps

You can optionally have a look at the following link to get some more information about “The ArcGIS Book: Cartographic Design using ArcView GIS (learn.arcgis.com/en/arcgis-book/). As cartography is a specialised form of graphic communication that requires training, practice and a certain sense of style, GIS will never (now as well as in the future) allow you to create automatically “National Geographic quality maps. You will learn, that most of the cartographic outputs from GIS are bad or false from a cartographic point of view.

Discover the cartographic tools within a GIS with some examples: Push the blue arrow on the right bottom to explore the slideshow.

Please note:

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Figure 11: image source: [?]

Disadvantage of cartography using GIS

When creating a map, if the user does not indicate a projection and grid system, a number of GIS software packages default to a “Plate Carree Projection. „Plate Carree is a projection which distorts the shape, area, and scale as the displays moves away from the equator. And therefore, there are countless examples of bad maps whose creators do not realise that they must indicate an appropriate projection (the default projection is, of course, usually not the best. This is a classic problem by using GIS for cartographic purposes: the user has not to understand the characteristics of the data or of the mapping techniques used because the GIS automatically selects the default settings. This problem is exactly the same for many other cartographic considerations like:

- **Classification:** The classification tools included in most current GIS package allows quick and easy classing schemes. This can lead to inappropriate choice, because no significant experimentation is needed. Another factor to consider is the number of classes: the default number of classes in GIS package is frequently too high: nine or ten, whereas five or six classes are enough.
- **Text Placement:** Labelling points, lines and polygons automatically is often imprecise or cartographically false. Overposting (labelling for one feature placed on top of labelling for another feature), bad polygon labelling (on left/centre/right) are other placement, are classic errors.
- **Colour schemes:** Often the default colour schemes are qualitative, this can be a real problem for choropleth mapping (which use quantitative data).

If your still want to create your map with GIS, never accept GIS default parameters as cartographic standards, and take in consideration that your map will look like a draft because colour calibration does not occur within

GIS. You can optionally download the following PDF to get some more information about classic errors of using GIS for cartography: “GIS Cartography Courses in GIS Certification Program (www.gitta.info/InstDigiCart/en/multimedia/GISCARTOGRAPHY.pdf)” (326 Kb).

Classical errors by using GIS for cartographic purposes

The following animation gives a short overview of the most classic errors using GIS for cartographic purposes. These errors are mostly due to the “default” configuration of the tools.

Push the blue arrow on the right bottom to navigate the slideshow.

Please note:

Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed.

Figure 12: mapsource: [?]

1.2.2 Cartography functionalities using CAC

Cartography using CAC

The task of digital cartography is to realise a meaningful presentation and a perfectly readable choice, for paper or electronic media distribution, of the GIS processed data. This is why an ergonomically graphic software with a wide range of special cartographic functions must be available to the mapmaker. As seen in the previous unit (GIS versus Cartographic Systems), many CAC systems exist. We will now present you the most needed tools for mapmaking, and also show you the advantages and disadvantages of cartography using CAC.

The most needed CAC tools for mapmaking

To depict the most needed CAC tools for mapmaking, we will have a look on the detailed functional demands for a new digital cartographic production system realised at the Federal Office of Topography in Switzerland:

- Input of analog and digital map data
- Visualisation of data on screen (WYSIWYG)
- Internal coordinate system
- Raster image manipulations
- Vector manipulations
- Editing of raster data (line art)
- Editing of vector data
- Hybrid processing of vector and raster data
- Text processing
- Processing of continuous tone data
- Bézier interpolation
- Data output

You can optionally download the following PDF to get some more information about the cartographic tools needed by Swisstopo for mapmaking: “Hybrid ”WYSIWYG” Techniques for updating the swiss topographic map series (www.gitta.info/InstDigiCart/en/multimedia/proc_hurni_christinat_stockholm_1997.pdf) (390 Kb).

There is no sense in listing all the tools within a CAC here. We will just describe two of them in order to have a better understanding of the functionality differences between CAC and a GIS.

- **WYSIWYG**

WYSIWYG is an acronym for “What You See (on your screen) Is What You Get (in printout).”

A common problem in cartography is getting graphic displays and printed colours to match. Ideally, when creating a map on a graphic display, we would like to push a button and print a map having exactly the same colours. Unfortunately, this is generally not possible, because the colour production methods of graphic displays and printers are dissimilar. Fortunately, most of the CAC software have the potential to assist this process with a *Colour Management System*², which make an attempt to match the colours produced on graphic displays and printers. GIS does not currently support properly WYSIWYG colours functions.

