Master Thesis

im Rahmen des
Universitätslehrganges „Geographical Information Science & Systems“
(UNIGIS MSc) am Zentrum für GeoInformatik (Z_GIS)
der Paris Lodron-Universität Salzburg

zum Thema

„Interoperability between CAD and GIS“

vorgelegt von

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u1106, UNIGIS MSc Jahrgang 2004

Zur Erlangung des Grades
„Master of Science (Geographical Information Science & Systems) – MSc(GIS)”

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Dornbirn, 31. März 2006

Erklärung

Hiermit versichere ich, daß ich die vorliegende Master Thesis selbständig verfasst und keine anderen als die angegebenen Quellen verwendet habe.

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Dornbirn, im März 2006

Zusammenfassung

„Interoperabilität“ ist ein viel strapazierter Bergriff im GIS Umfeld. Diese Arbeit versucht aufzuzeigen, was sich dahinter verbirgt. Dabei wird die Vielschichtigkeit von Interoperabilität deutlich.

So fehlt in vielen Fällen schlicht der Wille der zuständigen Stellen zur Kooperation. Aber auch fehlende Standards bei Datenbeschreibung oder beim Aufbau von Datenbanken sind ein gewichtiges Hindernis für Interoperabilität. Es wird deutlich dass das Problem Interoperabilität nicht nur ein Problem der Dateiformate ist. Nicht zuletzt gibt es auch semantische Differenzen, die Interoperabilität erschweren.

Die technischen Lösungsansätze für das Interoperabilitätsproblem reichen von der Entwicklung spezieller Datenaustauschstandards und Programmiersprachen über die Schaffung zentralisierter Datenbanken bis zu Web Services.

Verschiedenste Organisationen, von denen das Open Geospatial Consortium (OGC) wohl eine der gewichtigsten ist, beschäftigen sich mit diesem Thema genauso wie reine Zusammenschlüsse von Softwareherstellern. Die Schaffung von Standards wird als vordringliches Problem erkannt und daher vorangetrieben.

GIS und CAD Systeme wurden aus völlig unterschiedlichen Gründen für ebenso unterschiedliche Anwendungen entwickelt. In GIS und CAD Systemen werden daher Inhalte auf ganz verschiedene Art zum Ausdruck gebracht.

Ein spezielles Problem stellen Datenupdates in Basisplänen dar. Diese Daten dürfen unter Umständen nicht einfach in daraus abgeleitete Pläne übernommen werden, da dies ein Update in den abgeleiteten Plänen ebenfalls erforderlich machen würde. Dies ist aus rechtlichen Gründen nicht immer zulässig.

Nachdem die Vielschichtigkeit von Interoperabilität aufgezeigt wurde, wird anhand konkreter Softwaretests gezeigt, welche Probleme in der Praxis tatsächlich auftreten. In diesem Zusammenhang wird auch die verwendete Software genau vorgestellt um deren Möglichkeiten zu beleuchten.

Die Hindernisse beginnen beim Nicht-Erkennen bestimmter Geometrien, die eine Software standardmäßig verwendet, die andere aber eben nicht erkennt. Noch größer werden die Probleme beim Austausch von semantischer Information in Form von bestimmten Blockdarstellungen oder Linienarten. Zwei Usecases verdeutlichen auch Probleme beim Austausch von Daten, die in bestimmten Datenmodellen gehalten werden müssen bzw. Probleme bei Updates. Ganz wesentlich erscheint das Problembewusstsein als Hürde für die Interoperabilität.

Während der Trend der Interoperabilität sicherlich durch das Internet in Richtung der Darstellbarkeit oder raschen Verfügbarkeit von Information geht, wird es weiterhin auch Anwendungen geben, die eine Datentransformation zwischen verschiedenen Systemen erforderlich machen. Neben der Verfügbarkeit der Daten ist es also auch ganz wesentlich, dass diese Daten in der richtigen Form verfügbar, also wenn nötig auch editierbar sind.

Abstract

„Interoperabilityt“ is an often used term in GIS environment. This Master Thesis highlights what is concealed behind this term. As a result the many dimensions of interoperability came into focus.

In many cases simply the lack of willingness prevents cooperation. But all the same the absence of standards for data description or database design are a big problem for interoperability. It becomes clear that interoperability is not just a problem of data formats. Last but not least exist semantic differences that complicate interoperability.

Technical solutions for the interoperability problem extend from the development of special data exchange standards and programming languages to the creation of decentralized databases to web services.

Different organisations the Open Geospatial Consortium (OGC) probably being one of the most important, are concerned with this topic same as pure cooperations of software vendors. The creation of standards is recognised as the priority task and is therefore pushed.

GIS and CAD systems originate from completely different beginnings and were developed out of different reasons for different applications. Therefore the contents are expressed in various ways in GIS and CAD systems.

A special problem is data updates. When the basic data is mutated the interoperability with the derived plans becomes difficult because of contents differences. Under some circumstances the new data may not be exchanged and integrated into the derived maps because this would trigger updates in the derived data. This is a legal problem.

After focussing on the levels of interoperability software tests proof the problems in practice. In this context the applied software will be presented in order to demonstrate the opportunities.

The obstacles start at the not-recognition of special geometries that one software has integrated but that the other software might not support. Problems become even more obvious when exchanging semantic information; for example blocks or linetypes. Two usecases highlight problems with interoperability when data has to be managed in special data models respectively with data updates.

Very essential seems the consciousness of the problem as a barrier towards interoperability.

Because of the internet the trend in interoperability goes in the direction of displaying or the fast availability of information. But nevertheless there will further on be applications where it is necessary to have data transformed between different systems. Besides the availability of data it is essential that these data is available in the proper way so it can be edited if necessary.

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1 Introduction

1.1 Reason

Data Interoperability is a widely discussed topic. There are a lot of articles concerning data interoperability to be found. A lot of them concentrate on live data integration instead of data transfer. Also the Open Geospatial Consortium (OGC) specialises on interoperable solutions for the web or wireless and location-based services. Nowadays the demand is to quickly exchange information and not necessarily to exchange data. But against this mainstream there still exists the necessity to exchange and convert data from one software system to another. "Traditional, or thin pipe, GIS data translators force data through a limited data model that strips complex features of many attributes to arrive at the lowest common denominator for the source and target data formats. Typically, this is a one-way trip." (Monica Pratt, 2005)

The concrete reason for this work is that Leica Geosystems AG, Heerbrugg, Switzerland has designed a software solution for the interactive processing, visualization and maintenance of survey data directly in the field and for seamless dataflow between field and office called Leica MobileMatriX. (compare Leica MobileMatriX Product Catalogue, 2005). They are faced with customer's demands of importing and exporting various data into and from their system. Data from CAD systems has to be imported, manipulated and finally be exported back to the customer's system.

1.2 Aim

Based on literature research and on practical testing the main problems of GIS-CAD data exchange shall be highlighted in this work. An overview over the most popular theories concerning interoperability shall be given. To what extent do the theories cover the topic? Where are the strengths and the weaknesses of the theories? The theories shall be compared to each other and be contrasted to practical experience. Finally the limitations of the theories shall be explored. Do the theories keep their promise when it comes to practice?

Data models, semantic interoperability and the theme of updating processes will be discussed. The role of the OGC is also considered. And finally the attempt to gain information about future trends shall be made.

As the Interoperability problem concerns the average GIS or CAD user it is not the aim of this work to concentrate on technical solutions but to highlight the "every-day" interoperability problems and to find a simple solution without programming interfaces.

1.3 Questions and Approach

At first the question what interoperability is occurs. What kinds of interoperability are there and what solutions are to be found in the literature? What reasons make data exchange that difficult? Where are software vendors and organisations like the OGC on their way to interoperability? Is everything already solved or is there anything more to be done to achieve total interoperability?

After answering these questions by literature research interoperability will be practically tested. AutoCAD (Autodesk) and MicroStation (Bentley), being widely used CAD Software, were chosen as examples to show the possibilities and restrictions of the data exchange. Leica MobileMatriX is based on ESRI ArcGIS technology. Therefore the ArcGIS Data Interoperability Extension was chosen to test the possibilities of data import to ArcGIS and export from ArcGIS to AutoCAD and MicroStation.

The first questions in the practical testing are to find out what is possible at all using the Data Interoperability Extension, what can not be managed and what kind of data can be exchanged by using what means? After these tests the software developers know what is possible by this means and what they have to implement themselves. The emphasis is on importing and exporting data so it can be edited and not just to view data. Because of licence problems this question can only be tested with AutoCAD and not with MicroStation. But the main conclusions are independent from software. First a test scheme has to be found. All possible AutoCAD geometries are imported to ArcGIS and exported again. So it is possible to see where problems occur. If problems arise a possible solution is to be found and finally everything not possible has to be pointed out and explained. The aim is to make clear statements to every AutoCAD feature. In addition to simply conversion of geometries some practical workflows are described.

Furthermore two concrete use-cases will be solved. The aim is to find a solution for these two use-cases. The first use-case concerns data models. Someone wants to generate data by surveying in the field and export it to MicroStation after the fieldwork. The problem is that data has to be exported on the correct level, with a defined line style, colour etc. The challenge is to find a way to export all data so it fits the data model.

The second use-case is to update a nature preservation map with less possible effort after all forest extensions have been updated. The nature preservation map itself is updated in the field. The surveyor’s data is the legal bases for the map so it has to be integrated. The modified data has to be exported to AutoCAD Map and will there be processed with a special application. The methodology with the two use-cases is first to find out what kinds of problems emerge. Then possible solutions have to be developed and tested. After deciding which solution is best this one will be applied.

2 Literature Research / Theory

2.1 Interoperability

At first the literature research shall answer what interoperability really means. Why can data not be simply transferred into another format? What are the dimensions of interoperability that make it such a widely discussed topic?

2.1.1 Definition

Preetha Pulusani (2003) gives a good example for non-interoperability in every-day-world. She compares it to a Sony CD-player only playing Sony CD´s. Another example for being only partly interoperable is sending an e-mail in html format and the recipient gets it in rich text.

The term "interoperability" is used in a wide range of connections. In most definitions people agree that interoperability requires at least two systems that work together in some sort of way.

- Operable: so that one can work with (Duden, 1996)
- Interoperability: "A condition that exists when the distinctions between information systems are not a barrier to accomplishing a task that spans multiple systems." (Fernuniversität in Hagen, 2005)
- Interoperability: "The capability of components in a computer system to communicate with other components or to perform in multiple environments. In GIS, interoperability standards determined by the (Open Geospatial Consortium) allow Web services from different origins to be used cooperatively." (ESRI, 2005)
- "For most, interoperability refers to the ability of two systems to work together without having to modify one or the other. For others, it means the ability to utilize one or more components in one or more systems in a plug and play manner. For some, it means that data from one system can be shared with another." (Kurt Buehler, 2005)
- Interoperability: "capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units" [derived from ISO 2382-1 and 19119]" (OGC, 2003)
- Interoperability is the ability of two or more systems or components to exchange information, and to use the information that has been exchanged (Chin-Lung Chang et al., 2005).
- "Many definitions of interoperability exist but in the context of information sharing it is fundamentally the ability to exchange and use information across different hardware and software without special effort." (Michael Rose et al., 2005)
- Open Interoperability: "applications must be able to other applications (regardless of vendor brand format or platform)" (Preetha Pulusani, 2003)

In the following interoperability will be used as defined by Michael Rose et al. With the additional specification that using information includes being able to edit this information or the data containing the information.

2.1.2 The Dimensions of Interoperability

Michael Rose et al. (2005) define the following interoperability principles:

- “that data should be collected once and maintained at the level where this can be done most effectively
- that it must be possible to combine seamlessly spatial data from different sources across the EU and share them between many users and applications
- that it must be possible for spatial data collected at one level of government to be shared between all levels of government
- that spatial data needed for good governance should be available on conditions that do not restrict its extensive use, and
- that it should be easy to discover which spatial data are available, to evaluate their fitness for purpose and to know which conditions apply for their use. “

This implies that there is more about interoperability than just the format problem. Carl Reed (2005) also emphasizes that beyond the technical interoperability, systems, procedures and culture of organizations have to be “managed in such a way as to maximize opportunities for exchange and re-use of information,...”

Allan Levinsohn (2005) names in his article in Geoworld the following parameters for interoperability and so also focuses on the different aspects of interoperability:

Interoperability level	Prerequisite for interoperability	Status
Institutional	Willingness to interoperate	Varied and unspecified
Information models	Formalization of data descriptions	Early stages of development
Data schema	Adoption of database standards	Vary depending on sector
Data exchange	Industry-standard APIs and tools	Available and expanding
Networks	Standard network protocols	Well established

Tab. 1: parameters for Interoperability (Allan Levinsohn, 2005)

Kurt Buehler (2005) distinguishes various dimensions to interoperability:

- Data Format Interoperability
  In the history of GIS many file formats have been invented and partly disappeared again. Well known formats are for example Esri shape or Autodesk dwg or the dxf file designed for data exchange. In recent years the Extensible Markup Language (XML) has become very important for the creation of structured files. “XML provides a simple and powerful data encoding language that can be used with additional structural definition to represent geospatial information very effectively.” Geographic Markup Language (GML) is a XML derived language defined by OGC to integrate across vendor systems.

- Metadata Interoperability
  Sharing information about information or data is valuable specially when data is stored for later use. Kurt Buehler names two important content standards: the Federal Geographic Data Committee (FGDC) content standard for digital geospatial metadata

and second the ISO 19115: metadata. Both standards have XML schemas defining the content model.

- Data Content Interoperability
  “The interoperability of data content can refer to (a) the ability to determine what the content is and how it is defined ... when combined with actual standardization of content, is what we refer to when speaking of *data content interoperability.*” Kurt Buehler (2005) also outlines two aspects of data content interoperability. One is “the representational or type system”. Structured Query Language (SQL) and XML are named as the two most common representational systems. The other aspect when talking about content interoperability is “the content model itself”. To ensure data content interoperability both aspects should be highly standardized. He names two examples of abstract modelling tools to represent the content. One is the entity-relationship model and the other is Unified Modeling Language (UML).

- Database (or Query) Interoperability
  The standardized query language SQL underlies a development process. The latest generation of SQL contains a spatial extension. This is related to the OpenGIS® Simple Features for SQL and to ISO Standard 19125-2 for simple feature data access. The Simple Feature Model together with feature content standards enable ”interoperable access to geospatial feature data in relational data stores at the level of SQL queries.”

- Component (or Application) Interoperability
  This is not only a problem of interoperability between desktop software applications but has also to be considered with distributed systems. Geospatial vendors have to decide which components to support.

- Services Interoperability
  “The term services interoperability refers not only to Web services but to all serviceoriented architectures.”

- Semantic Interoperability
  This term is close to data content interoperability. Semantic Interoperability does not only tell what geospatial features are and what attributes they have, but also “what they mean in an application context.” This is considered to be the highest level of interoperability.

  Tobun Dorbin Ng (1998) defines semantic interoperability as follows: “The ability of a user to access, consistently and coherently, similar (though autonomously defined and managed) classes of digital objects and services distributed across heterogeneous repositories, with federating or mediating software compensating for site-by-site variations.”

- Integration Interoperability
  “The ability to integrate components from all parts of an enterprise requires as many of the dimensions of interoperability to be supported as possible. All the types of interoperability listed and previously defined will help support *integration*.”

Very often people talking about interoperability only refer to the first dimension of data format interoperability. But all this dimensions have to be considered to achieve real interoperability.

2.1.3 Syntax and Semantics

Geospatial semantics is a research area that deals with understanding GIS contents.

Sumit Sen (2005) says that one of the problems with interoperability is that the subjects in GIS are no real world subjects but representations of the real world. A symbol language is used to represent the real world features. Based on Ogden & Richards he displays a Meaning triangle.

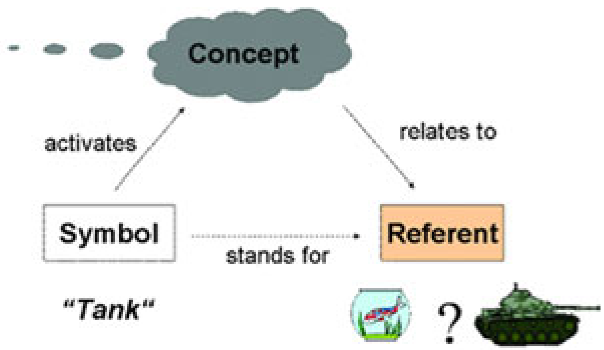

Fig. 1: The Semantic Triangle (Sumit Sen, 2005)

The Symbol "Tank" can mean different things. It can be a water tank or a military tank depending on the user's background or the context. So the "existence of common language does not necessarily insure interoperability." (Sumit Sen, 2005)
One has to agree that as long as people do not stay directly in front of the tank the plain word or symbol will always cause confusion and can only be interpreted out of the context.

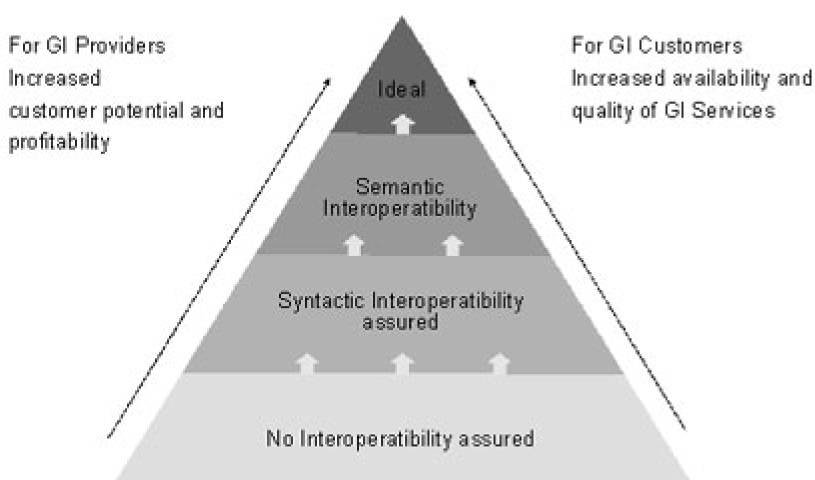

Fig. 2: Value of Interoperability (Sumit Sen, 2005)

To define semantic interoperability Doerr et al. (2003) maintain that “information integration at semantic levels consists of mapping between concepts of the two systems or communities.” Whereas the standardization of language and data formats are called syntactic interoperability.

Allan Levinsohn (2005) also identifies the semantic problem when he says that “Each geographically related discipline and its many sub-disciplines (e.g., forest management, urban planning, land registration, cartography and photogrammetry, transportation, etc.) has its own language and conventions for defining "real-world" features. ... Bridging the gaps that artificially divide geospatial reality requires a semantic and information modeling framework...”

W. Kuhn (2005) concerned himself with Semantic Interoperability. An overview of his statements shall be given in the following. He even calls Semantic Interoperability “the only useful form of interoperability”. Languages are based on agreements. Even technical terms like “overlap” do have a fixed meaning “that is sometimes formally defined and often made explicit in the form of feature-attribute catalogues, interoperability standards, legal regulations, and other defining documents.”

He further claims that before semantic interoperability can be obtained, the semantic heterogeneities have to be sorted out. This process is called matchmaking. It refers to the compatibility of offers and requests for data or services. The heterogeneities can be:

- Naming heterogeneities (same concept but different expressions)
    - Syntactic naming heterogeneity (different symbols)
    - Structural (different expressions)
- Conceptual heterogeneities (same symbol expresses different concepts). For example a distance measured once on a plane and once on a sphere.

Finally he defines problem classes of semantic operability

- Data Discovery and Evaluation
- Service Discovery and Evaluation
- Service Composition

As services are not subject of this thesis the only relevant problem class is data discovery and evaluation. This is a problem of ambiguities in interpreting terms or the attribute names. Existing metadata standards could help to solve this problem.

A lot of coordination will be necessary so that for example every road department even within one state uses the same attribute schemas, measurement types and data types in describing a road. The same problems occur with their metadata. (Mark Reichardt, 2004) And a lot more of coordination is afforded for different states like within the European Union and to achieve interdisciplinary standards.

2.1.4 The “Soft” Dimension

Michael Rose et al. (2005) see interoperability as a theme that is more than a discussion about standards and technology. They declare policy, education, partnerships and co-ordination as the “barriers towards interoperability in the UK”.

They claim that policy and education barriers include:

- “continuing domain silos that result in inoperable information being produced. Often a product of a discipline oriented approach to delivery
- the continuing lack of awareness of the relevance of broader information issues and a failure to recognise new best practices
- a lack of awareness of the wider benefits of interoperability such as the cost savings and wider use of information for other initiatives and policies
- a lack of overarching information management policies within organisations and across sectors covering standards, metadata, information sharing, future proofed solutions, updatability, etc., and,
- a perceived complexity and uncertain application of the freedom of information and copyright laws. “ (Michael Rose et al., 2005)

Concerning partnership and coordination they make out the following issues:

- “a lack of understanding of drivers and inferred drivers underpinning the formation of partnerships. Many agreements and partnerships exist, but few have an explicit objective to deliver interoperability. Current examples of interoperable partnerships are largely due to the efforts of visionary individuals;
- differing 'commercial' drivers between organisations and a lack of understanding of these differences;
- copyright and intellectual property rights (IPR) issues are dealt with in different ways leading to misunderstanding or avoidance of dealing with the issues; and
- a bottom-up approach to developing interoperable solutions in the absence of central co-ordination.” (Michael Rose et al., 2005)

As a result of these barriers there is still a lack of information interoperability although information volumes are growing.

Allan Levinsohn calls „willingness to interoperate“ a „prerequisite for interoperability“. Before this can be provided the participants of the interoperability have to know each other’s data. But even then the willingness is subject to several factors like

- Behavioral factors such as "turf" protection
- Economic factors such as cost recovery and the added costs associated with enabling interoperability
- Legal factors associated with copyright and other information legislation
- Job security issues (perceived or real)
- The organization's role in relation to its peers and clients” (Allan Levinsohn, 2005)

These articles show that besides all technical achievements or standardisation the human component will always be part of the interoperability problem. Out of the most diverse reasons single humans, organisations or whole states can be a barrier towards interoperability. This will be the most difficult dimension of interoperability to solve.

2.2 Possible Solutions

Now that the problem has become more obvious the solutions suggested in literature shall be highlighted. Obviously there is not one solution but a bunch of answers to a widespread problem like interoperability.

2.2.1 Technical approach

It is not the aim of this thesis to deepen the technical issues concerning interoperability. So just a short overview shall be given.

2.2.1.1 Standards, Architectures and Languages

As interoperability became a topic of interest, Spatial Data Transfer Standard (SDTS) was invented to have a single format for a data type. The U.S. Geological Survey (USGS) and its partners approved SDTS in 1992 after 12 years of development.

"During the past decade, several technologies have emerged that provide the infrastructure to enable interoperability, of which the Component Object Model (COM), the Common Object Request Broker Architecture (CORBA), and Java technology are the most notable." (Intergraph, 2003).

COM is an object oriented standard by Microsoft. It enables the exchange of binary components. COM is a client-server technology. Because of COM application development can be managed component based. Components are binary files that make up the application. The advantages of components are that they can be actualised, improved and replaced independently and that they can be re-used. COM is interprocessable because the same components can work in different processes and even on different computers and still be communicating with each other. (Michael Höck, Jochen Manegold, 2003).

XML is a text-based simple system to encode data. It is also independent from platforms. So it has emerged as "the standard for the exchange of data between heterogeneous systems." (Intergraph, 2003)

Based on XML the OGC (2004) developed GML and defined it like the following:

"The Geography Markup Language (GML) is an XML encoding in compliance with ISO 19118 for the transport and storage of geographic information modelled according to the conceptual modeling framework used in the ISO 19100 series and including both the spatial and non-spatial properties of geographic features.

This specification defines the XML Schema syntax, mechanisms, and conventions that:

- Provide an open, vendor-neutral framework for the definition of geospatial application schemas and objects;
- Allow profiles that support proper subsets of GML framework descriptive capabilities;
- Support the description of geospatial application schemas for specialized domains and information communities;
- Enable the creation and maintenance of linked geographic application schemas and datasets;
- Support the storage and transport of application schemas and data sets;

- Increase the ability of organizations to share geographic application schemas and the information they describe." (OGC, 2004)

The GML application schema(s) are an important part of GML data models. They are compliant with the standard OGC defined GML base schemas. A GML Application Schema defines a vocabulary for a particular domain of discourse by defining and describing the terms of that vocabulary (see ISO TC/211 19109) (OGC, 2004)

2.2.1.2 Databases

Another solution was the attempt to put all data into one database and have heterogeneous clients access this database. Workflows as well as infrastructure have to be reorganized. But it makes conversion processes with possible duplication of data unnecessary.

The solution of having one centralized database was for example realised by Intergraph, autodesk, Laser-Scan and MapInfo together with Oracle:

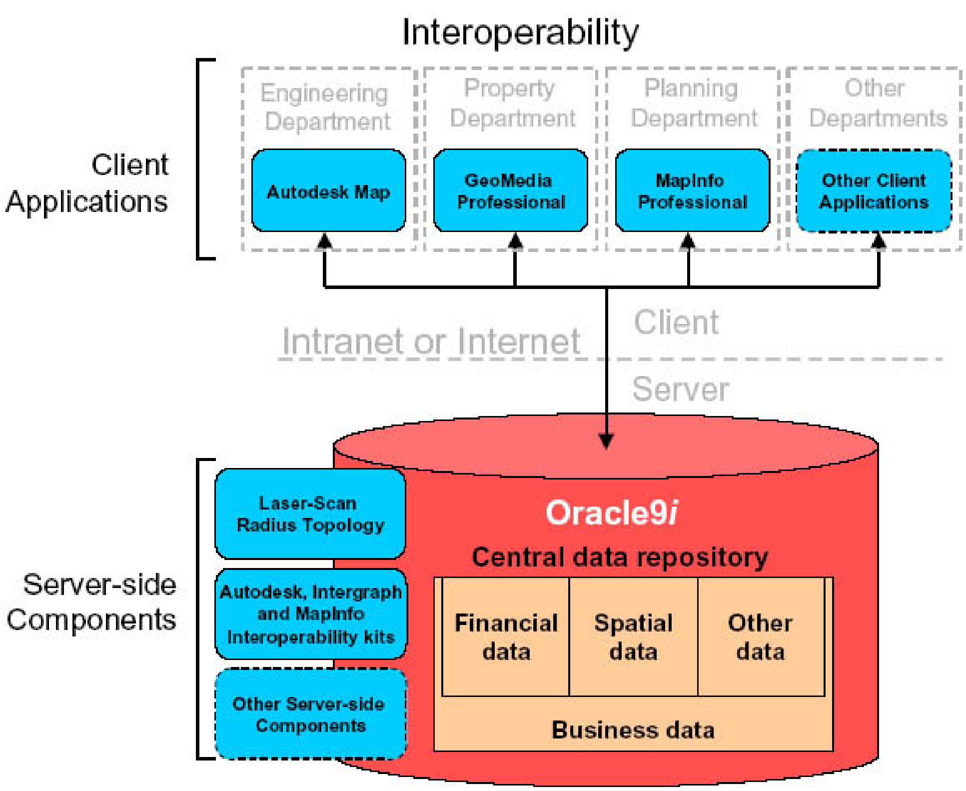

Fig. 3: Centralized database (autodesk, Intergraph, Laser-Scan, MapInfo, 2003)

In 2005 the update to Oracle 10g was carried out. Data can be managed by using Oracle tools rather than GIS middleware.

After having centralized database management systems (DBMS) the trend goes towards so-called "federated GIS".

CAD vendors increasingly adopting to industry DBMS standards, the full interoperability of CAD data in GIS and vice-versa is becoming more of a reality.

2.2.1.3 Federated GIS

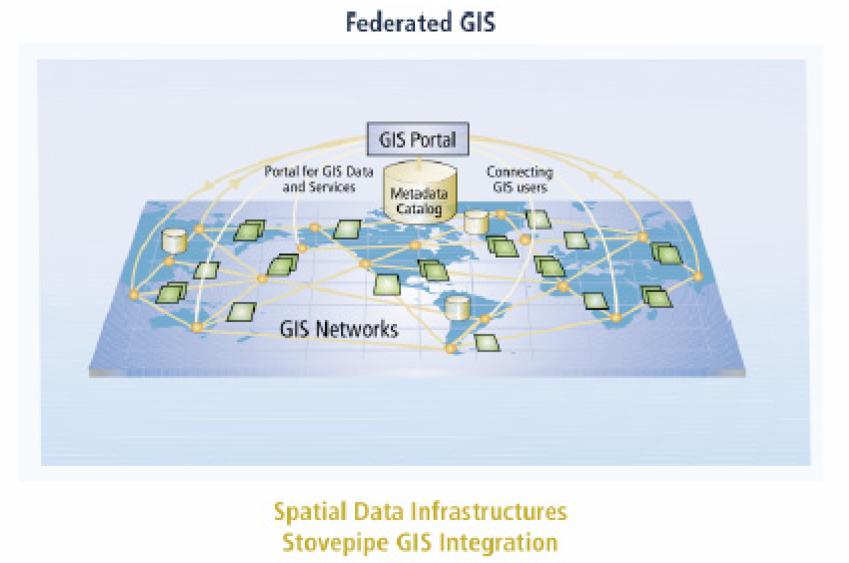

Fig. 4: Federated GIS (Esri, 2004)

The new Services-Oriented Architecture (SOA) is a concept developed by IBM, Microsoft and other organizations. SOA shall integrate heterogeneous application logic by using “servicesbased architectures developed originally for Web computing. GIS will be just one part of these implementations besides Enterprise Resource Planning (ERP) and other systems.” (Esri, 2004)

The trend goes on towards interoperable, independent, autonomous and distributed services. Web Services are very flexible because they can communicate independently from software platforms.

2.2.2 Standards

All the named technical solutions depend on agreements about standards. Therefore standards shall be discussed more deeply.

2.2.2.1 Trends

Two recent studies highlighted the importance of standards. The Delphi Study (“The Value of Standards”) observes “that there is a clear and sudden shift in attitudes towards software standards.” (Delphi Study cited by Peter Woodsford and Chris Wright, 2005). The second study conducted by DIN, the German Institute for Standardisation deals with the benefits of standards for business and economy. Mark Reichardt (2004) also cites the Delphi Study in his OGC White Paper and says that inter- and intra-enterprise interoperability is getting more important in recent years. He states that this is probably due to the Internet and Web, “whose open standards (HTTP, TCP/IP, XML, etc.) and extraordinary success give us a taste of what interoperability is all about.”

2.2.2.2 <u>Organisations and Initiatives</u>

It seems not likely that the whole global GIS community will ever agree to one single geospatial architecture or data standard. At the moment a lot of important standards exist. To name some of them there are:

- OGC (Open Geospatial Consortium)
  The OGC sets standards for "geoprocessing" (Lance McKee, 2005). OGC recognizes the importance of the International Organization for Standardization (ISO) and has established a very active so-called Class A liaison with its Technical Committee 211..." (Martin Klopfer, 2005) GML and other OGC specifications are becoming International Standard Organization (ISO) standards.
- International Organization for Standardization (ISO)
  ISO/TC 211 is becoming the authority for geographic standards. The standards "may specify, for geographic information, methods, tools and services for data management (including definition and description), acquiring, processing, analysing, accessing, presenting and transferring such data in digital/electronic form between different users, systems and locations." (ISO/TC 211, 2005)
- European Committee for Standardization (CEN) TC287
  CEN works in close cooperation with ISO. "The scope of CEN/TC287 Geographic Information is standardization in the field of digital geographic information for Europe." (Martin Klopfer, 2005) "The committee woks on a methodology to define, describe and transfer geographic data and services."
- NATO Standardization Agency (NSA)
- Organization for the Advancement of Structured Information Standards (OASIS)
- Internet Engineering Task Force (IETF)
- World Wide Web Consortium (W3C)
- Object Management Group (OMG)
- Institute of Electrical and Electronics Engineers (IEEE)
- Global Spatial Data Infrastructure Association (GSDI)
  „The purpose of the organization is to promote international cooperation and collaboration in support of local, national and international spatial data infrastructure developments that will allow nations to better address social, economic, and environmental issues of pressing importance." (GSDI Association homepage, 2005)

  This organisation has released "The SDI Cookbook" to enable the use of Spatial Data Infrastructure (SDI). SDI is more than a single dataset. It "hosts geographic data and attributes, sufficient documentation (metadata), a means to discover, visualize, and evaluate the data..., and some method to provide access to the geographic data." (GSDI, 2004). To make it work, organisational agreements are necessary.
- Infrastructure for Spatial Information in Europe (INSPIRE)
  "The initiative intends to trigger the creation of a European spatial information infrastructure that delivers to the users integrated spatial information services." (INSPIRE homepage, 2005)
- National Spatial Data Infrastructure (NSDI)

The Federal Geographic Data Committee (FGDC) develops the NSDI. It "encompasses policies, standards, and procedures for organizations to cooperatively produce and share geographic data." (FGDC homepage, 2005)

- World Wide Web Consortium (W3C)
- Open Mobile Alliance (OMA)
- Internet Engineering Task Force (IEFT)
- Open Design Alliance

  "Unlike typical standards-setting bodies, we focus on the practical matter of developing high-quality component software libraries which enable our members to develop applications capable of reading and writing popular CAD file formats, including: DWGdirect ... DGNdirect" (Open Design Alliance™ homepage, 2005). Although Autodesk promotes its dxf formats, the DWGdirect seems better for data exchange because dxf formats are 2.5 to 3 times larger than dwg files, because there is no automated synchronisation between dwg and dxf files and because dxf files can not be created automatically.
- And others

These organisations and initiatives create the frameworks and reference model. This is the basis for designing customer-specific open architectures, open data models and open interfaces etc.

2.2.2.3 Open Standard

"The OGC defines an open standard as one that:
1. Is created in an open, international, participatory industry process,...
2. Has free rights of distribution. ...
3. Has open specification access. ...
4. Does not discriminate against persons or groups. ...
5. Ensures that the specification and the license must be technology neutral. ..."

(Lance McKee, 2005)

2.2.2.4 Data Model

A conceptual model represents the real world. It is independent from technological issues. It can be represented in a graphical way through Unified Modeling Language (UML) or Entity Relationship Model (ERM) or as text using XML or Structured Query Language (SQL). CASE (Computer Aided System Engineering) Software can be useful to generate models. But tools specialized on modelling geographic data do not exist so far. The Swiss "Koordination der geografischen Information und geografischen Informatiossystems" (KOGIS) recommends Perceptory Software for Data Modeling.

a) Perceptory

Perceptory was developed at the Université Laval in Canada, Centre de recherche en géomatique. This freeware is "a tested, simple and efficient spatial database and spatiotemporal database visual modelling tool. It was created from a standard object-oriented formalism which was enriched to handle spatial references that take into account the ISO-TC211 standard;" The name Perceptory implies that it is “the user’s own store of perceptions whether...expressed formally... or expressed informally.” (perceptory homepage, 2005)

b) ESRI

A Data Model provides a set of simple data types and their attributes. ESRI has developed data models for many different industries. These application-specific models are not designed as formal standards. The models shall help users to develop their own system.

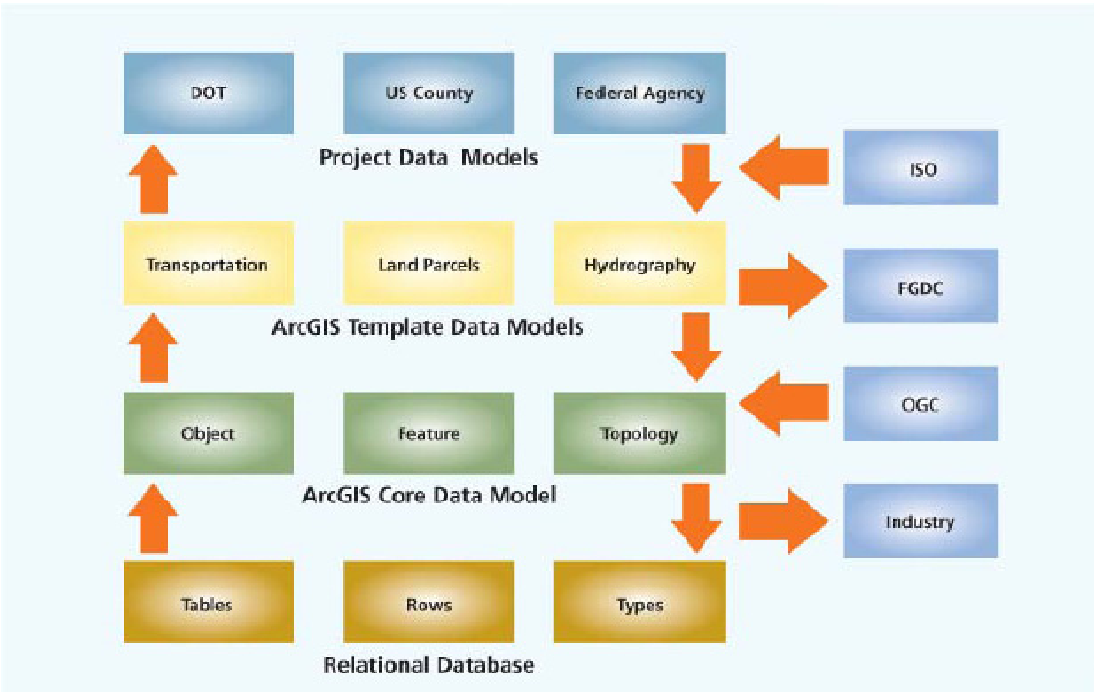

Fig. 5: ESRI Data Models (Esri, 2004)

c) The OGC Model

GML developed by OGC makes it possible to resolve many of the difficulties concerning incompatible data models. The XML tools can map GML encoded data from one model to another. There will remain elements of a model that cannot be transferred to the other model. But the XML tools highlight the inconsistencies so that professionals can concentrate on these.
(Mark Reichardt, 2004)

2.2.2.5 Geometry Object Model

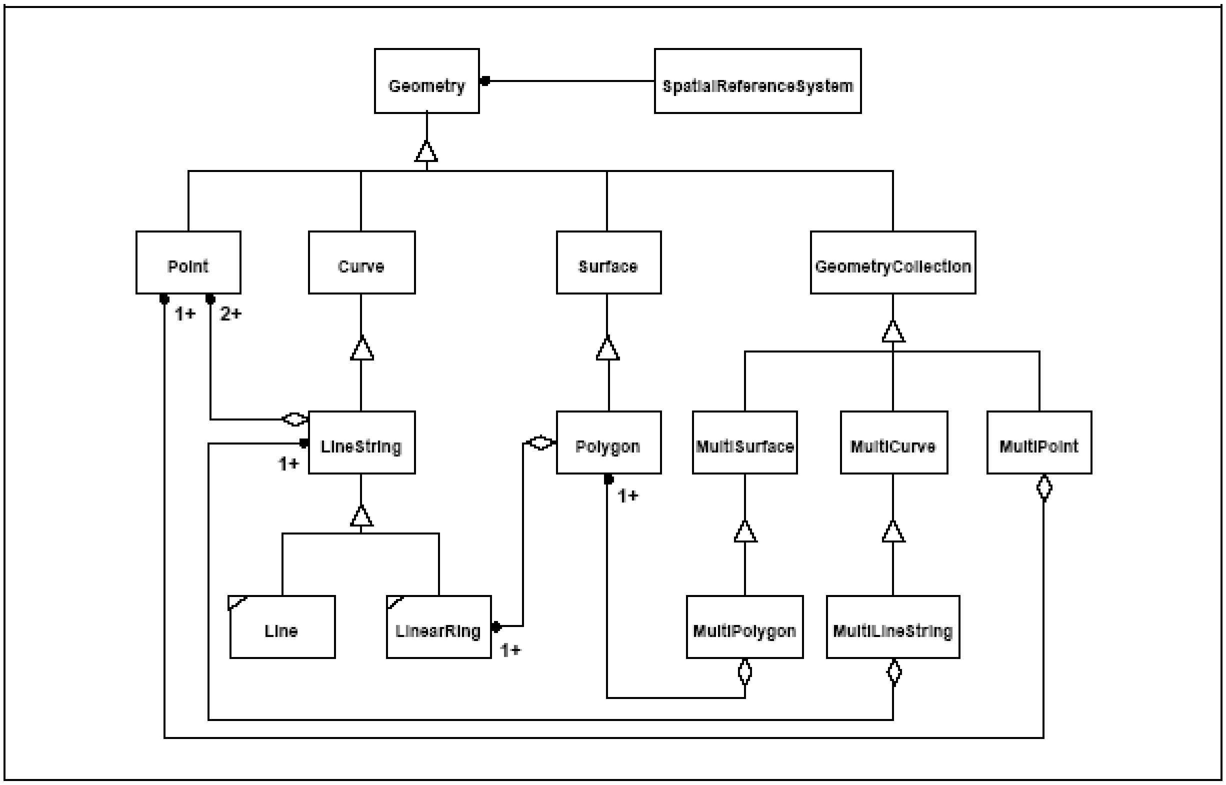

Fig. 6: Geometry Class Hierarchy (OGC, 1999)

The root class of this model is Geometry. Geometry has subclasses for Point, Curve, Surface and Geometry Collection. "Each geometric object is associated with a Spatial Reference System, ...". (OGC, 1999) In the Simple Features Specifications there are also attributes, methods and assertions for each geometry class specified.

2.2.2.6 Interlis

As this thesis is written in Switzerland the Swiss standard shall be explained. INTERLIS is a language for describing and exchanging geodata. An official documented and platform independent interface exists. The geodata content is defined in INTERLIS through application schemas. The INTERLIS Specification can be obtained as Swiss Norm SN612030.

In INTERLIS geodata transfer is done in text format with system independent ASCII format. Compared to this OpenGIS with its open interfaces and distributed nets is the more modern approach. INTERLIS is an addition to OpenGIS because it regulates a standardizised data description. Contrary to OpenGIS INTERLIS is focused on Business-to Business and not on the mass market represented through the Internet. INTERLIS offers more basis geometries than OpenGIS.

2.2.2.7 Open Geospatial Consortium OGC

One of the most important institution trying to set standards is the OGC. Therefore this special institution has to be mentioned specially.

a) Definition

OGC:

"*Acronym for Open Geospatial Consortium*. An international industry consortium of companies, government agencies, and universities participating in a consensus process to develop publicly available geoprocessing specifications. Open interfaces and protocols defined by OpenGIS Specifications support interoperable solutions that "geoenable" the Web, wireless and location-based services, and mainstream IT; and empower technology developers to make complex spatial information and services accessible and useful with all kinds of applications." (ESRI GIS Dictionary, 2005)

Self-explanation on http://www.opengeospatial.org/: (2005)

"The Open Geospatial Consortium, Inc. (OGC) is a non-profit, international, voluntary consensus standards organization that is leading the development of standards for geospatial and location based services. Through our member-driven consensus programs, OGC works with government, private industry, and academia to create open and extensible software application programming interfaces for geographic information systems (GIS) and other mainstream technologies. Adopted specifications are available for the public's use at no cost."

Open System:

"An 'open system' is one with characteristics that comply with specified, publicly maintained, readily available standards. Those systems can therefore be connected to other systems that comply with these same standards." (Carl Reed, 2005)

b) Programmes

- The OGC approach

- "Formalize OpenGIS Specifications Through Consensus: Through OGC's structured committee programs and consensus process, OGC members develop, review, and release OpenGIS Specifications.
- Organize Interoperability Projects: OGC employs testbeds, pilot projects, planning studies etc. to rapidly and efficiently test, validate, and document vendor-neutral specifications based on user requirements.
- Develop Strategic Business Opportunities: We identify user communities and markets in need of open spatial interfaces and engage those communities in development and adoption of OpenGIS Specifications.
- Develop Strategic Standards Partnerships: OGC harmonizes its geoprocessing standards with other IT standards through partnerships with international standards efforts.
- Promote Demand for Interoperable Products: Through our marketing and public relations programs, we work with our members and the public to increase users' awareness and acceptance of OpenGIS Specifications." (OGC, 2005 a)

The OGC coordinates its work with ISO especially with the technical committees TC/211 and TC/204.

"Interoperability success will require a complete translation environment that consists of a common spatio-temporal modeling language, a concomitant modeling tool, a database capable of supporting the structures in the model and a mechanism that provides an interface for information exchange. These tools are being developed through initiatives such as OGC, ..."
(Allan Levinsohn). To name this tools there is GML, UML models GML schemas, the Styled Layer Descriptor and others.

➢ Program overview

The OGC has three programmes to develop, release and promote open standards.

- Specification Program: Abstract – and Implementation Specifications are developed.
- Interoperability Program: This is a series of initiatives to promote the OpenGIS® Specifications. The work is based upon concrete use-cases.
- Outreach and Adoption: The OGC offers a lot of documents and resources to spread the open standards among the user-community.

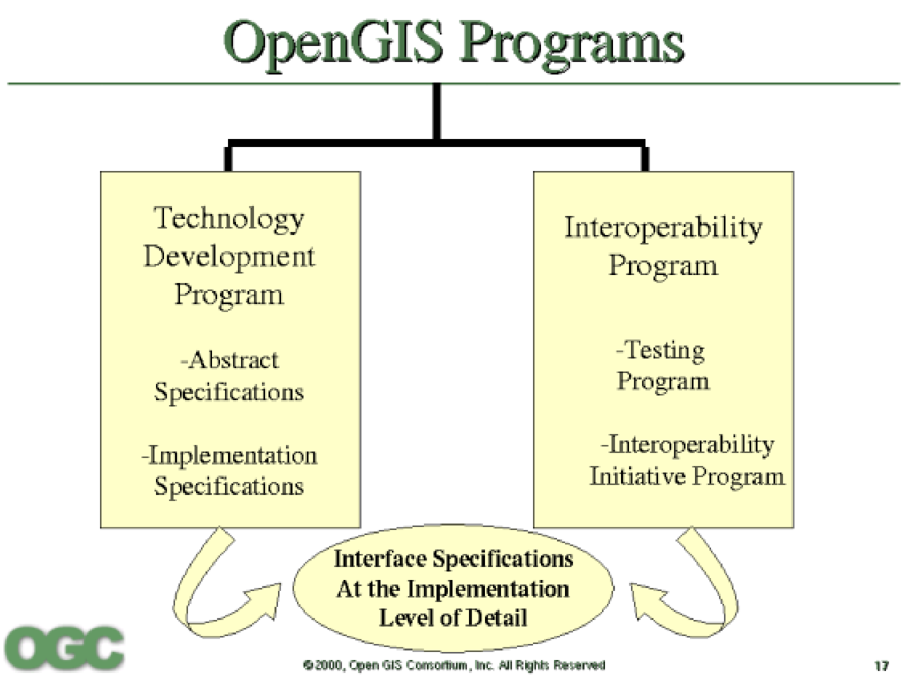

Fig. 7: OpenGIS Programs (Jens Fitzke, 2005)

The development of the concept model is defined in the Abstract Specification whereas the Implementation Specification gives technology specific information.

➢ Examples

"The OGC Reference Model provides a framework for the OGC Technical Baseline." (OGC homepage, 2005)

One Implementation specification important for this thesis is the Simple Features Specification. OpenGIS® Implementation Specification for Geographic information - Simple feature access - Part 1: Common architecture is also called ISO 19125. It "describes the common architecture for simple feature geometry." (OGC homepage, 2005). This object model is "Distributed Computing Platform neutral and uses UML notation." (OGC homepage, 2005). It defines a base Geometry class with subclasses for point, curve, surface and geometry collection. A Spatial Reference System describing the objects coordinate space defining the objects is associated with each object.

The OpenGIS® Geographic Objects Implementation Specification "defines a set of core packages that support a small set of Geometries,..." (OGC homepage, 2005)

Besides of specifications the OGC has also published recommendations like the Units of Measure Recommendation.