- **Transparency**

Transparency, which is an important tool for cartography, is presently unavailable in most of GIS, whereas most of CAC software includes it as a basic function.

Disadvantages of cartography using CAC

One of the main disadvantages of cartography using CAC is the loss of data attributes when importing GIS data. Indeed, when moving geographic data in a CAC software, shapes will be held whereas all the geographically critical aspects such as associated tables, coordinates, projections, scale and the resulting relationships among the elements will be lost. Therefore, you will not be able to edit attribute data, or undertake mathematical calculations on the attributes (for example, to calculate a percentage) of the geographical data within a CAC software. Some other common problems when importing GIS data in CAC software are:

- The GIS designated colours, fills and strokes, line weights, pattern styles for fills and strokes, fonts, etc. are quite often altered, or even lost.
- Labelling using attributes from the layers associated tables is not possible.

²Software (or software tool) that, in theory, enables colour to be matched on different display devices. E.g. a CRT display and an ink-jet printer.

- The projection properties and parameters are lost.
- Etc.

Some specific software (like Avenza MAPublisher) fill the gap between GIS technology and CAC software. They allow to view, edit and update GIS data attribute/code, select objects and view their attributes in CAC software.

Visualise with Examples some Advantages of Cartography using CAC

Roll over the red circles of the following GIS map with your mouse to visualise some modifications made in a CAC software to improve the GIS map. To look at the whole CAC map push the "Show the CAC map" button on the left.

Please note:

Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed.

Figure 13: Carto_discovery_GIS.swf

1.2.3 Summary of Main Differences between GIS and Cartography Software

For specific needs, users of cartographic software increasingly require attached databases and options to create high quality maps within one and the same program. Unfortunately, GIS programs are not very user-friendly and do not have important symbolisation and editing options. On the other hand, cartographic software lack functions for modelling, storage, management and analysis of referenced and interconnected data. Recently developed GIS desktop software tries to combine both, standard GIS operations and more user-friendly as well as more challenging visualisation options. Furthermore, extensions for simple graphic software now allow the user to import GIS data without loss of spatial information. Beside this, various mapping programs have been created in order to combine spatial information with a more flexible and user-friendly visualisation [?].

Conceptual and Functional Comparison between GIS and CAC software

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Figure 14: Overview of some GIS and Computer Aided Cartography Software

The overview of the main differences between GIS programs and CAC software in the previous table leads to a relatively strict division of tasks and applications [?].

Overview of GIS and CAC Software Products

The number of computer programs for spatial data analysis and visualisation has increased during the last decade. Find following, an overview of main GIS and CAC Software products. Roll over the table with your mouse to visualise the software options.

Please note:

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Figure 15: Comparison of Software Options

1.2.4 Summary

When using GIS for creating maps, it is crucial that you understand how the different mapping techniques are achieved within GIS, more particularly regarding the design elements and cartographic convention. GIS defaults are usually not the best choice when creating a map for communication purposes, this is why it is on your responsibility to be aware of the limitations of the software concerning cartographic output. Furthermore, the finest GIS cartographic packages have none of the capabilities of true high-end graphics packages as CAC software has. The problem with such graphic packages, however, is that they have no capacities for things like coordinate systems or data attributes when importing geographical data.

1.3 Mapping with GIS and Cartographic Software Evaluation

Test your knowledge about mapping with GIS and cartographic software with the following self-evaluation.

Start the evaluation by clicking with your mouse on the bottom right arrow "Click to start".

Please note:

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Figure 16: test_InstDigiCart.swf

This evaluation is a self-evaluation! Therefore, no feedback has be send to the tutor.

1.4 Summary

To design cartographic products you should have knowledge of different computer programs and their relevance for your work: when using GIS for creating maps, it is crucial that you understand how the different mapping techniques are achieved within the GIS, more particularly regarding the design elements and cartographic convention. GIS defaults are usually not the best choice when creating a map for communication purposes, that's why it is your responsibility to be aware of the limitations of the software concerning cartographic output. Furthermore, the finest GIS cartographic packages have none of the capabilities of true high-end graphics packages as CAC software have. But the problem with such CAC packages is that they have no capacities for things like coordinate systems or of data attributes when importing geographical data.

1.5 Recommended Reading

- GOODCHILD, M.F., 1980 *Algorithm 9: Simulation of Autocorrelation for Aggregate Data.* [?]
- JONES, CH., 1997 *Geographical Information Systems and Computer Cartography* [?]

Glossary

Colour Management System: Software (or software tool) that, in theory, enables colour to be matched on different display devices. E.g. a CRT display and an ink-jet printer.

GIS: Geographic Information System