Most of the specifications concerning interoperability show that the OGC concentrates on Internet services. Therefore specifications for WebMapServers, WebFeatureServers or Styled Layer Descriptions are to be found.

2.3 CAD versus GIS

As special problems occur when transforming CAD data to GIS and vice versa this topic has to be looked at separately.

2.3.1 Differences

CAD and GIS can be seen complementary. Whereas CAD provides GIS with new content, GIS gives CAD context of the existing world. (Don Kuehne, 2004 b)

One reason for non-interoperability is that there are many fundamentally different kinds of geoprocessing systems. Besides GIS systems there are systems for Earth imaging, computer-aided design (CAD), location based services, facilities management etc. (Mark Reichardt, 2004)

Oosterom, 2004 also claims that CAD and GIS have one important thing in common which is that they both deal with geometry, but that they differ in many different aspects like size, storage, analysis, semantics, attributes etc.

The semantic differences can be portrayed

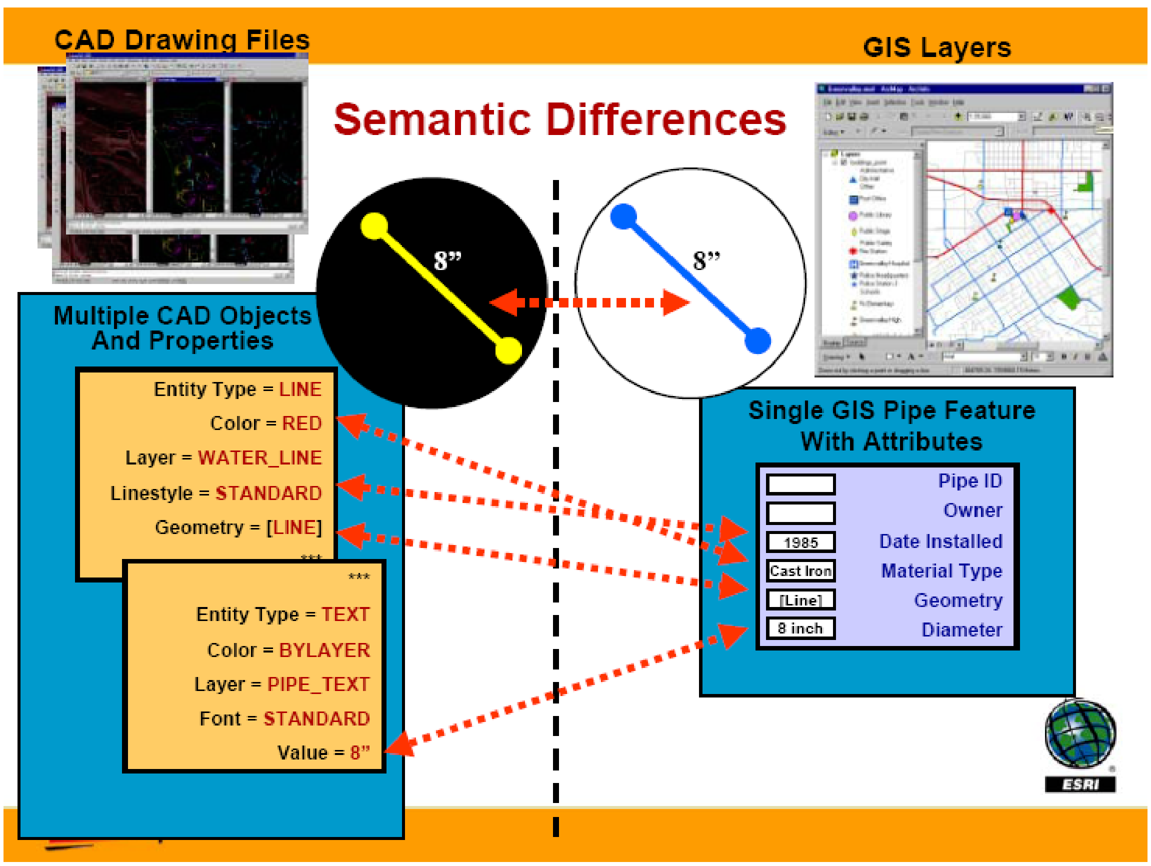

Fig. 8: Semantic Differences (Don Kuehne, 2004 b)

From the very origin CAD and GIS were different. While CAD has its origin in engineering, GIS was invented for cartography. This explains the different focus of the two systems. While CAD is used mainly to generate graphic models of the reality, GIS is a system for generating, managing, analysing and visualizing of geographic information. In CAD spatial data is interpreted as graphic. Data cannot be connected with information in a database. Recent developments overcome this. CAD is mostly used to construct objects that do not exist in reality but are to be planned. GIS on the contrary is used to model the real world. GIS data use to be spatially referenced. In GIS the graphic objects can be related to information in a database. The main advantage of GIS is the generation of new information from combination and analyse of existing data.

Don Kuehne (2004a) explains the differences between CAD and GIS as follows:

CAD	GIS
AEC/CAD applications	Horizontal applications
AEC/CAD Design & Analysis /Mapping	Cartography/spatial analysis/modeling
Graphic-centric	Data-centric
Drawing/model/document paradigm	Database paradigm
AEC Content	Topographic_/thematic maps
Large scale	Medium-small scale
Tools for unconstrained data creation	Tools leverage formally defined database schema for editing

AEC... Architecture, Engineering, Construction

Tab. 2: CAD/GIS differences (Don Kuehne, 2004a)

Van Oosterom (2004) finds the following explanation for the different focus of CAD and GIS:

	CAD	GIS
Different mathematical descriptions	Represents the man-made world. Single complex objects in 3D, high degree of accuracy	Captures the natural environment. Capture large numbers of objects in a common embedding
Different timescale	CAD works on project basis. Lifecycle is a recent issue	Long period of data collection and maintenance. Almost endless lifecycle
Data storage	File format	Large databases
Coordinate system and projection	2D or 3D orthogonal world is assumed	Many different coordinate systems, model the spherical world

Tab. 3: CAD/GIS differences 2 (Peter Van Oosterom, 2004)

Because of their different focus CAD and GIS have different geometries.

CAD	GIS
Circular arcs and curves are essential	In some GIS there is no way of representing a curve
Polygons with few vertices	A polygon may have thousands of vertices
Operations like mirror, rotate, scale and copy	Lines often have a fractal nature (like coastlines)
Schematic, stylised drawings	Drawings resemble the real world
Often no database. Databases used as catalogues of standard components or drawing registers	Databases are the most important aspect

Tab. 4: CAD/GIS geometries (Richard G. Newell & Tom L. Sancha, undated)

The geometry-problem also has another reason. In CAD users tend to represent elements from a plotting perspective. For example one polygon can be represented by multiple line segments on different levels. This is a challenge to import this data into GIS where a single polygon feature would be used instead. And it is almost impossible to export these geometries back to its original levels in CAD.

2.3.2 Integration

But in spite of many differences between the two systems, the trend in the industry goes towards integration of CAD and GIS systems. Examples are Autodesk´s AutoCAD Map or the abilities of ESRI´s ArcGIS of integrating CAD attributes like layer, colour, block attributes etc.

The integration is necessary because the two systems often represent the same real world objects.

Van Oosterom (2004) gives reasons for an integrated approach:

- Plan development
  In large infrastructure projects CAD is widely used for the design. Afterwards the data is transferred to GIS for planning and layout.
- Visualization
  CAD and GIS provide different plan presentations and data interaction. While for analyse a 2D "plan-view" in a GIS is appropriate, the 3D "world-view" is best to realistically visualize the project.
- Data collection
  For example some "photogrammetric techniques assume knowledge about objects ... in a CAD like format."
- Location-based services and augmented reality

He further suggests that GIS/CAD integration has to cover two lines. One is "formal semantics and integrated data management". ..."After solving the semantic differences, the next step is to create an integrated model that can serve multiple purposes." The integrated model has to maintain consistency when updating data or "when model data is added to the data base management system (DBMS). So, the same model is used as the foundation for planning, design, construction management, analysis, presentation, and so on."

The OGC has formed a working group concerned with CAD-GIS interoperability (CAD-GIS Interoperability Working Group CAD-GIS WG) in 2005. This shows the actuality of the problem.

Another example of the integration of CAD and GIS is the technical approach of Bentley and ESRI. The relationship between these two software vendors results in a step towards AEC/GIS interoperability. MicroStation is able to read ArcGIS maps and data and ArcGIS is able to read .dgn and .dwg files. ArcGIS files are supported within Bentley's Content Management & Publishing environment. And there is a synchronisation on server side. (Bentley, 2003)

2.4 Data update

Even in case total interoperability can be provided what happens in case of data updates? Whenever a base data is updated it triggers updates in many other datasets. For example the update of the extents of forests, which is very dynamic, can cause necessary updates in cadastre, agricultural landuse, nature preservation, zone planning etc. In most cases all those maps belong to different departments and are therefore created on different software platforms. The changing of one line (border of forest) causes the necessary change of a lot of other features in a lot of different datasets. So besides of the interoperability problem there is also a problem of the update process.

2.4.1 Automated updates

One example for automation is the so called iTRIM: "Spatial data update can be viewed as a series of automated ETL (extract, transform and load) processes where each step in the series represents a move from one persistent state to another." (David Skea, Yao Cui, 2005) The ETL process can perform this only if objects meet a number of predefined criteria. Update policies are defined through these criteria and associated transformation processes.

A lot of spatial data like topographic maps does not exist on their own but is the foundation on which other derived products are constructed. These derived products can be the foundation for more derived products. A product hierarchy can be made out. "In the context of this product hierarchy the problem of spatial data update becomes central to any integrated data management strategy." David Skea and Yao Cui report about updates being accepted at one level of this hierarchy. Then policies have to be defined to check if the update shall also be carried out at the next level. To do this in an automated way a framework of policies for defining rules and actions is necessary.

The Base Mapping and Geomatic Services Branch of the Province of British Columbia has proposed an integrated data management framework called iTRIM. The main aim was to tighten the integration of base data and derived products so that updates can be progressed in derived products automatically.

The iTRIM Data Architecture is based on a four tier model.

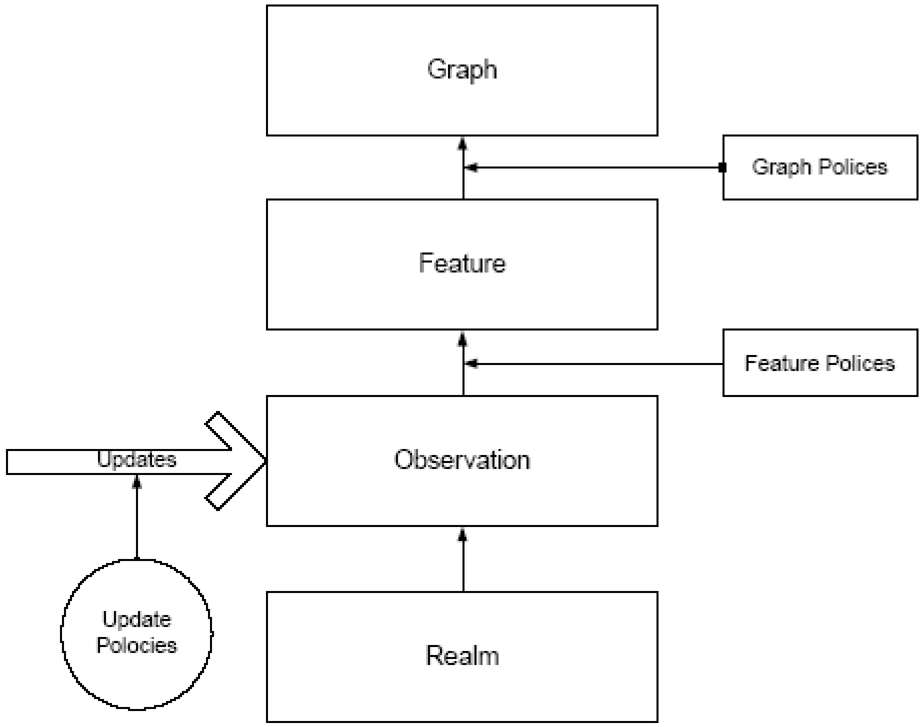

Fig. 9: Four tier architecture (David Skea, Yao Cui, 2005)

- Realm Tier: It is responsible for the coordinate representation of geometry.
- Observation Tier: The points and lineStrings contained in this tier represent the measurements of the real world, no matter if photogrammetric, GPS or other.
- Feature Tier: The features representing the real world are contained here. These features "know" which observations they are made from. This can be ambiguous because one measurement point can be part of different feature representations depending on the application.
- Graph Tier: "These are abstract collections of features into nodes and relations between nodes (edges). Stream and road networks are the principle examples." (David Skea, Yao Cui, 2005)

Several problems occur with the four tier architecture. First is that in GIS communities the clear distinction between observations and features is seldom be made. Second is "the problem of long transactions." Observations often are an almost permanent process. It can take years to remap large features.

In iTRIM WFS transactions are used. Policies for each tier are defined and checked during each update. Some of these policies can also require processing of data.

Concerning datageneration and –update in the field versioning is also an important topic. But this shall not be theme of this thesis.

2.5 Trends in interoperability

During the last decade GIS has become widely used. Costly soft- and hardware and specialised GIS departments are not mandatory. Cheap and easy-to-use GIS have become part of many offices. The increased need for geographic information has different reasons like terrorism, natural disasters etc. The basis for this information comes from different sources.

Because of the wider distribution of GIS interoperability becomes even more important. Data conversion software for different data formats is not enough. Ron Lake (2005) sees the following trends for interoperability:

- Create Once, Use Many Times
  People can access data through the Internet. In recent times it is necessary to share data on an ongoing basis.
- High Cost of Data
  Data acquisition is very costly. So networked spatial data integration is essential to share data and keep the cost low.
- The Case for Competition
  If a proprietary industry standard becomes leading, within short time only one significant GIS vendor would remain. This would mean expensive software solutions for the customers. Therefore open standards keep the competition alive and benefit software buyers.
- The IP and Web Analogy
  Similar to IP and http or html becoming the one standard for the Internet the OpenGIS Web Feature Service and GML are becoming the standards for geospatial interoperability framework.
- Building on Existing Platforms
  Because GML is consistent with a variety of data platforms it is possible to take data from existing platforms and map it to GML-encoded features.
- Improving Capabilities
  Web Feature Servers allow a bunch of functionalities.
- Building on the Internet
  “A GIS server that "exposes" an interface implementing the OpenGIS WFS Specification can store data in any proprietary format, but all WFS queries to the server will return data encoded in GML. Different applications can access the same data and present them in different ways, in real time, without data conversion.” (Ron Lake, 2005)
- ISO and the World
  Several OGC specifications are becoming International Standard Organization (ISO) standards.

3 <u>Practical Tests</u>

After having discussed the topic interoperability in theory practical tests shall show where the problems are in real world. What problems occur when exchanging data and what, on the other hand can easily be managed?

3.1 Software

As Leica MobileMatriX is based on ESRI ArcGIS it was self-evident to use ESRI ArcGIS Data Interoperability Extension for the practical testing. At first this product shall be looked at so that the special possibilities can be highlighted.

3.1.1 Data Interoperability Extension for ArcGIS 9.0, SP3

This is an ESRI product derived from FME suite (Safe Software). FME (Feature Manipulation Engine) is used to translate locations and attributes from one system to another. It provides a collection of Spatial ETL (Extract, Transform and Load) tools for translation and transformation of data. As line style, text fonts and point symbology are format specific these are not generically supported by FME. Concerning data translation with CAD these attributes can be essential. FME preserves this information as attributes but does not output them in the display.

The Data Interoperability Extension has less functionality than the original but is specialised on the use of various data formats within Esri ArcGIS. The extension is fully integrated in the ArcGIS Geoprocessing environment and the ModelBuilder. More than 70 data formats can be read and more than 50 can be written. More than 120 transformers are provided. “The extension uses a strategy that has been around the database world for a long time- extract, transform, and load or ETL.... Data in various formats, from multiple systems, can be accessed, viewed, updated, used for analysis, and, if needed, exported back to the original systems.” (Monica Pratt, 2005)

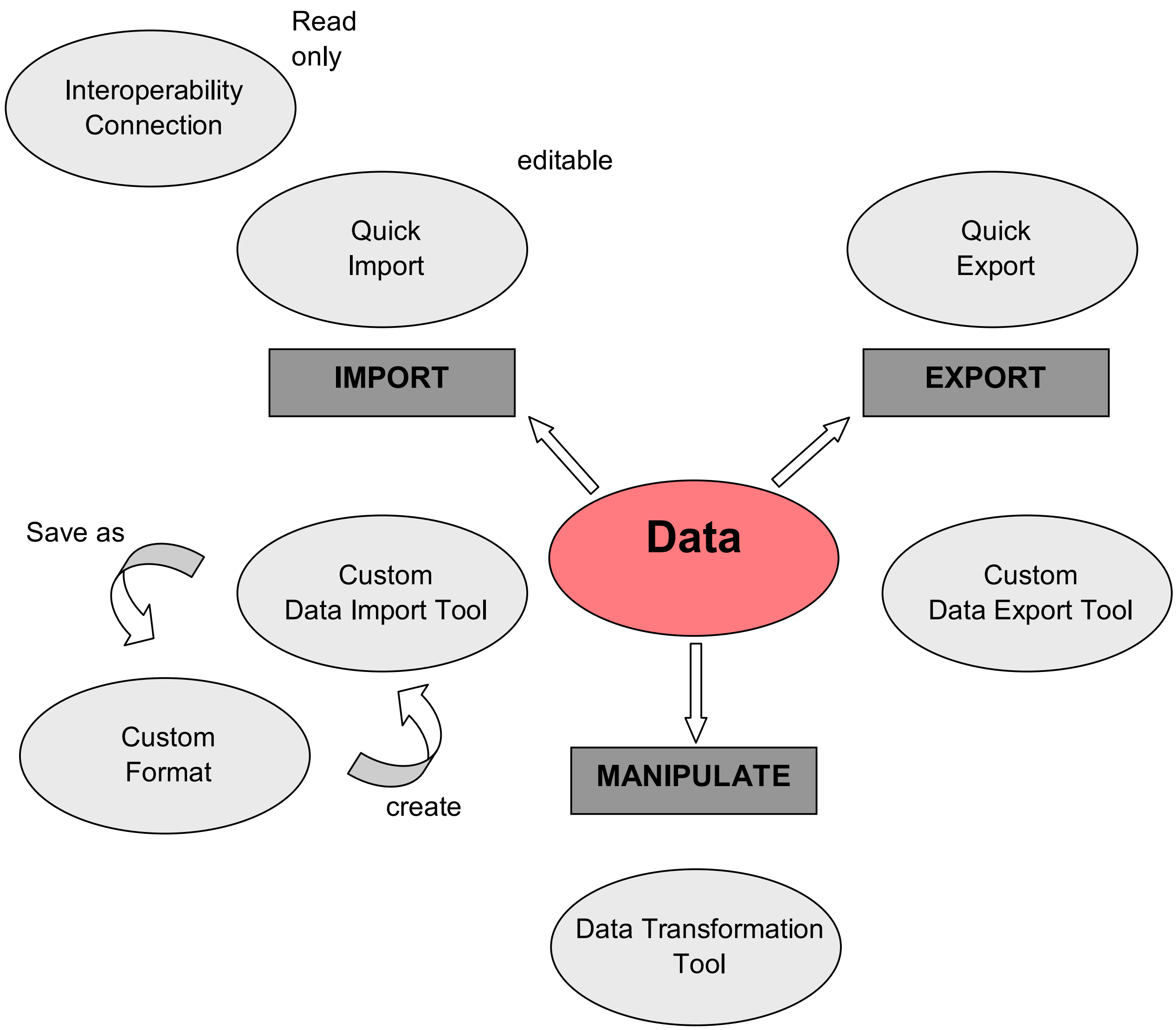

Fig. 10: ArcGIS Interoperability Extension

The following explanations of the software components correspond to the ESRI Data Interoperability desktop help.

3.1.1.1 Interoperability Connection

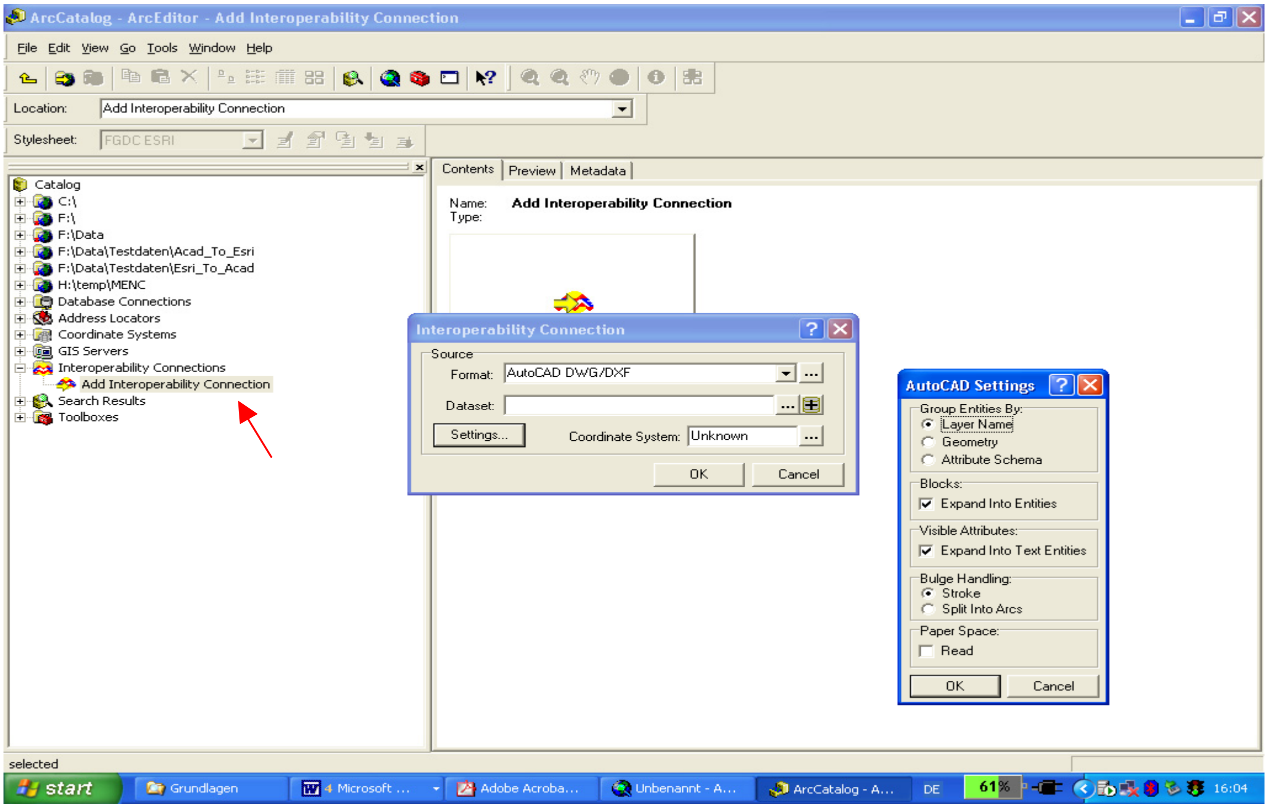

Fig. 11: Interoperability Connection

The Data Interoperability Extension offers the opportunity to maintain a live connection to various data. All supported formats can be visualized and used for analysing without conversion. The so visualized data is read only. Therefore other tools have to be used to make data editable in ArcGIS.

3.1.1.2 Quick Import

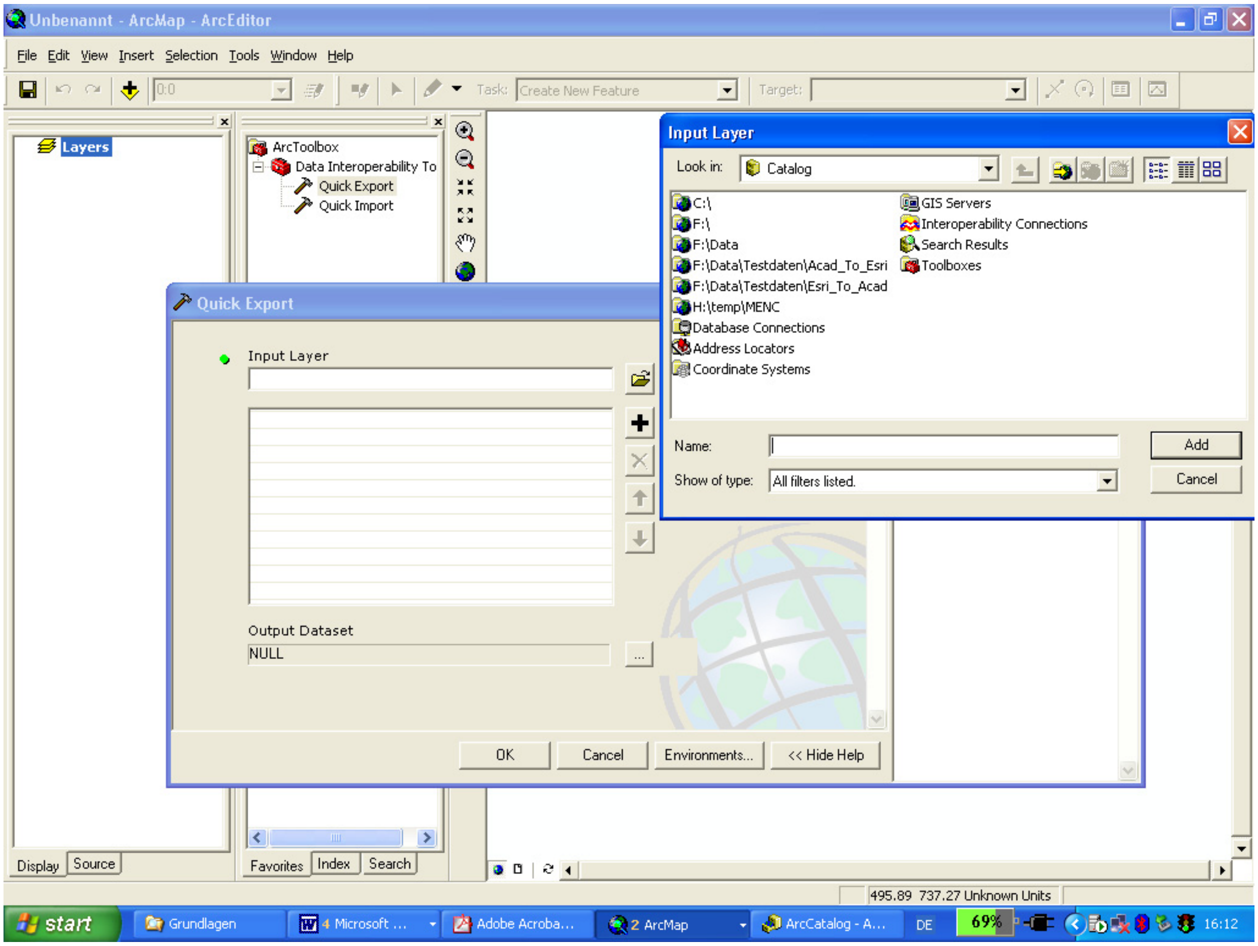

Fig. 12: Quick Import

Data in any format supported by the Data Interoperability Extension can be converted into feature classes. The output is stored in a new geodatabase. As data is imported, no changes to the data model are made.

3.1.1.3 Quick Export

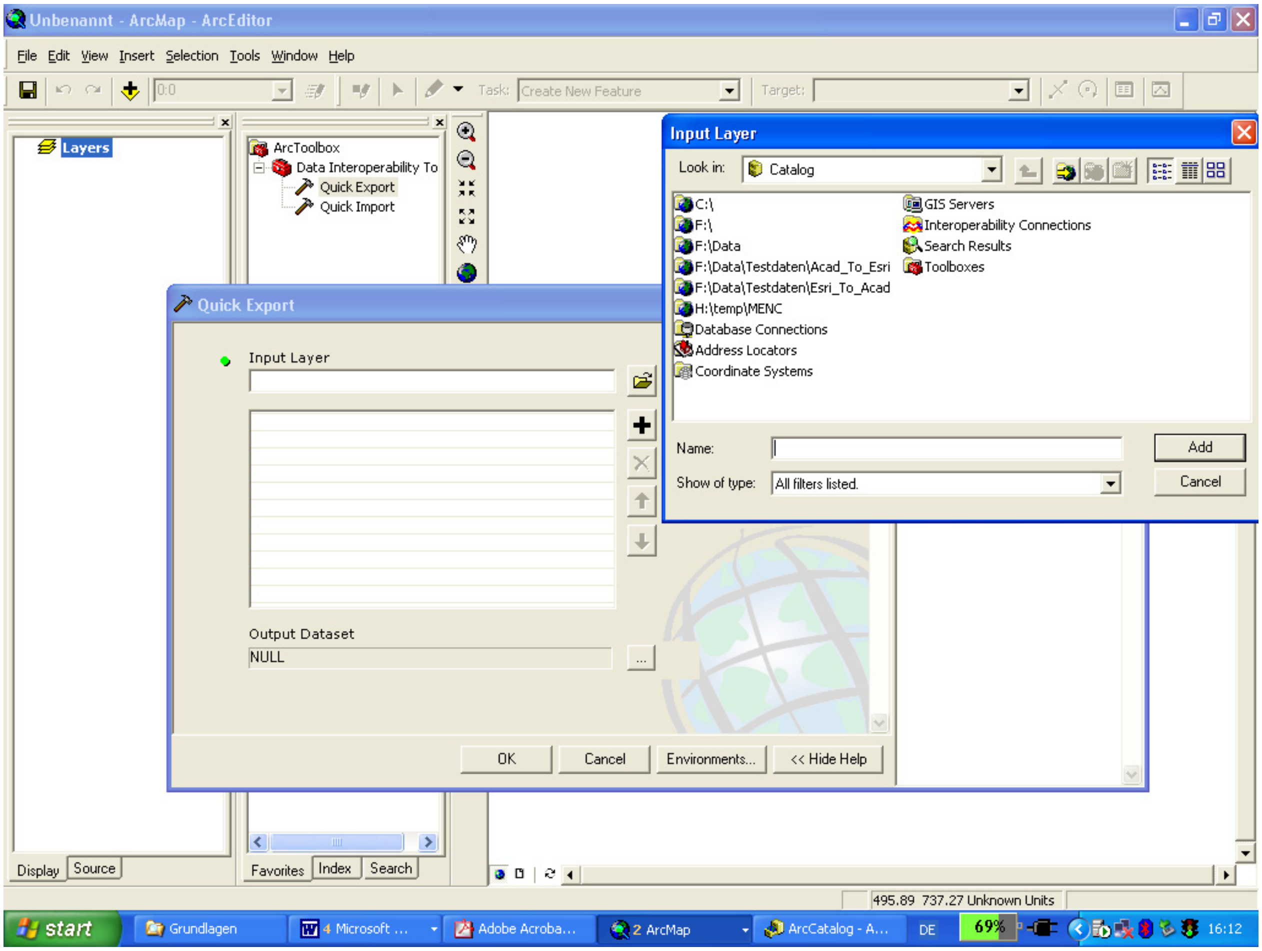

Fig. 13: Quick Export

To convert one ore more Feature classes or Feature layers into any format supported by the Data Interoperability Connection the Quick Export Tool can be used. No changes to the data model are made during export. This tool is generally used to either export data from ArcGIS, or as the final step in a model or script where data should end up outside ArcGIS.

3.1.1.4 Workbench

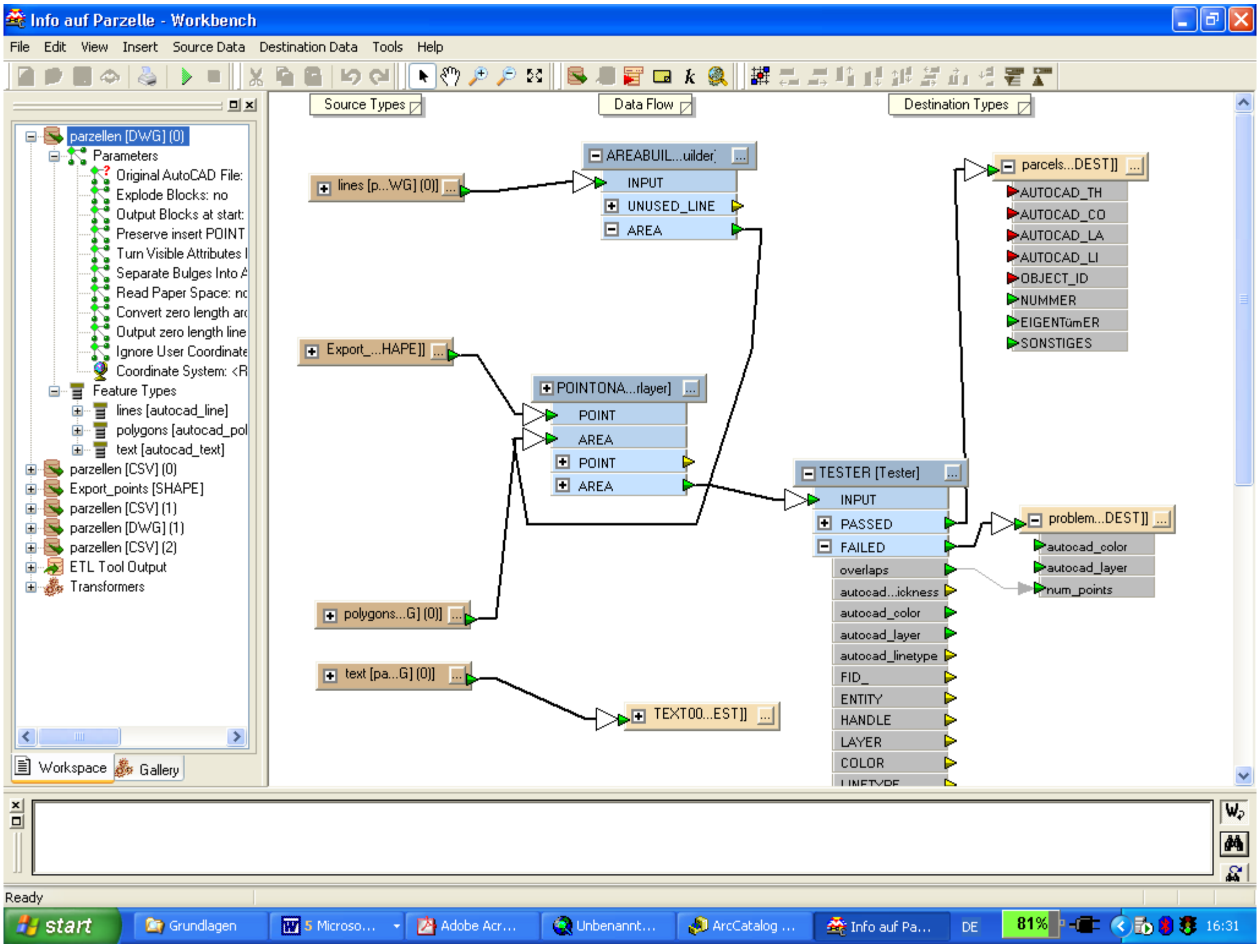

Fig. 14: Workbench

The workbench is a graphical user interface for spatial translation. Multiple formats or datasets can be input, manipulated with transformers and output in a defined destination schema. With workbench one works in a window called “workspace”. The workspace consists of the Navigator pane on the left and a graphical layout called the canvas on the right. When generating a new mapping file, source and destination data is added and information about the data is displayed. Attributes or Transformers can be added to manipulate the data.

Transformer

Transformers are used to manipulate source data to achieve the desired output. Several transformers can be used in the same process. The output of one transformer can be the input for another one. Transformers can add or erase attributes to features or alter the geometry.

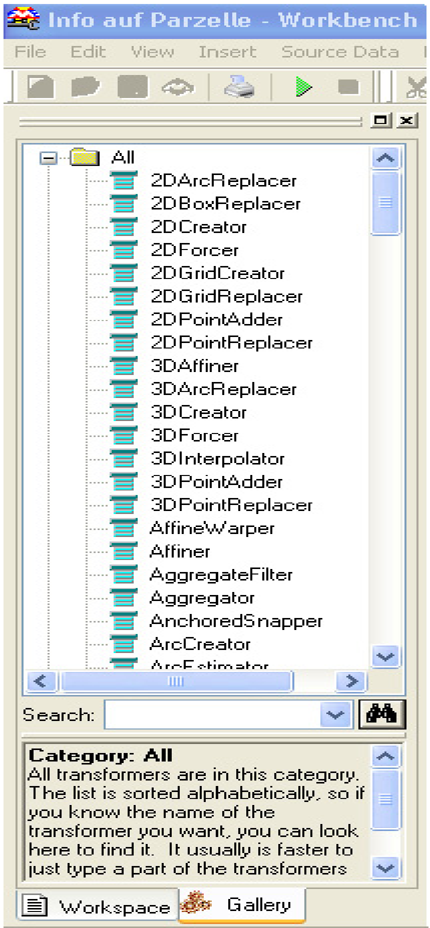

Fig. 15: Transformer

3.1.1.5 Custom Formats

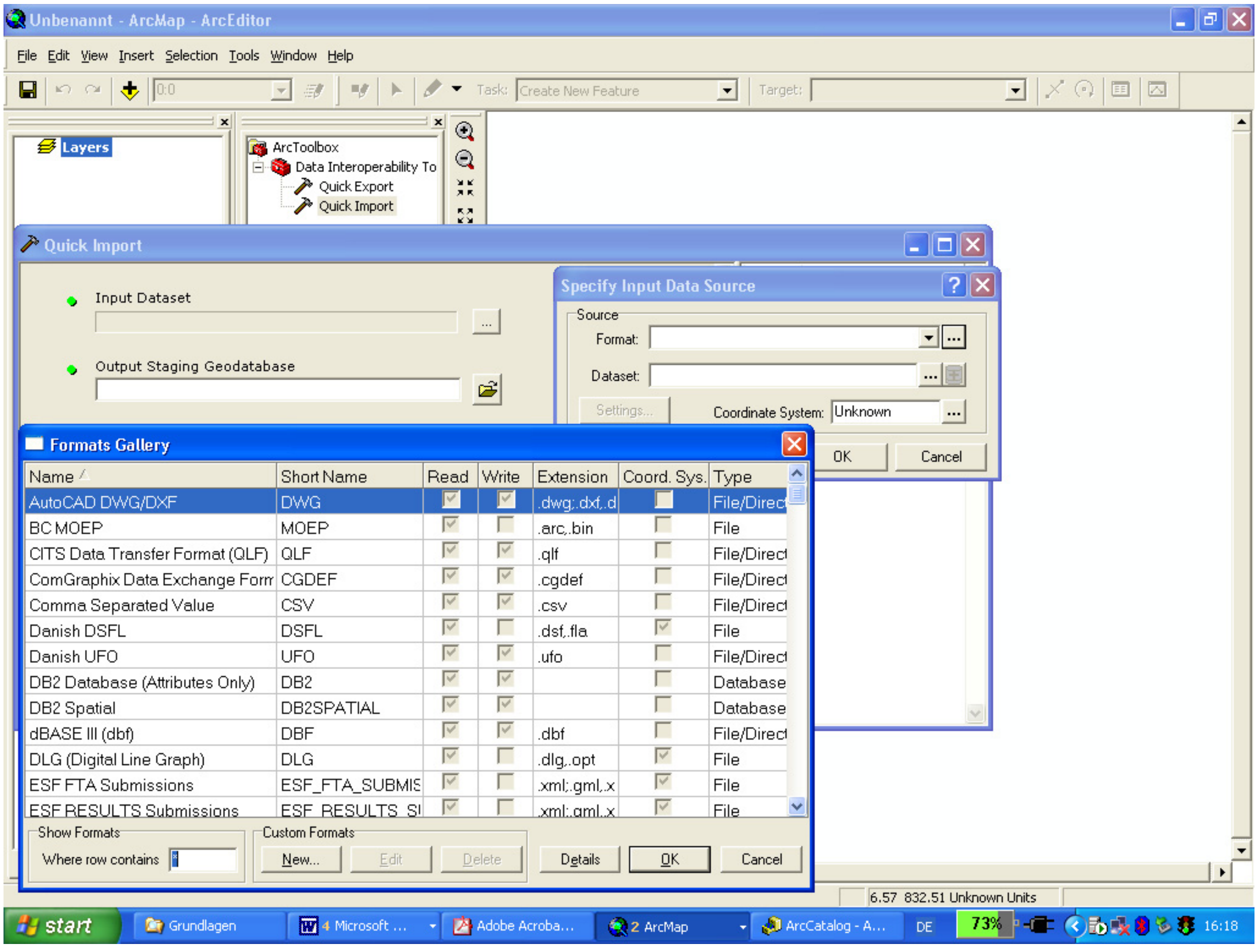

Fig. 16: Custom Format

The creation of Custom Formats is a very powerful tool if a user has to connect repeatedly to data that requires processing. A manipulation process for example to generate line features from text files has to be defined only once. Then it can be saved as a Custom Format. Whenever data with the same schema has to be processed it can be run automatically.

3.1.1.6 Custom Tools

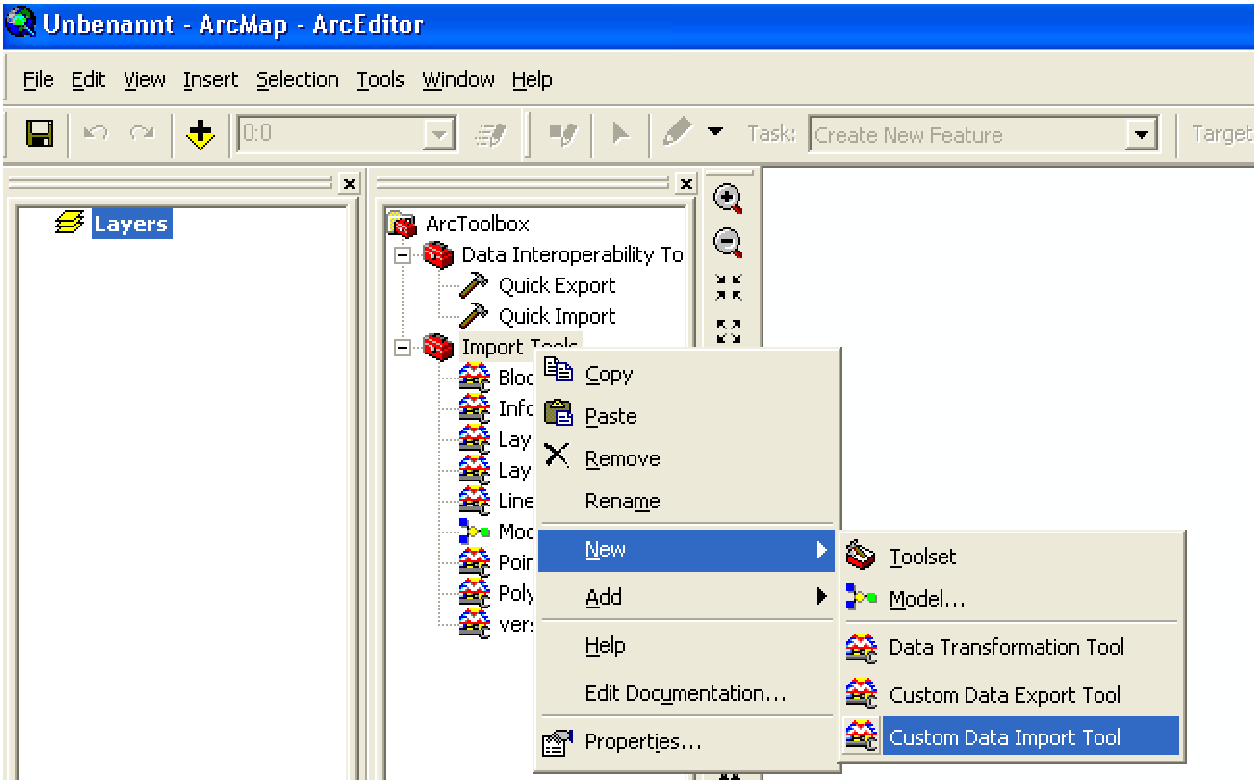

Fig. 17: Custom Tools

<u>a) Custom Import</u>
Multiple source formats can be merged in a single workspace. Whenever attributes and geometry need to be manipulated when being imported to ArcGIS a Custom Tool can be defined. Output is a geodatabase. When the tool is defined and saved it can be used for every input data with the same format and schema, which needs to be processed in the defined way.

<u>b) Custom Export</u>
Any number of ArcGIS feature classes can be transformed and exported to any FME-supported dataset.

<u>c) Data Transformation</u>
Data transformation tools are used to manipulate and transform feature classes within the geoprocessing environment. Attributes can be manipulated as well as schemas.

3.2 Test description

For the tests it is assumed that data shall be transferred from a CAD system into ArcGIS. Simple data viewing is not satisfying. Data shall be imported to ArcGIS for further processing and afterwards be exported back to the source format.

Therefore the Interoperability Connection of the Data Interoperability Extension was not tested. It is assumed that if it is possible to import data to ArcGIS it is also possible to view the data using the Interoperability Connection.

The aim of the tests was to show the limits of data exchange. Are there limits at all? And if yes where are they? The requirement is to aggregate into groups of "can be done without effort", "a workaround can be found", "is not possible at all".

At first single geometries are tested. They are constructed in AutoCAD. After highlighting the problems with simple features more complex structures like AutoCAD blocks and their attributes or special workflows are tested. Finally two use-cases with complex specifications and processes are tested using both AutoCAD and MicroStation data.

The hypothesis is that problems will occur. The demand is to solve as much as possible of these interoperability problems using the Data Interoperability Extension.

3.3 Issues AutoCAD Conversion

At first the data exchange between AutoCAD 2006 and ArcGIS 9.0 was tested. AutoCAD was chosen because it is a widely used CAD software. So Leica Geosystems customers demand a seamless data exchange to and from Leica MobileMatriX which also means a seamless data exchange to and from ESRI ArcGIS Desktop.

3.3.1 Overview

The following table summarises the topics for the data exchange between AutoCAD and ArcGIS using Data Interoperability Extension.

Format Type Identifier	DWG
Reader/Writer	Both
Dataset Type	File
Feature Type	Layer name
Typical File Extensions	.dwg, .dxf
Automated Translation Support	Yes
User-Defined Attributes	Yes
Coordinate System Support	No
Generic Color Support	Yes
Spatial Index	Never
Schema Required	Yes
Transaction Support	No
Geometry Type Attribute	Autocad entity

Tab. 5: AutoCAD - FME Readers and Writers (Safe, 2005)

3.3.2 Attributes

AutoCAD entity attributes are stored in special FME feature attributes when being imported. During export these attributes are used to fill in an entity structure.

Export:

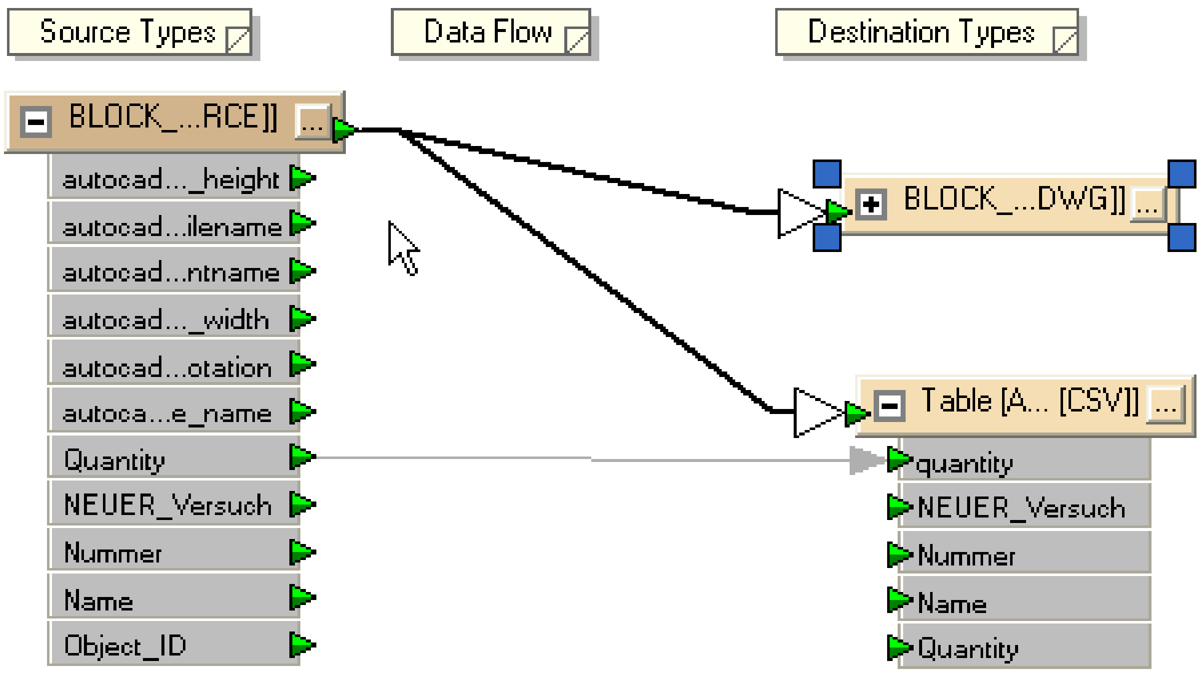

Fig. 18: Attribute export

While AutoCAD supports Excel, dBase, Access, Oracle, Paradox, MS Visual Fox Pro and SQL Server Data and can contain blocks with attribute tags the ESRI Data Interoperability Extension only supports Access formats. Excel data can be converted to .txt or .csv and can be imported that way. Inserts are point features used in AutoCAD to specify block locations and associated attribution. Inserts are another way in which attribution is stored within an AutoCAD drawing file.

3.3.2.1 Blocks and Attribute tags

There are two different ways of Import:

- Import all the features of a block (geometries, text) as independent features
- Import the block as insert point with attributes stored in a table. This makes more sense because the attributes stay with the insert.

3.3.2.2 **Special Workflows**

a) Import

When there are two different blocks on the same layer that have different attributes, it is possible to import different blocks to different feature classes by using a transformer:

AttributeFilter

„Routes features to different output ports depending on the value of an attribute. The set of possible attribute values can be entered manually, or extracted from some input source in the properties dialog. If the feature's attribute has no value, the feature is output via the <BLANK> port. If the feature's attribute has a value not in the list, the feature is output via the <UNFILTERED> port.“ (Data Interoperability Extension)

b) Export:

With the following custom export tool it should be possible to export the blocks again.

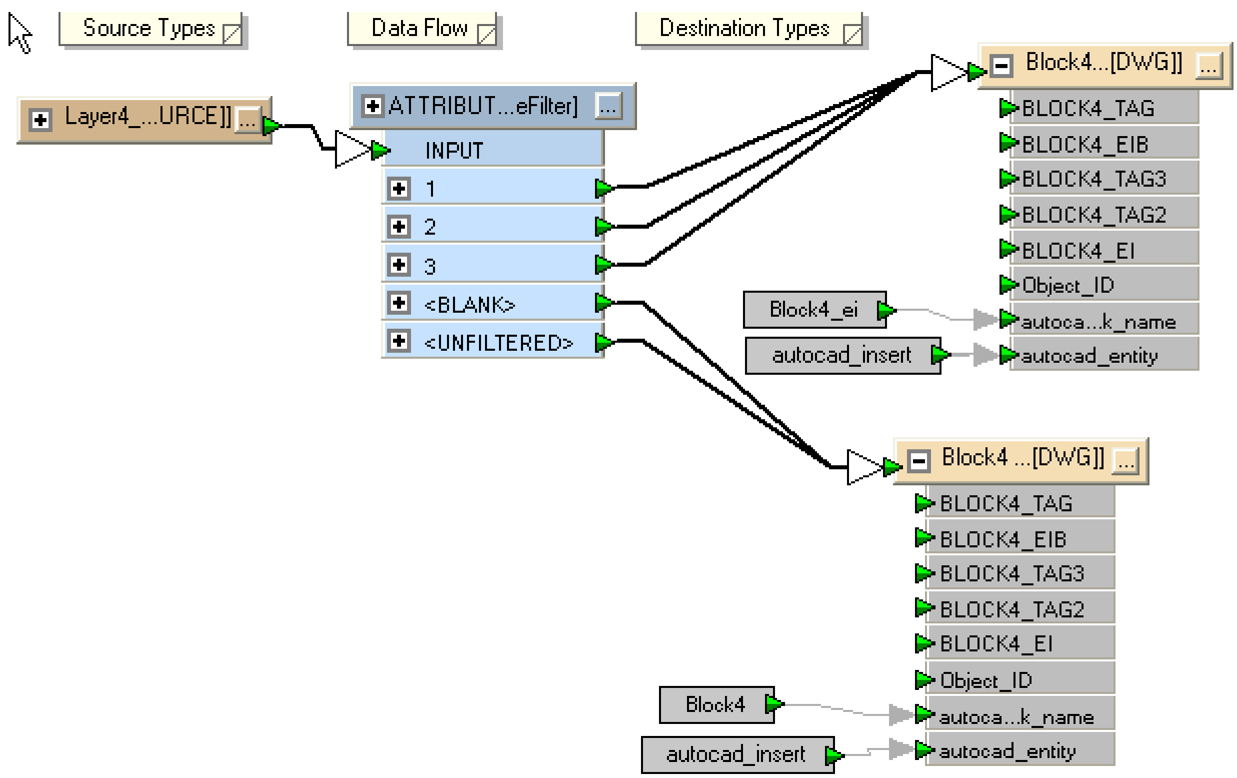

Fig. 19: Block export

The main thing is to define autocad entity = autocad_insert and autocad_block_name. But when executing the tool FME always says, that there is insufficient memory available. The export does not work. No reason could be found in the tests.

```
"…Translation was SUCCESSFUL. Insufficient memory available -- error
code was 14 Tool execution failed.
Failed to execute (ExportTool6_4)….”
```

With the command Insert Block (in Acad) another problem occurs: the blocks are inserted in different units. They are much larger than before the import to ArcGIS. One reason could be the use of different Acad template files (acad.dwt or acadiso.dwt) to generate the drawings and the special templatefile. Or the block has to be defined in a different way concerning the units.
Solution:
After the export to Acad it is possible to replace the point images of the block by: Insert block – Browse for file that contains these blocks. The former block will be shown in the file still containing the attributes.

3.3.3 Geometries

The following table gives an overview of the geometries supported by AutoCAD. In the practical tests a test scheme has been created (see attachment A). Every geometry possible was generated in AutoCAD and then imported to ArcGIS. Only those, which could be imported, were afterwards tested to be exported back to ArcGIS.

Geometry	Supported	Geometry	Supported
aggregate	No	Polygon	Yes
circles	Yes	Donut polygon	Yes
Circular arc	Yes	Line	Yes
Elliptical arc	Yes	Point	Yes
Ellipses	Yes	Text	Yes
none	No	3D	Yes

Tab. 6: AutoCAD geometries (Safe, 2005)

3.3.3.1 Import Tests

First it was tested to handle the import with the Quick Import Tool. Only if this did not work, a Custom Import Tool has been created to find a workaround.

Line
Line
3D-Line
assembled Lines
crossed Lines
closed Line
Ray
Construction Line
Multi Line
Polyline
simple Polylinie
closed Polylinie
assembled Polylinies
crossed Polylines
3D Polyline
Polygon
complex Polygon
Polygon with hole
Badly snapped Polygon
Rectangle
Curve
Arc
Circle
Donut
Spline
Ellipse
Block
Table
Point
Boundary
Hatch
Gradient
Region
Mtext
Dtext (Single Line)
Dimensions
Groups
Chamfer
Fillet

	Import is no problem
	Import is possible, but needs a workaround
	Import is not possible

Tab. 7: AutoCAD Import

a) Import absolutely no problem (Quick Import) with geometries like:

Line, crossed Lines, simple Polyline, assembled Polyline, crossed Polylines, Arc, Point, Chamfer

b) With the following geometries an import to ArcGIS is possible but there are restraints:

- 3D Line and 3D Polyline:
  It was possible to import 3D-features by defining Z-Values "enabled".

- assembled Line, closed Line:
  Every line will be imported as a single polyline feature. There's no connection between them. It is possible to connect the single lines with a transformer in workbench: LineJoiner *
  "Takes non-intersecting lines and connects them into longer lines whenever doing so does not remove a significant node. Any nodes with only two lines connecting to them (sometimes called pseudonodes) are removed. Lines remain broken at points where three or more converge. Features with invalid geometries are sent to the INVALID output."

- closed Polyline, Rectangle:
  with Quick Import polygons are generated. If this is not desired, the data either has to be imported with ArcGIS Add Data – select lines feature class or with workbench:
  GeometryFilter *
  „Routes a feature based on its geometry type.
  Each feature that enters is output via the port corresponding to its geometry type. Each output feature has a complete, unaltered copy of the source feature's attributes and geometry."
  GeometryCoercer *
  Resets the geometry type of the feature. Depending on the feature's actual coordinates, the transformer may have no effect.

- Ray, Construction Line (xline):
  with Quick Import these geometries get shortened very much so that they look like points. ArcGIS defines them as lines. It should be possible to define the orientation of a ray with workbench transformer Orientor: Adjusts the orientation of a polygonal feature or the direction of a linear feature. This didn't work in the tests. Features with autocad_entity set to autocad_xline are stored in and read from drawing files as an FME feature with two coordinates representing a line. The reader and writer modules automatically convert the xline to and from its unit vector representation into a line. Features with autocad_entity set to autocad_ray are stored in and read from drawing files as a two coordinate line. The

reader and writer modules automatically convert the ray to and from its unit vector representation into a line.

- MultiLine:
  when one multiline is imported, the attribute table of this feature contains only one entry. But: when editing, each of the two lines can be edited on it's own. So at the end of editing, the multiline can look like two separate lines. When reading a multiline feature, the FME will output an aggregate of lines thereby hiding all AutoCAD format peculiarities. The AutoCAD Reader only supports this entity.

- Polygon
  It is common in CAD to represent polygon features as a network of individual line boundaries rather than closed polygons. There is no standard way to create polygon attributes in CAD, and it is common to include a point, symbol or text entity inside the inferred boundary as attribution. Polygons in AutoCAD are always regular geometries where it is possible to define the number of sides. It's no problem to import such polylines as polygons with Quick Import. But: if the "polygon" in AutoCAD consists of more than one polyline or even of line features, there will be no polygon imported. It has to be one closed polyline for one polygon import. The workbench transformer Feature to Polygon generates polygons from a linear network of lines, and can optionally include the attributes of point features found to be inside the newly created polygons.

- Complex Polygons (selfintersecting), Polygons with holes, badly snapped Polylines

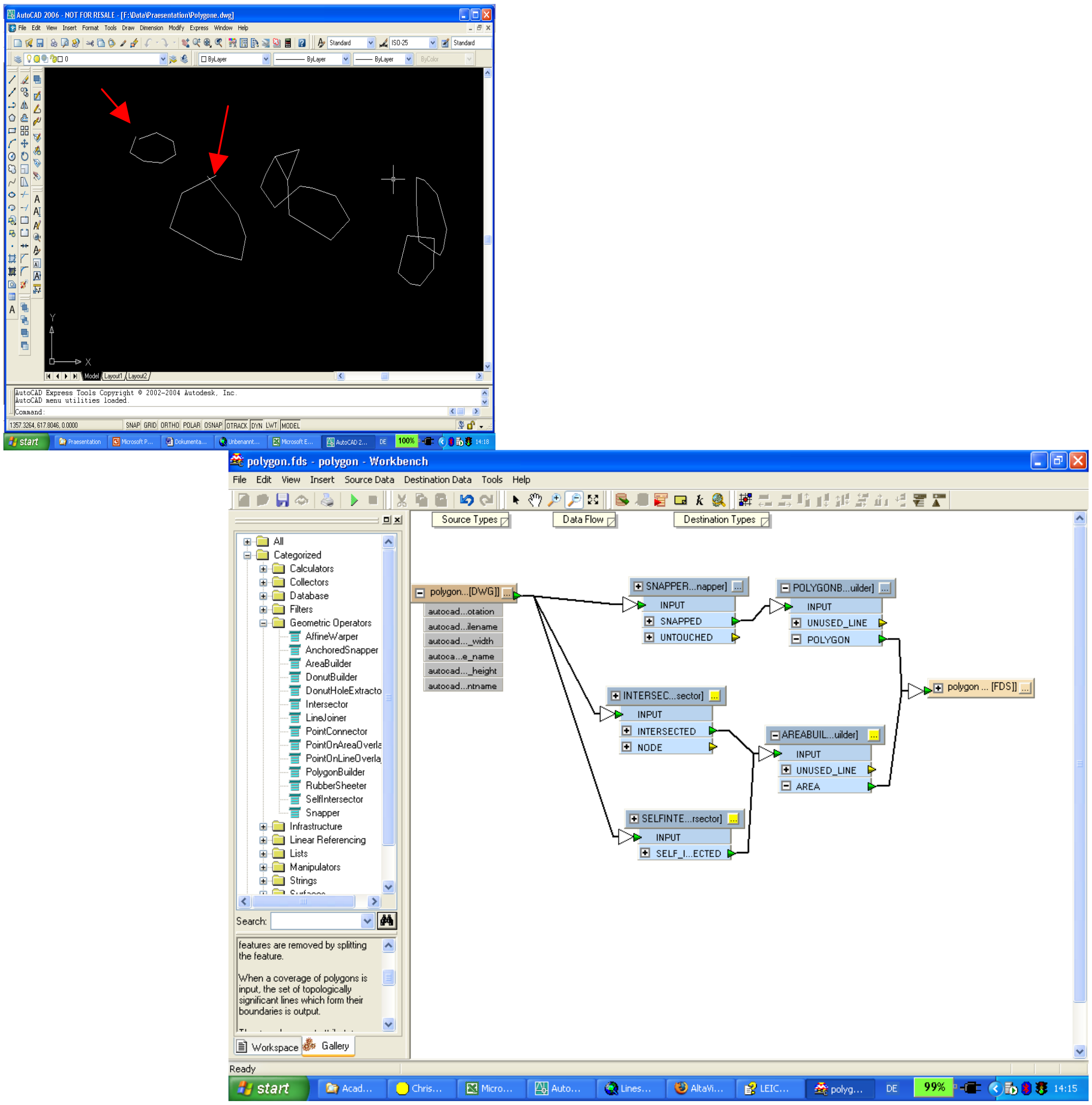

Fig. 20: AutoCAD Polylines and Workbench Import

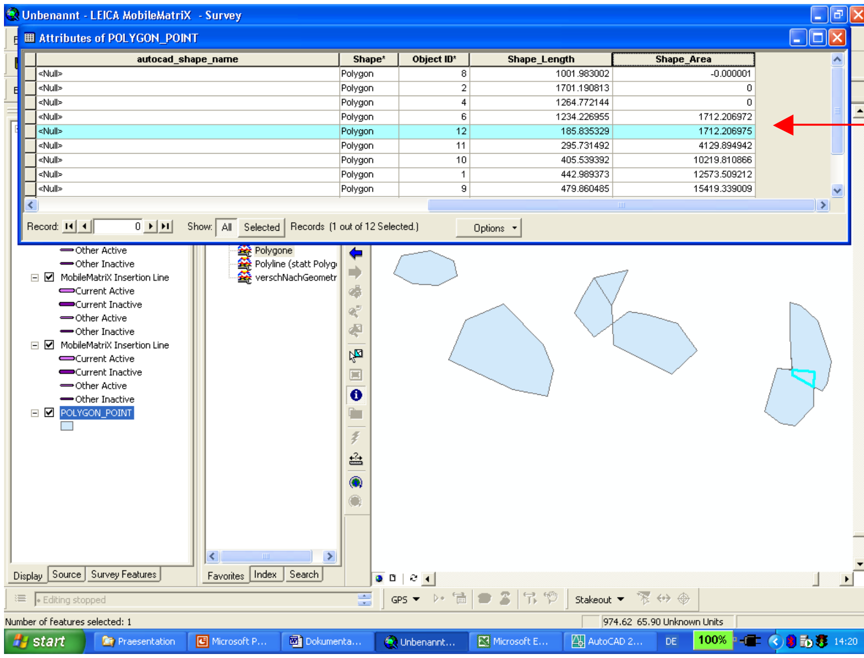

Fig. 21: Imported Polygon features

With workbench it's possible to import these features as polygons. But some features come double. It's necessary to correct the generated polygons by hand.

Transformer

<u>Snapper*</u>

When SNAPTYPE is END_NODE the following is done: Snaps end points of lines together if they are within the <tolerance> distance of each other. Polygonmeshes are not supported in ArcGIS.

<u>Intersector*</u>

Computes intersections between all input features, breaking lines and polygons wherever an intersection occurs. In addition, all overlapping segments are reduced to one segment before being output, and any self-intersections in the input features are removed by splitting the feature.

<u>SelfIntersector*</u>

Checks each feature and remove self-intersections.

If a linear feature self intersects, it is split into separate features, one per non-intersecting piece. Each resulting feature will have the total number of pieces created from the original feature added as an attribute.

If an area feature is self intersected and in so doing it results in more than one area, the resulting areas are gathered into an aggregate. This behaviour may change in future releases.

<u>PolygonBuilder*</u>

Forms polygons from lines. The lines must be topologically correct and must not self-intersect nor intersect each other. They must close at nodes.

The Snapper, Intersector, and SelfIntersector can be used to attempt to clean data that does not meet these conditions before it enters this transformer.

If these conditions are met, any polygons implied by the input lines are created and output via the POLYGON port. Note that no donut polygons will be created -- the DonutBuilder can be used on the output of this transformer if holes are to be cut in the resulting polygons. Alternately, the AreaBuilder transformer can be used in place of this transformer to both form polygons and nest holes in them in a single operation.

AreaBuilder*

Forms area features from lines and optionally cuts out any resulting holes from their containers. The input lines must be topologically correct and must neither self-intersect nor intersect each other. They must close at their endpoints.

The Snapper, Intersector, and SelfIntersector can be used to attempt to clean data that does not meet these conditions before it enters this transformer.

If these conditions are met, any area features implied by the input lines are created.

If the <create donuts> parameter was set to "no", the resulting polygons are output via the AREA port. Note that no donut polygons will be created -- the DonutBuilder would be required to do this operation.

If the <create donuts> parameter was set to "yes", then the resulting polygons will have holes cut in them by any other resulting polygons they completely contained. Following this, any holes, which share a common edge, will be dissolved together to make a larger hole. The results are output via the AREA port.

If the <create donuts> parameter was set to drop_holes, the operation is the same as when the parameter is yes, except that any polygons that were holes of another polygon will not be output.

- Circle, Ellipse:

In ArcGIS Import Data the circle will be imported as ellipse, same as the autocad entity ellipse. With the DataInterop. Tools (Interop. Connection and Quick Import) circles and ellipses will be imported as polygons. In the tests it was not possible to use the transformer Geometry Coercer (like with the rectangle). Solution: It is possible to copy the polygonfeature in ArcGIS Desktop to a line shape.

- Donut

is imported as a polygon. It should be possible, to drop the hole with the area builder transformer in workbench.

- Curve, Spline, Fillet:

Curve Geometries are not supported in ArcGIS. In AutoCAD Curve defines the smoothness. Splines and Fillets are imported to ArcGIS as polylines (or polygons). Many vertices are generated and connected with straight polylines.

Spline features are linear or area features – depending on whether or not they are closed – and are used to represent features that have smooth curves. Each spline has a number of attributes that completely make up the spline. When STORE_SPLINE_DEFS is set to yes, the reader sets the coordinates to be either the fit points or the control points (depending on what is used to define the spline). Splines are always 3D – there is no way in AutoCAD to indicate if the feature was intended to be only 2D. If STORE_SPLINE_DEFS is not specified or set to no, then the coordinates of the spline returned by the reader are interpolated values based on the spline definition. When performing an AutoCAD-to-AutoCAD translation, then you should always set STORE_SPLINE_DEFS to yes to get the best results.

- Block:
  see chapter Attributes

- Boundary:
  no matter if the boundary was defined as polyline or as region in AutoCAD Quick Import will generate a line feature plus a polygon feature.

- Text:
  autocad_entity: autocad_text: Features with autocad_entity set to autocad_text are stored in and read from drawing files as text entities. Dtext (Single Line) and Mtext are imported, but: Can the text size be edited? autocad_text_size: The text height. When reading, this value is calculated using the height of the bounding box of the feature and the estimated number of lines.

  Mtext seems to be imported only when Settings: Group By Layer is selected. Then the whole Mtext is imported as one object that is almost invisible. Only small rectangles are visible. Can it be edited at all? Probably the parameters can be set when using workbench.

<u>c) The following geometries can't be imported to ArcGIS at all:</u>

- Hatch, Gradient, Region
- Dimensions (Dimensions are aggregate features used in AutoCAD to specify dimensions within an AutoCAD drawing. These are currently supported by the reader only. Note: Dimensions are not currently supported in AutoCAD 2004) – in the tests it was not possible to import dimensions. Why?
- Group (A group is a saved set of objects that you can select and edit together or separately as needed. Groups provide an easy way to combine drawing elements that you need to manipulate as a unit.) Groups are not imported as groups. With ArcGIS Add Data and with the Interoperability Connection some of the objects of a group can be imported as objects on their own (not splines). With Quick Import all of the objects of a group can be imported but also only as objects on their own. The connection of the group gets always lost.

* all explanations of Transformers refer to the Data Interoperability Extension where every Transformer is explained in the program.

3.3.3.2 Export Tests

Only those features that could be imported were tested for export.

a) No problems occurred when exporting the following features with Quick Export:
Line, crossed Lines, assembled Lines, closed Lines, simple Polyline, assembled Polyline, crossed Polylines, closed Polyline, Arc, Point, Chamfer, Polygon, Rectangle, Circle, Ellipse, Dtext

b) The following features can be exported with some restraints:

- Complex Polygons:

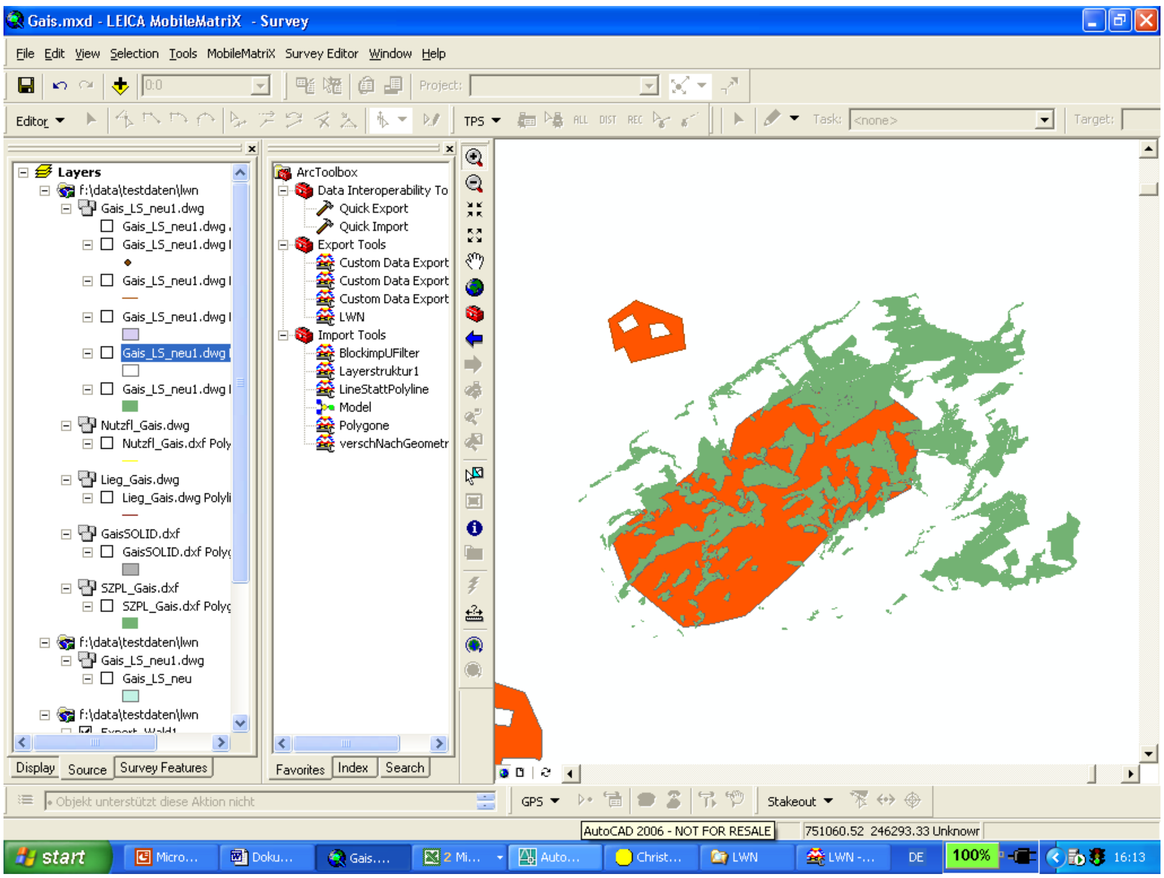

Fig. 22: Complex Polygon features

With the Clip tool the green areas have been cut out of the orange areas.
Problem: The generated complex orange polygon with holes can not be processed in AutoCAD (written to a database in ArcMap or even generated a simple hatch).

Solution:

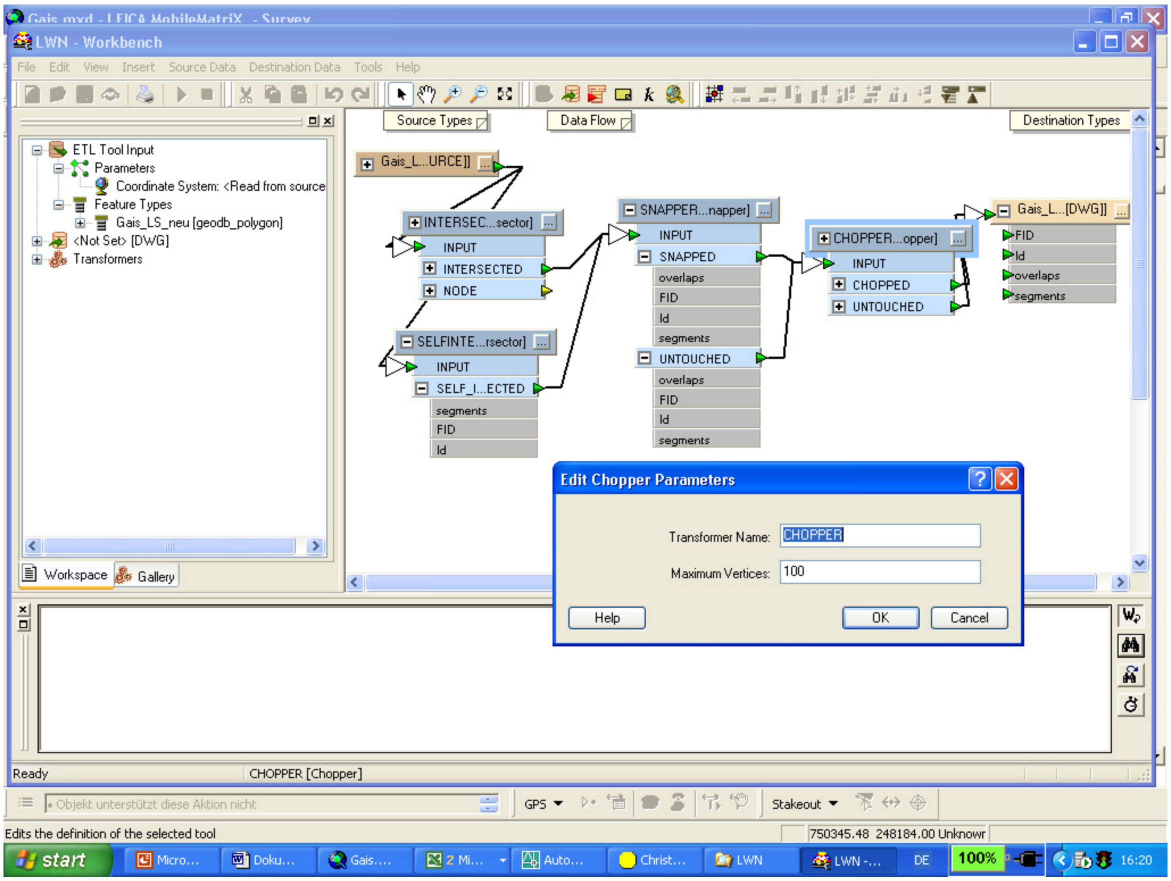

Fig. 23: Polygonexport with Chopper

In workbench use the transformer Chopper*
Ensures that all features output have less than or equal to <maximum vertices> vertices.

If the feature has more than this number of vertices, it is chopped into several smaller features. Each new feature will have <maximum vertices> vertices, except for the last one which may have fewer than <maximum vertices> vertices. All new features have the same attributes as the original feature had and are output via the CHOPPED port.

In the tests it was not possible to generate proper topologies. In addition to the polygons there were larger overlapping polygons and even some lines.

- Polygon with hole:
  Is exported to AutoCAD as a block. So it has to be explode in AutoCAD.

- Block:
  see Chapter Attributes

c) It’s not possible to export the following features to AutoCAD:

- Multiline:
  is exported to AutoCAD as a block. When exploded in AutoCAD, two Polylines are generated from the block. So from one multiline two separate features without connection have been generated.

- Boundary:
  As it was imported as a polyline, a polyline is exported to AutoCAD.

- Mtext:
  Although it was not possible to import the Mtext in a proper way to ArcGIS, the Mtext is almost fine when exported back to AutoCAD. But: The Mtext is converted to dText when exported to AutoCAD.

3.3.4 CAD Model (Layer Structure)

3.3.4.1 Import from CAD to Geodatabase

Acad drawing Layerstructure 1.dwg: Contains Layer 1 to Layer 4.
Layer 1 contains 1 Polygon and parts of the blocks
Layer 2 contains points, 1 Polyline and parts of Block4
Layer 3 contains a circle and parts of Block4_ei
Layer 4 contains block attributes and the blocks have been generated on this layer.
Therefore when generating a Custom Import Tool FME suggests this structure (Settings: Group Entities By Layer):

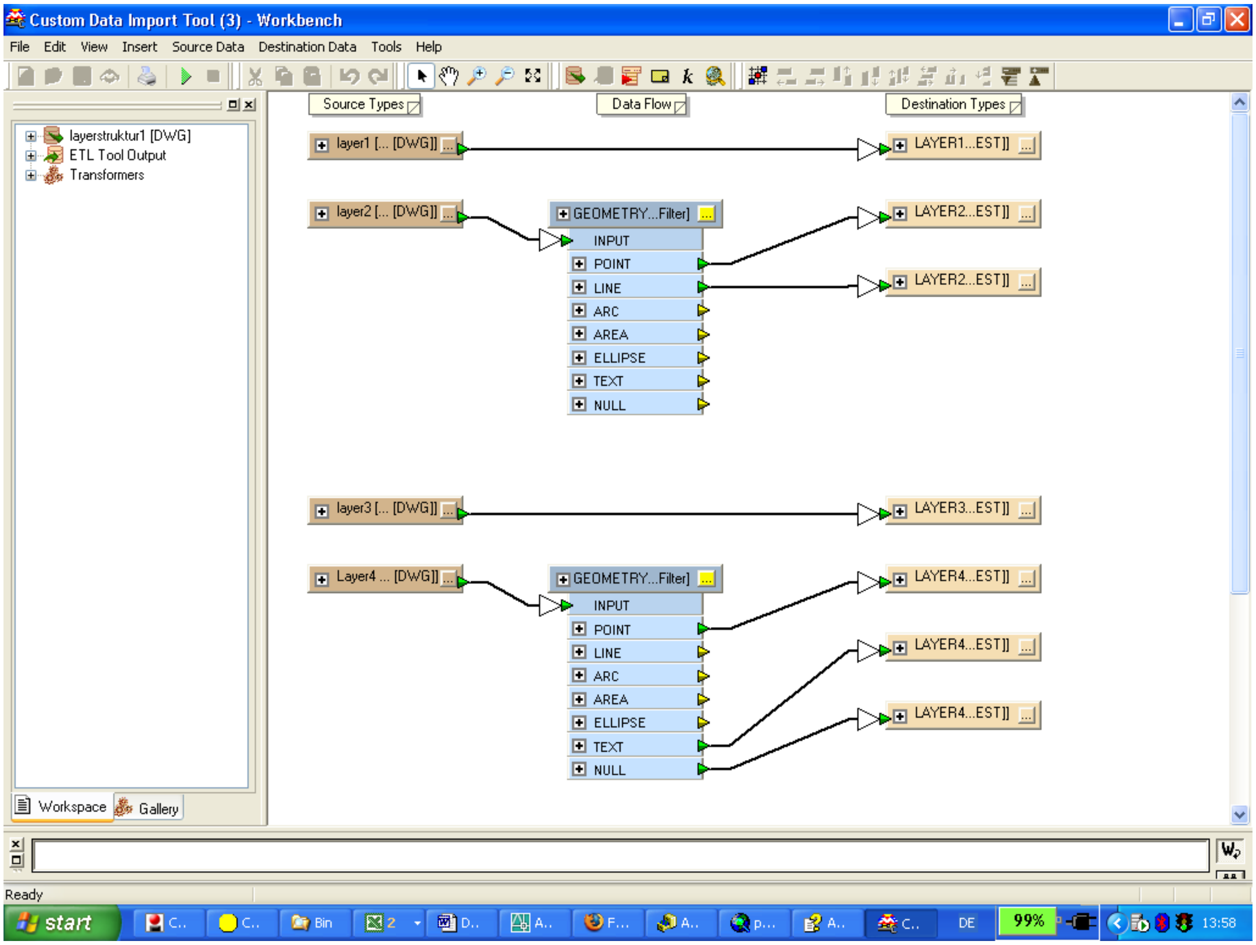

Fig. 24: Layerstructure

<u>Question:</u>

What happens if this Custom Import Tool is used for a different .dwg file with different layerstructure?

Nothing! The dwg-file cannot be read.

<u>Solution:</u>

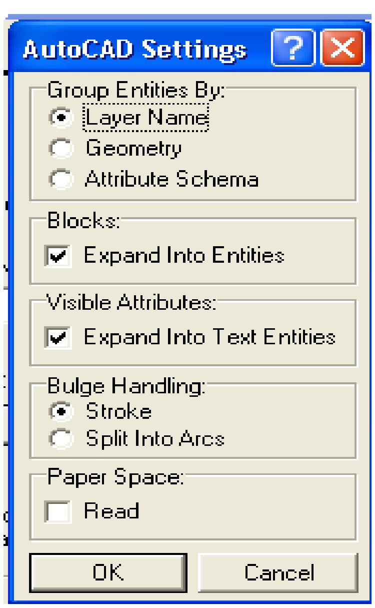

Fig. 25: AutoCAD Settings

Instead of Settings – Group Entities By Layer one can use Group Entities By Geometry. Then it is possible to do the same operations with the geometries of different structured dwg-files. But this is a different model and results in different attributes.

3.3.4.2 Export to CAD from Geodatabase

Question: Only one block or only one layer shall be exported back in the original .dwg-file.
Problem: The original dwg-file is overwritten on the whole. All previous data is lost (Layerdefinitions, contents…). Using Quick Export the selected block or layer is exported to the dwg-file and all the other data in this file is deleted.
Solution: Export the desired block or layer into a new .dwg-file. Afterwards this new file can be integrated in the original dwg-file as a block (insert block).

3.3.5 Special Workflows

3.3.5.1 Import from CAD to Geodatabase

- Coordinate systems (UCS):
  As most CAD systems AutoCAD does not support coordinate systems or projections. But it is possible to manipulate the AutoCAD coordinates during import.
  When using the workbench it's possible to set the parameter "Ignore UCS" to "No". But this seems to have no effect. Another solution to manipulate the coordinate system is to use workbench and the transformers:

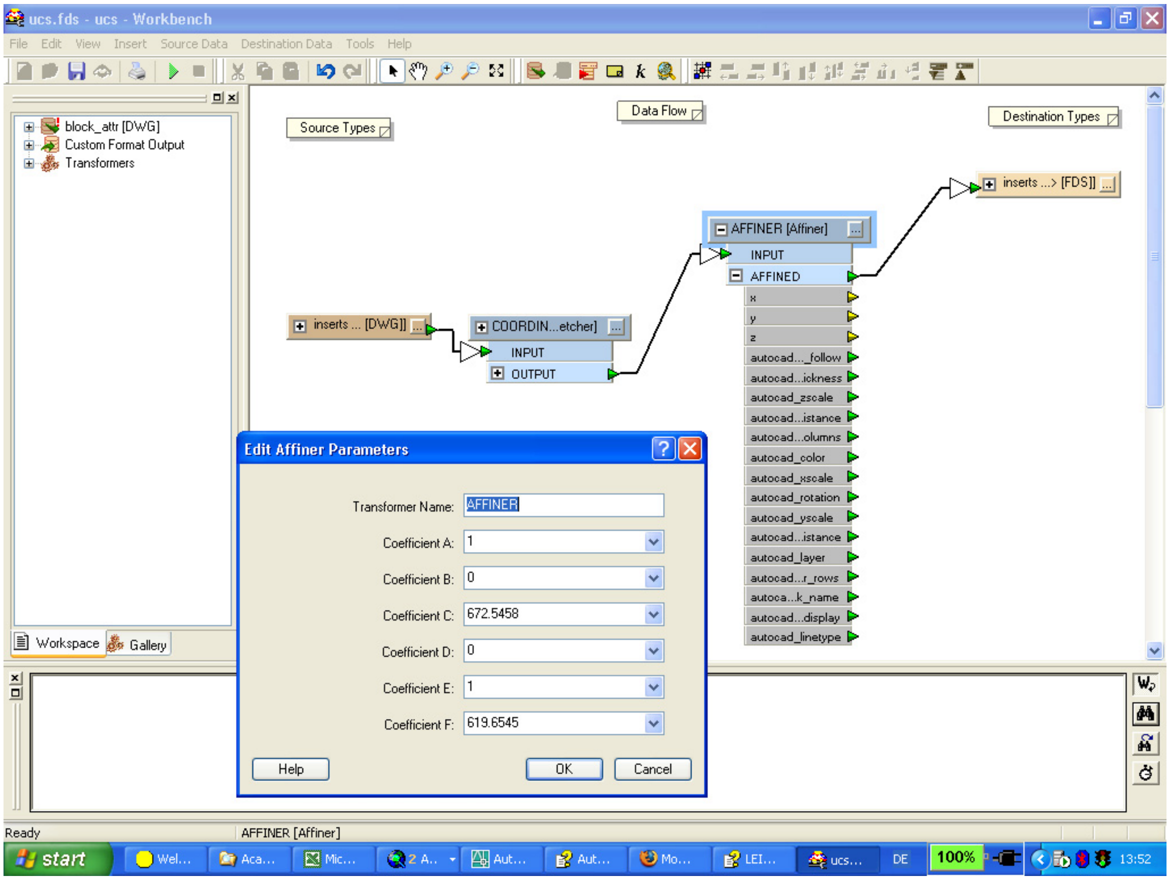

Fig. 26: Coordinate manipulation

<u>CoordinateFetcher*</u>

Retrieves the value of the x, y, and z coordinate at the specified index into attributes. A negative index can be used to indicate the position relative to the end of the feature (-1 is the last coordinate, -2 the second last, and so on). The index can be entered as an integer, or may be taken from the value of another attribute by selecting the attribute name from the pulldown list. If the index is invalid, then the translation will be terminated.

<u>Affiner*</u>

Performs an affine transformation on the coordinates of the feature.

The transformation results in the x and y coordinates being modified by

x' = Ax + By + C

y' = Dx + Ey + F

Coefficients <A> and <E> must be non-zero.

- Points to Line

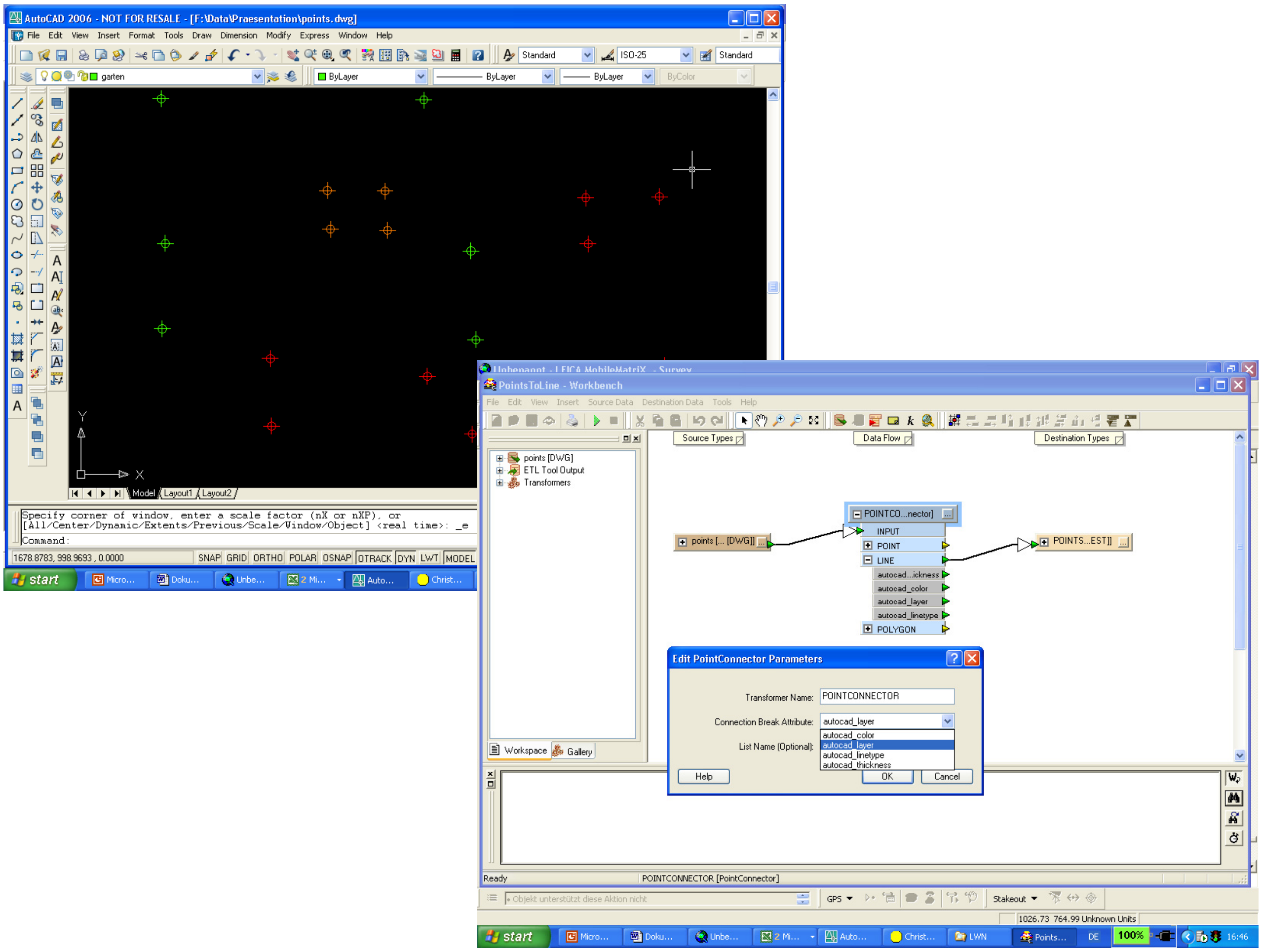

Fig. 27: AutoCAD Pointfeatures and Workbench Transformer

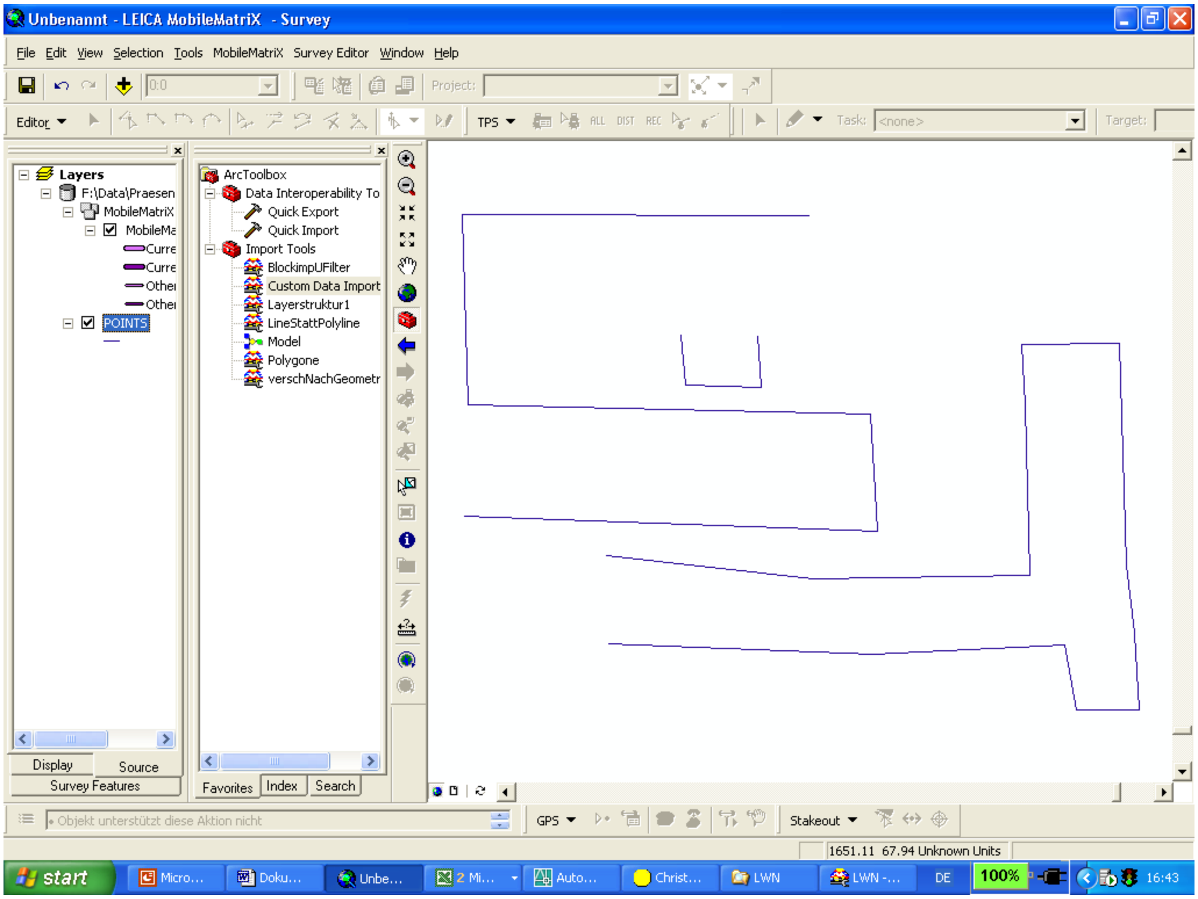

Fig. 28: Result Points To Line

There is a possibility to connect points in the sequence of their creation to lines. As a connection break element it is possible to select for example “Layer”.

Transformer:

PointConnector

Connects input point features in the order they enter, forming linear or polygonal features. For some datasets, it maybe necessary to use a Sorter to correctly order the data before it enters this transformer.

The feature being created is output whenever the connection break attribute's value changes.

When this happens, the point feature whose connection break attribute had a different value is not added to the current output feature, instead it begins the next feature to be output.

3.3.5.2 Export to CAD from Geodatabase

a) Troubles with Data Export (Template Files)

Problem:

When a template file is defined, it often happens that FME creates the error responce “Insufficient memory available“. Probably this is not a software problem.

Solution:
The AutoCAD template-file has to be saved as AutoCAD2000 (or lower) version. But still there are problems with reading the template file and either FME fails or an invalid AutoCAD file is created. The reason for this could not be located in the tests.

b) Troubles with Data Export (Example Line features, see also chapter attributes-blocks)

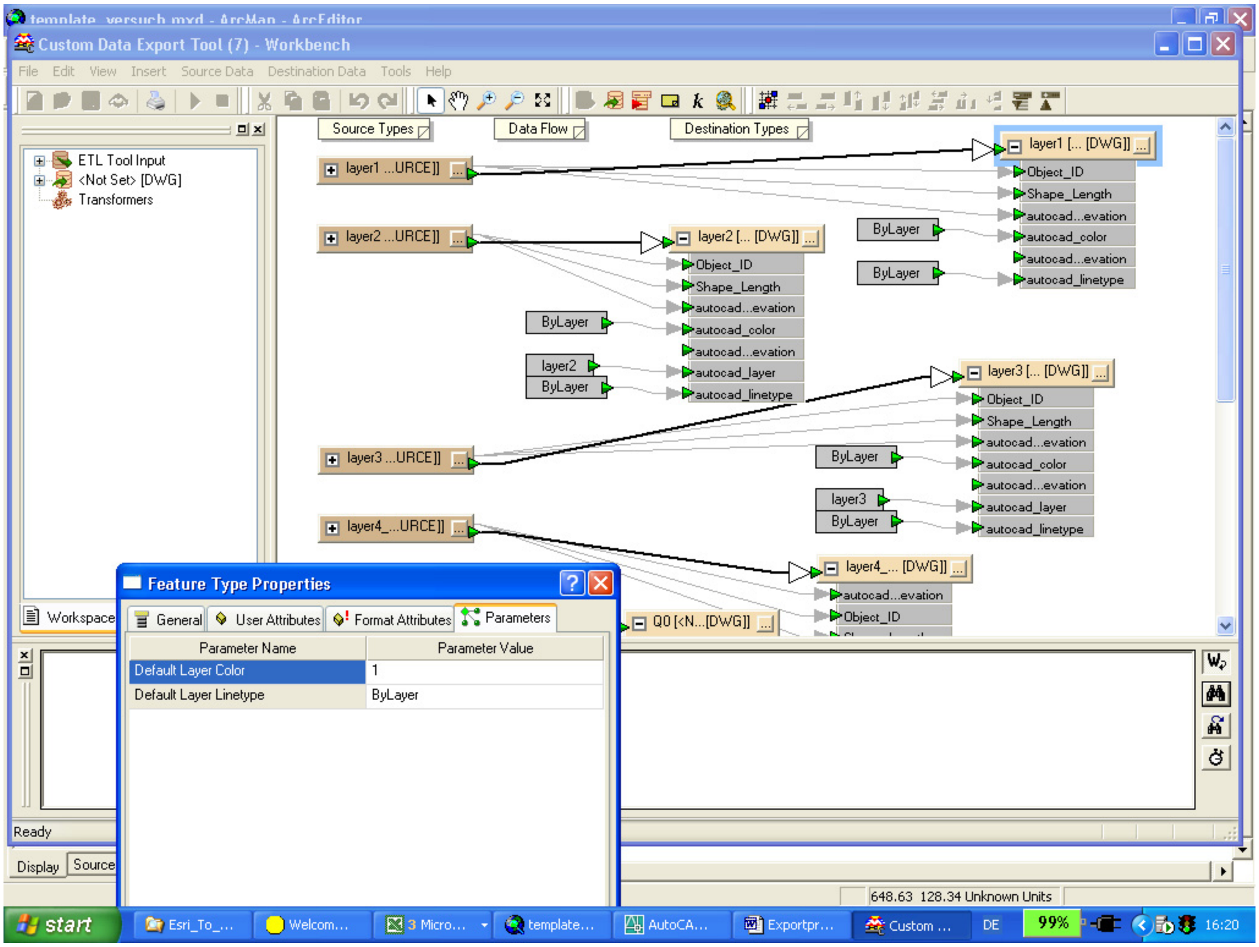

Fig. 29: Linetype and Colour

Problem:
Use a template file and set Feature Type Properties – Format Attributes: Color, Layer, and Linetype like in the picture:

The output Feature indeed has the Color "ByLayer", the Layer like specified in workbench and the Lintype "ByLayer" (in this example). But in Feature Type Properties there are default Parameters for Color and Linetype specified. The existing layers from the template file are overridden by the settings specified here. In this example the Color of the Layer would be 1 (red) and the Linetype of the layer would be "ByLayer" which is nonsense.

Solution:
Because the template-file is overwritten it is necessary to specify the parameters in the feature types tab instead of in the template-file. For example one Layer should have the color red and the linetype continuous. The format attributes tab is necessary to specify the features within a

layer (like Color ByLayer, Linetype ByLayer). Problem: The parameter color is defined to contain only integral parameters, so it is not possible to create true color layers.

3.4 Issues MicroStation Conversion

MicroStation is another widely used CAD software and was therefore chosen for the testing. One main reason for this choice was also that a concrete use-case was on hand. Because of existing data sources only the MicroStation Design (IGDS) could be tested, not MicroStation GeoGraphics or Intergraph MGE.

3.4.1 Overview

The following table summarises the topics for the data exchange between MicroStation and ArcGIS using Data Interoperability Extension.

Format Type Identifier	IGDS
Reader/Writer	Version 7 Both Version 8 Reader
Dataset Type	File
Feature Type	Level number
Typical File Extensions	.dgn
Automated Translation Support	Yes
User-Defined Attributes	No
Coordinate System Support	No
Generic Color Support	Yes
Spatial Index	Never
Schema Required	No
Transaction Support	No
Geometry Type Attribute	Igds_type

Tab. 8: MicroStation – FME Readers and Writers (Safe, 2005)

Seed and Cell files:
To create a new design file in V7, a seed file has to be specified. This seed file defines conversion parameters and whether the destination file will be two- or three-dimensional. In V8 this is no longer necessary.

A cell library file is optional with the V7 writer. V8 does not support writing named cells. The cell file contains the definition of named cells (comparing to AutoCAD blocks specified in template files).

3.4.2 Attributes

CAD entity attributes are stored in special FME feature attributes when being imported. During export these attributes are used to fill in an element structure. Design files as well as their associated databases can be read and written.

3.4.3 Geometries

The following table shows the geometries supported by MicroStation.

Geometry	Supported	Geometry	Supported
aggregate	No	Polygon	Yes
circles	Yes	Donut polygon	Yes
Circular arc	Yes	Line	Yes
Elliptical arc	Yes	Point	Yes
Ellipses	Yes	Text	Yes
none	No	3D	Yes

Tab. 9: MicroStation geometries (Safe, 2005)

3.4.4 Special Workflows

3.4.4.1 <u>Import same data, different methods</u>

- Quick Import; Settings: Group By Geometry, Element Expansions and Linkage Extractions not crossed, Units: Master

  <u>Result</u>: For each existing level and featuretype one feature class is created with the following attributes:

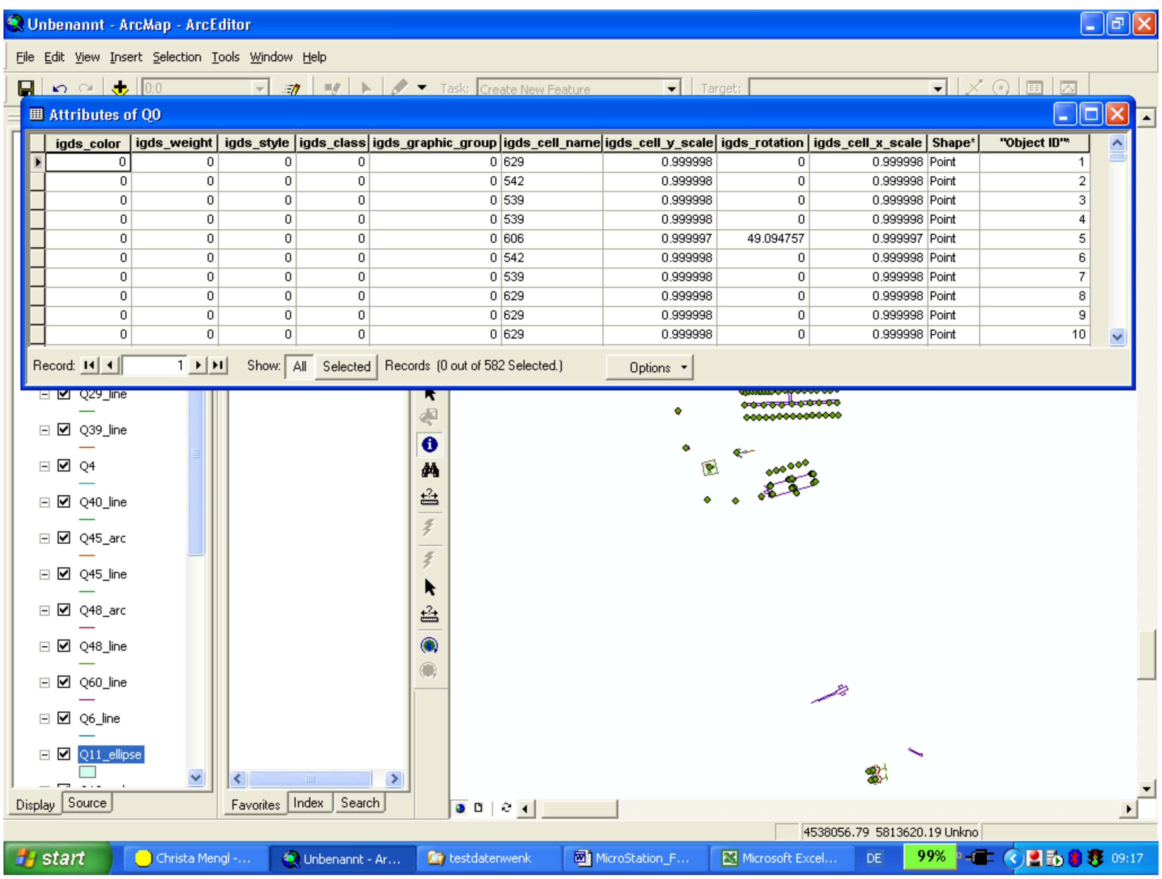

Fig. 30: Attribute Table 1

- Interoperability Connection; Settings as previous

<u>Result</u>: Far less feature classes are generated. The level definitions are lost like the x- and y-scale. The cells are output to a multipoint shape.

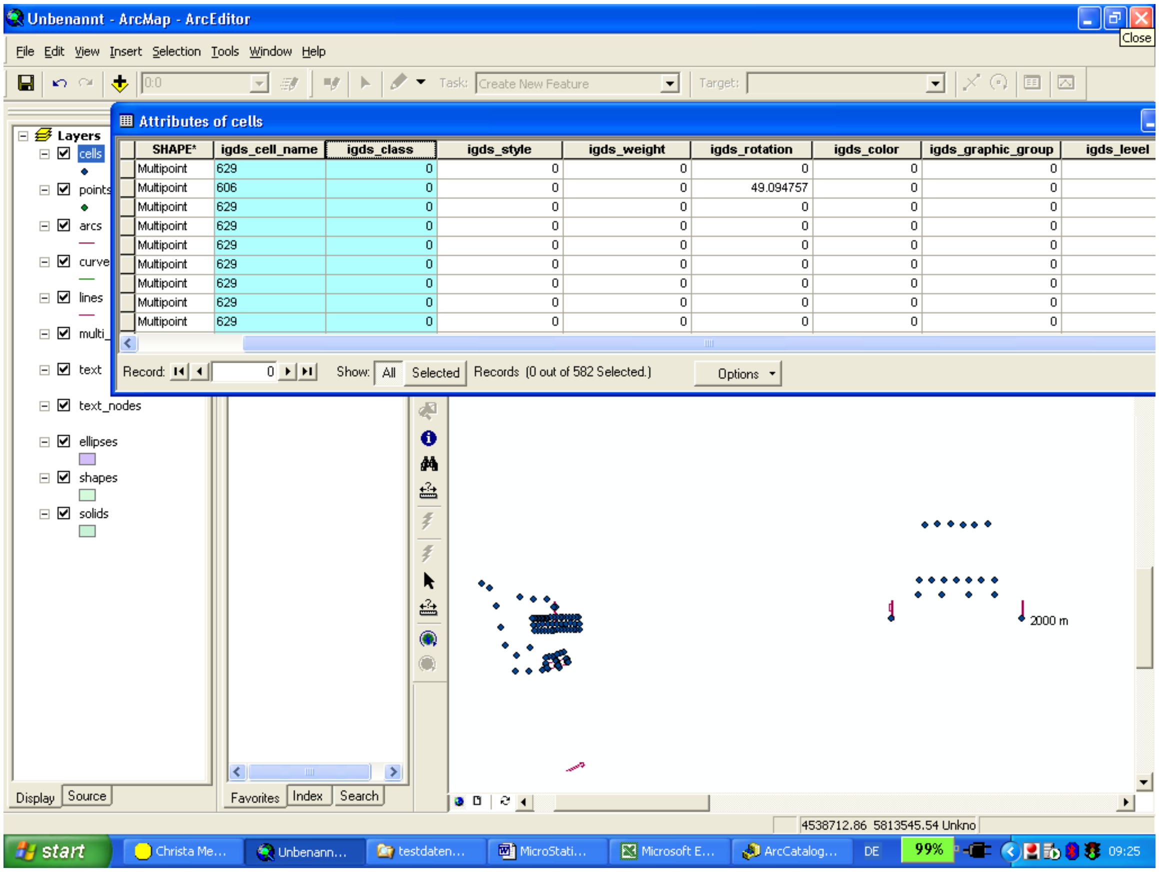

Fig. 31: Attribute Table 2

- Quick Import; Settings: Group By Level, rest like 1)
  <u>Result</u>: few featureclasses with few attributes (for example no more cell names).

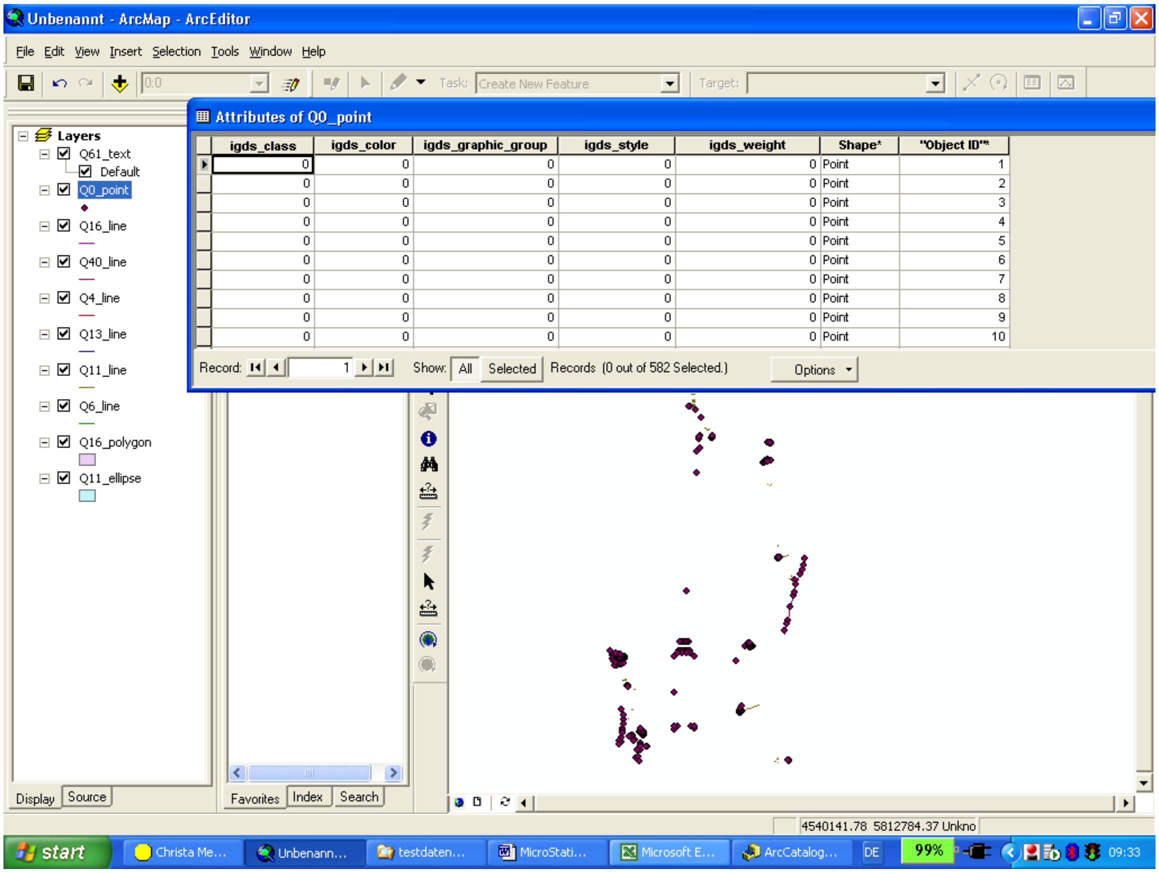

Fig. 32: Attribute Table 3

- Quick Import; Settings: Group By Schema, rest like 1)
  same results as in 1)

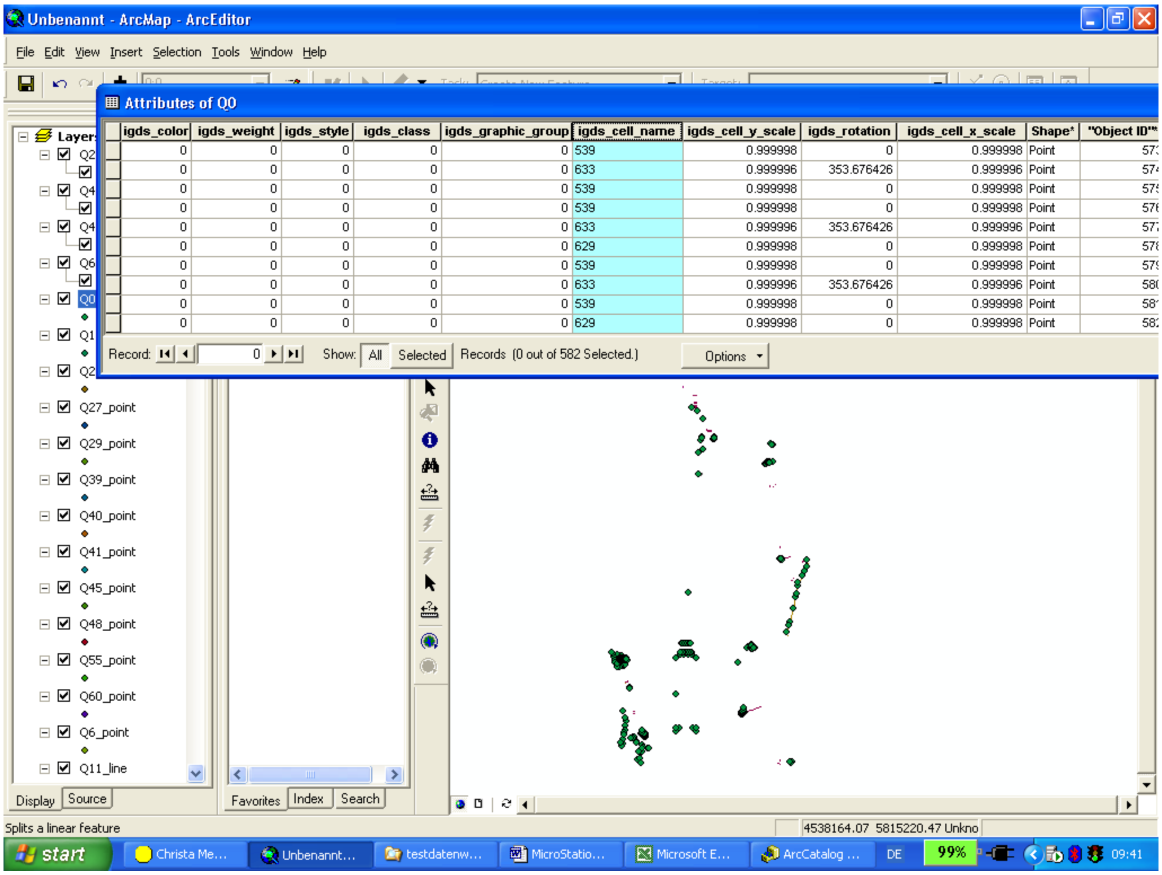

Fig. 33: Attribute Table 4

- Quick Import; Settings: Group By Level Names, rest like 1)
  same as Group By Level

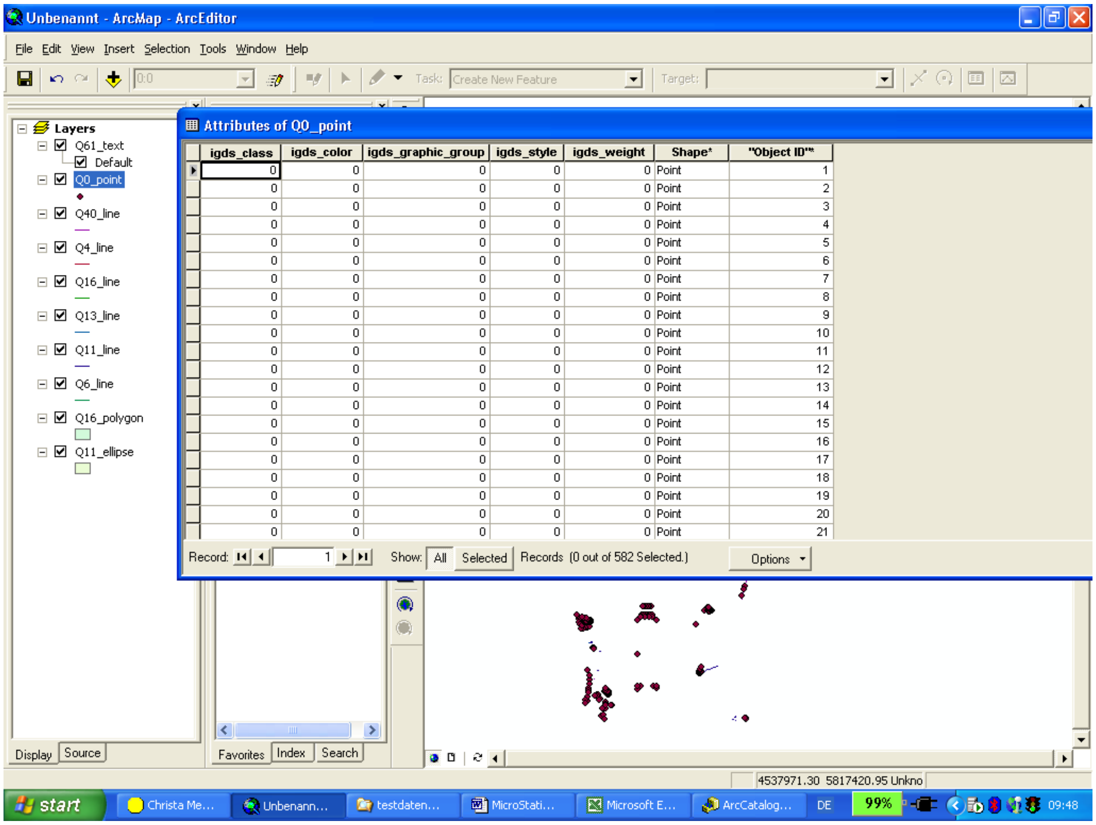

Fig. 34: Attribute Table 5

- Sometimes people don't really want to import their data. They just want to see it as background information in their map when collecting new data. So it is sufficient to have either an interoperability connection or to use the Add Data button in ArcGIS.

3.5 Use-Cases

3.5.1 Use-Case 1: Semantic Interoperability and MicroStation

3.5.1.1 Use-Case Description

Special Data Model
Question: Is it possible to create data in ArcGIS Desktop and export it to a special data model in MicroStation?
Solution: Yes, it is possible, but… . It takes a lot of effort to customize the export tool in Data Interoperability Extension.
Given are a seed- and a cell file. In ArcGIS Desktop created point- and line features are to be exported to MicroStation V7 so that they fit a special data model. That is they have to be on a certain level, have a certain linestyle, cells are to be represented in the proper way etc.
In the data model the level they are on identifies the lines. The points are identified by a special number, which is the cellname.

3.5.1.2 Workflow

1.) Data Creation in ArcGIS:
At first a geodatabase is created. It contains a line- and a point feature class. For the definition of the domains an xml schema can be created and imported to the geodatabase.

Data collection is done with e.g. GPS and the type of the object is controlled by an attribute. The point feature class has an attribute pointcode. This attribute is responsible for symbology representation in ArcGIS.

For the line feature class the attribute Linienart is defined. It is also responsible for the representation in ArcGIS.

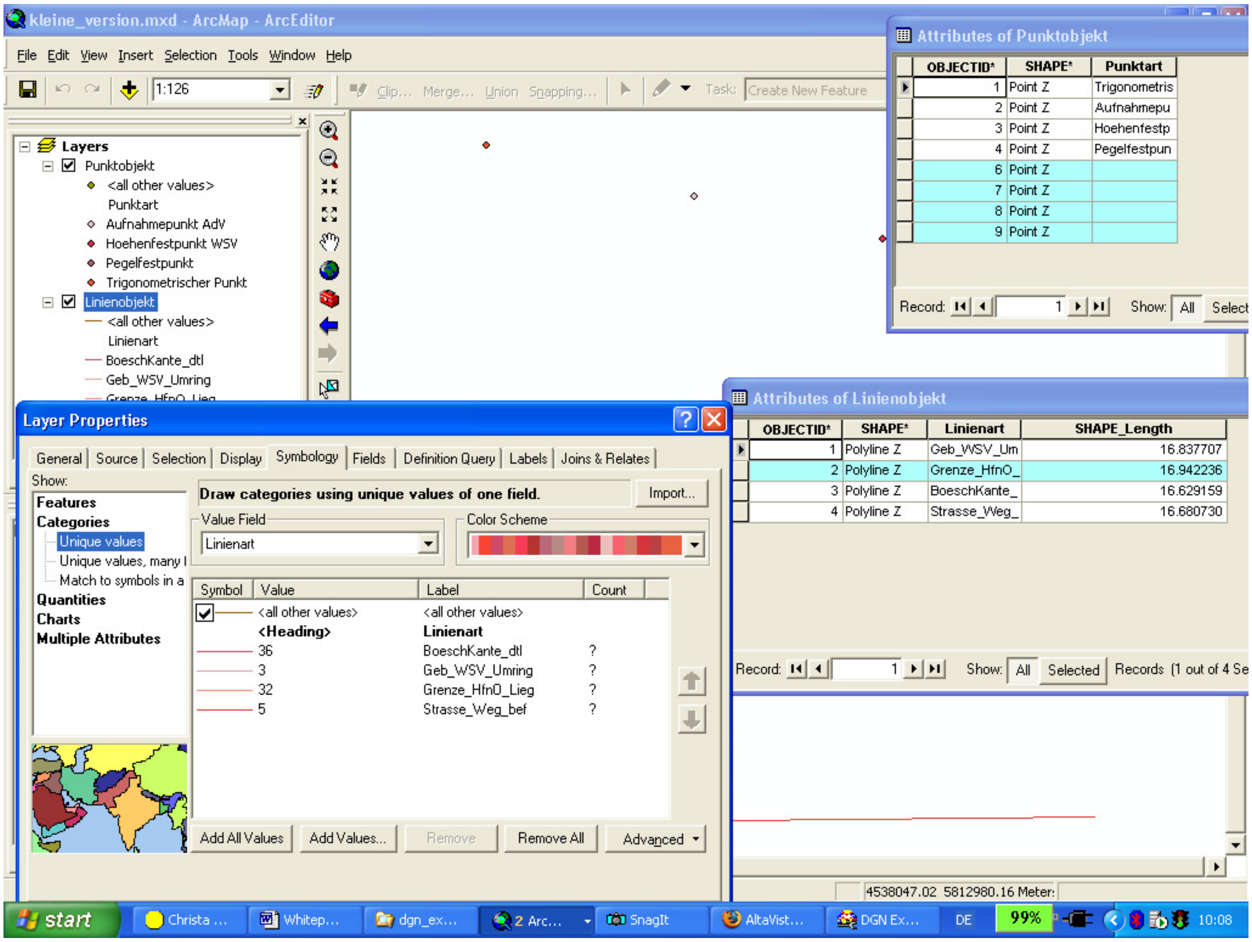

Fig.35: Point- and Line features in ArcGIS

2.) Create a Custom Data Export Tool

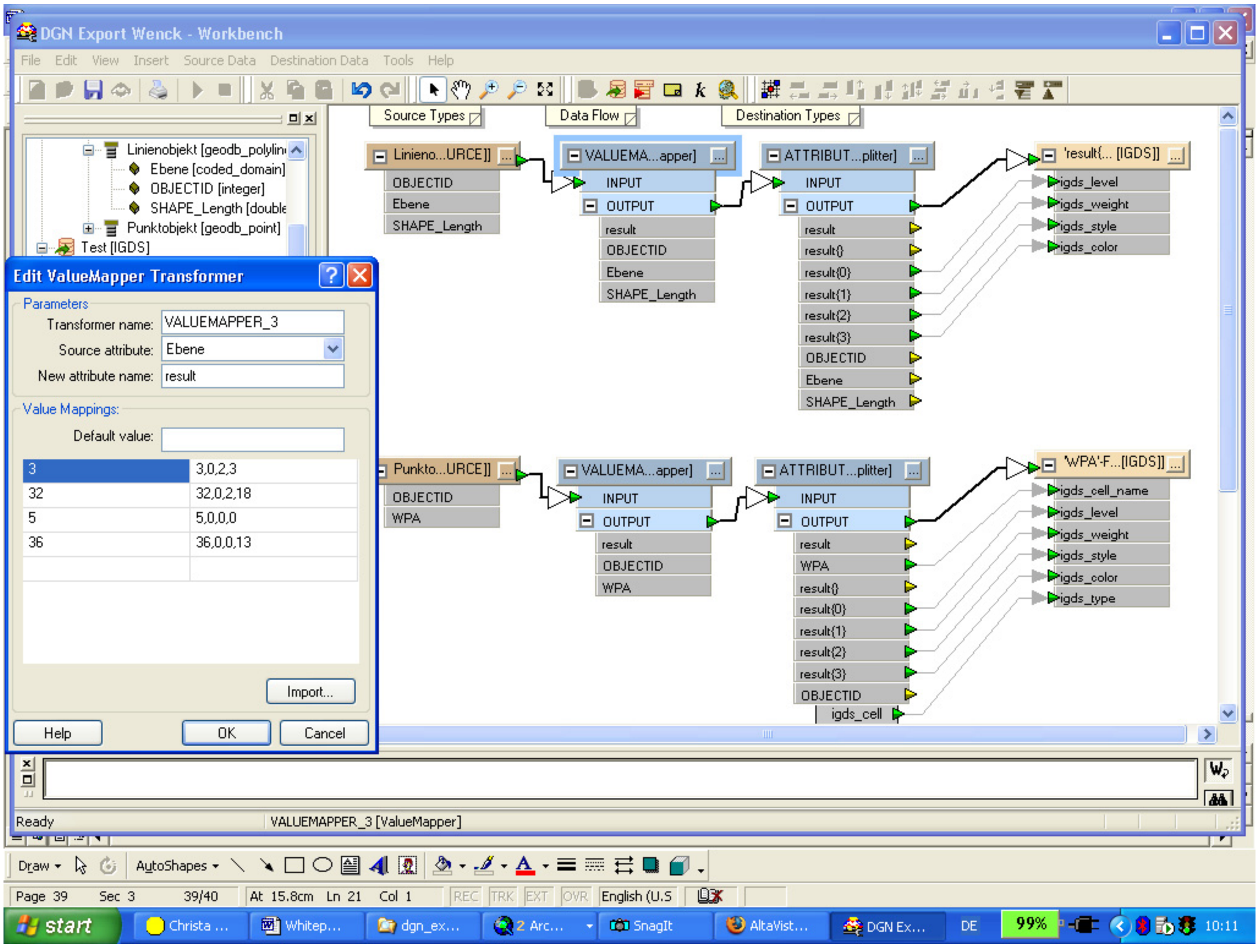

Fig. 36: Attributecreation in Workbench

The former created feature classes are the source data for the custom data export tool. To create the MicroStation data model from the ArcGIS data model there are two steps necessary.

<u>ValueMapper</u>

“Performs a lookup of the value of an attribute in a lookup table, and stores the looked-up value in a new attribute.” (Program help Data Interoperability Extension). This transformer can be used to add further information to a feature depending on its attribute values.”

In this case the Value Mapper defines for the attribute “Ebene”: level, weight, style, colour and stores this as the new attribute “result”. For the point features the attribute WPA (pointcode) is used to generate cell name, level, weight, style and colour and is also stored as “result”.

For huge amounts of data the lookup table can be imported from a. csv-file.

<u>AttributeSplitter</u>

“Splits a given attribute, using a given delimiter character, into a list attribute. Each item in the list will contain a single token split from the list. Alternatively, instead of using a delimiter character you can provide a string in the format #s#s#s, where each number is the length of the substring you wish to extract.” (Program help Data Interoperability Extension)

In this use-case the attribute to be splitted in both feature classes is “result”. The delimiter is “,”.

For the correct representation of the cells in MicroStation it is also necessary to define the point feature as a cell, which has a certain name (pointcode or WPA).

Result:

ArcGIS → MicroStation

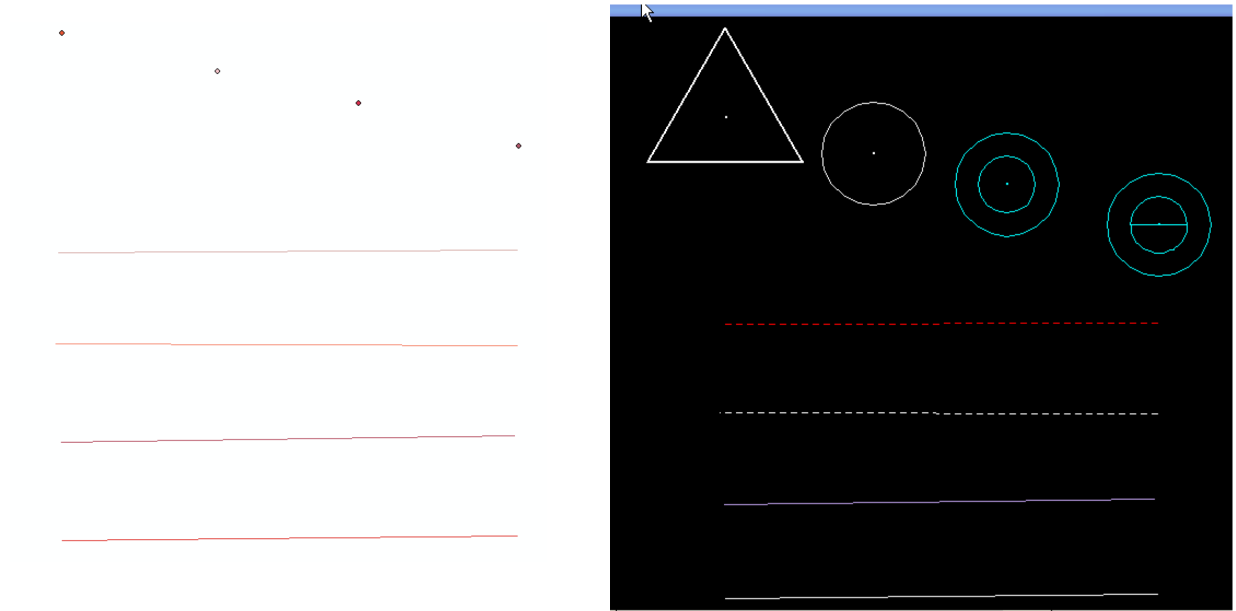

Fig. 37: Result Export to MicroStation

The following table gives an overview of the results of the use-case. There are obvious differences in the structure of ArcGIS and MicroStation files that make interoperability not impossible but demanding.

ArcGIS	MicroStation
One point feature class	Different cells for every object
One line feature class	Independent lines
One level for each feature class	Objects can be on different levels
Representation defined by layer properties	Representation defined by cell file

Tab. 10: Differences ArcGIS – MicroStation

3.5.2 Use-Case 2: Data Update and AutoCAD

3.5.2.1 Description

The canton Appenzell Ausserrhoden has a digital map for nature preservation.

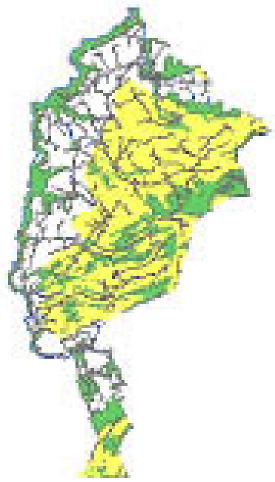

Fig. 38: Nature Preservation Map

The base data for this map was a cadastral map in 1:5000. Besides of different nature preservation areas like wetland, poor grassland or rough pasture there are also landscape conservation areas and point objects like houses or special trees. Forests are outside the reference of the department for natural preservation therefore all areas on the plan for nature preservation end at the forest's borders.

In the years 2004/2005 a huge project for data update of the agricultural areas took place in the canton. All forest borders were newly measured by photogrammetric means and the department for agriculture set the boundaries of all different agricultural areas (meadow, pasture, areas for ecological compensation etc.). As the natural preservation areas are within the agricultural areas these were to be involved in this project.

Because of the new orthofotos a lot of areas could be outlined more precisely than in former years. Some areas could not be distinguished on the orthofotos. Therefore someone had to go to the farmers and outline the areas´ borders together with them. In the end there was an updated plan for nature preservation but also newly updated borders of the forest. These two plans had to be merged.

The natural preservation plan was in ArcGIS format. The new forest borders came as .dwg. In the end everything had to be exported to AutoCAD Map and will be processed there using a special application.

3.5.2.2 Workflow

At first the relevant data has to be imported to a geodatabase. In this example it is the landscape conservation areas, forests, rivers and roads. Then a topology is created.

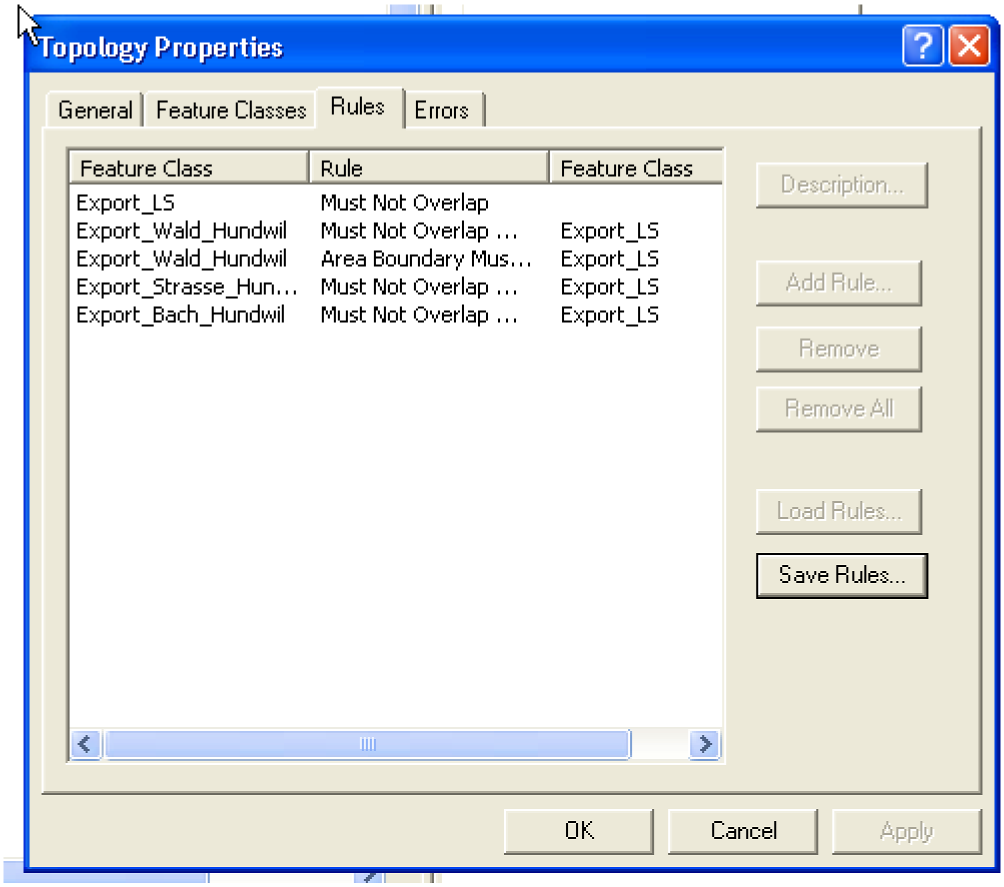

Fig. 39: Topology Rules

Landscape conservation areas must not overlap forests, rivers or roads. Clipping these features can solve this. The second thing is to find out where the forest has become smaller. Therefore the rule for the forest feature class is defined: area boundary must be covered by boundary of. Then the whole map has to be checked and corrected so that the topology is correct (including some exceptions). Both cases are covered the forest being smaller as well as the forest having grown into the landscape preservation areas. Finally the corrected map has to be exported to AutoCAD 2006 dwg.

To do this the following custom data export tool has been created:

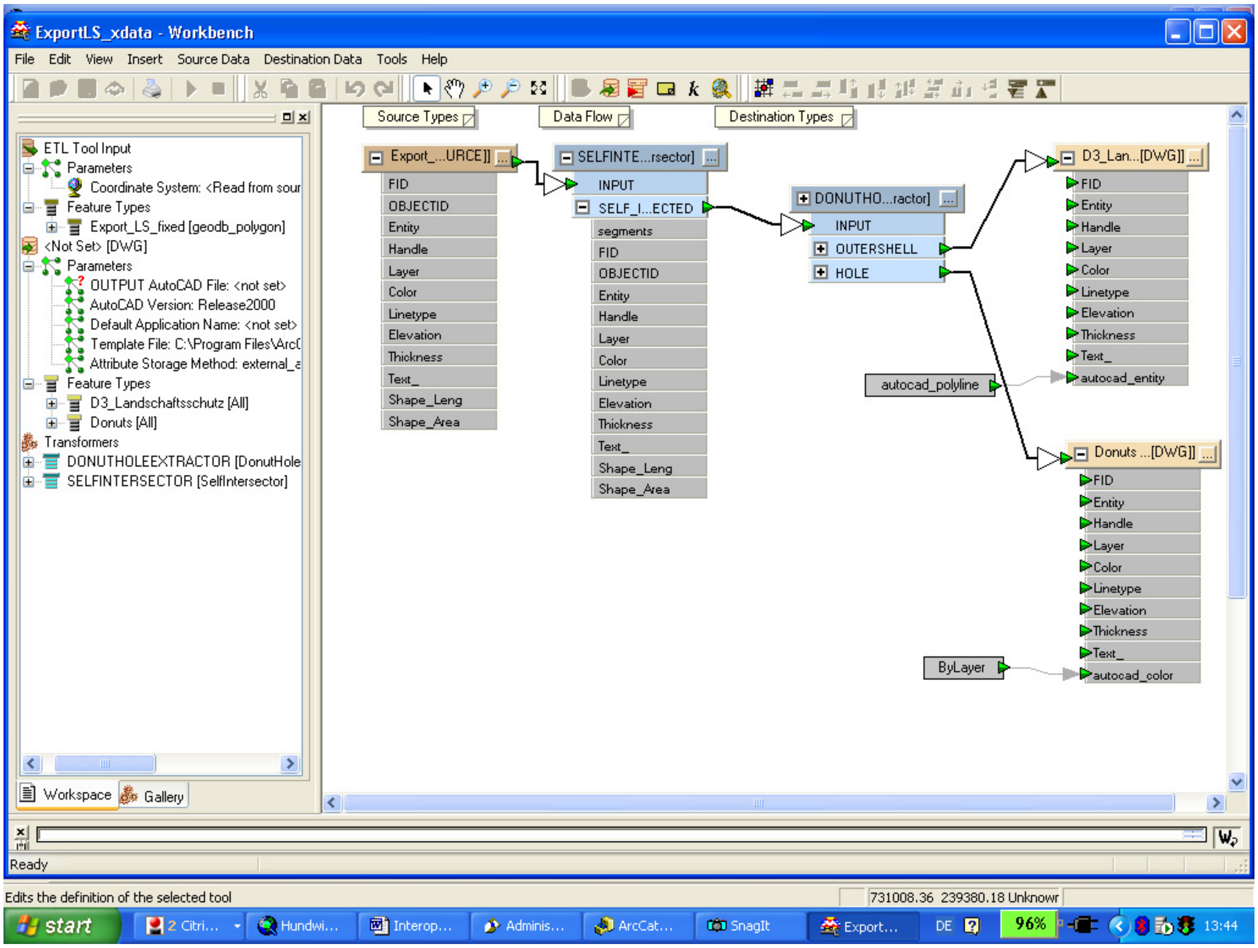

Fig. 40: Custom Data Export Tool for polygons

The Selfintersector is used to split selfintersecting polygons into single polygons. Because AutoCAD has problems with polygons having holes ("rings") these have to be marked. Otherwise they appear in AutoCAD as blocks and cause problems when being further processed with specialized applications. Therefore the transformer DonutHoleExtractor is used.

"Splits an area feature which has holes into its component rings. The outer boundary polygon is separated from the holes and output via the OUTER_SHELL port, and the individual holes are output as polygons via the HOLE port. If an area had no holes, it is output untouched via the OUTER_SHELL port. Each output feature has all the attributes of the original area feature." (Data Interoperability help)

3.5.2.3 Problem discussion

a) Xdata

When importing data to ArcGIS or creating data in ArcGIS an ObjectID is created. This attribute has to be filtered out when data is exported back to AutoCAD. Otherwise it is not possible to further process data with the GIS application in AutoCAD.

b) <u>2D Polyline</u>

When drawing a polyline in AutoCAD this feature has the attribute “polyline”. But when such a closed polyline is imported to ArcGIS and exported back again, the attribute in AutoCAD changes to “2D-Polyline”. This is no problem for AutoCAD but when the feature is processed with an application, error messages appear and processing is not possible. To define the AutoCAD entity as “polyline” or even as “polygon” in a custom data export tool does not make any difference. So it was tried to import self-drawn simple polylines from AutoCAD and export them back. Then the attribute was “Polyline”. In AutoCAD “polygons” are always regular features like rectangles or pentagons etc. Irregular features are always defined as “polylines”. To create areas in AutoCAD one usually draws a closed polyline and then creates a hatch. But now closed polylines are imported to ArcGIS and here they are recognized as polygons. Probably this is the reason for changing the attribute to “2D Polyline” when exporting these features back to AutoCAD. So it was tried to use the transformer “Geometrycoercer” during data export. As can be seen below, the transformer worked only on some features. It appears to be limited to relative simple polygons. Polygons having a lot of vertices where not transformed.

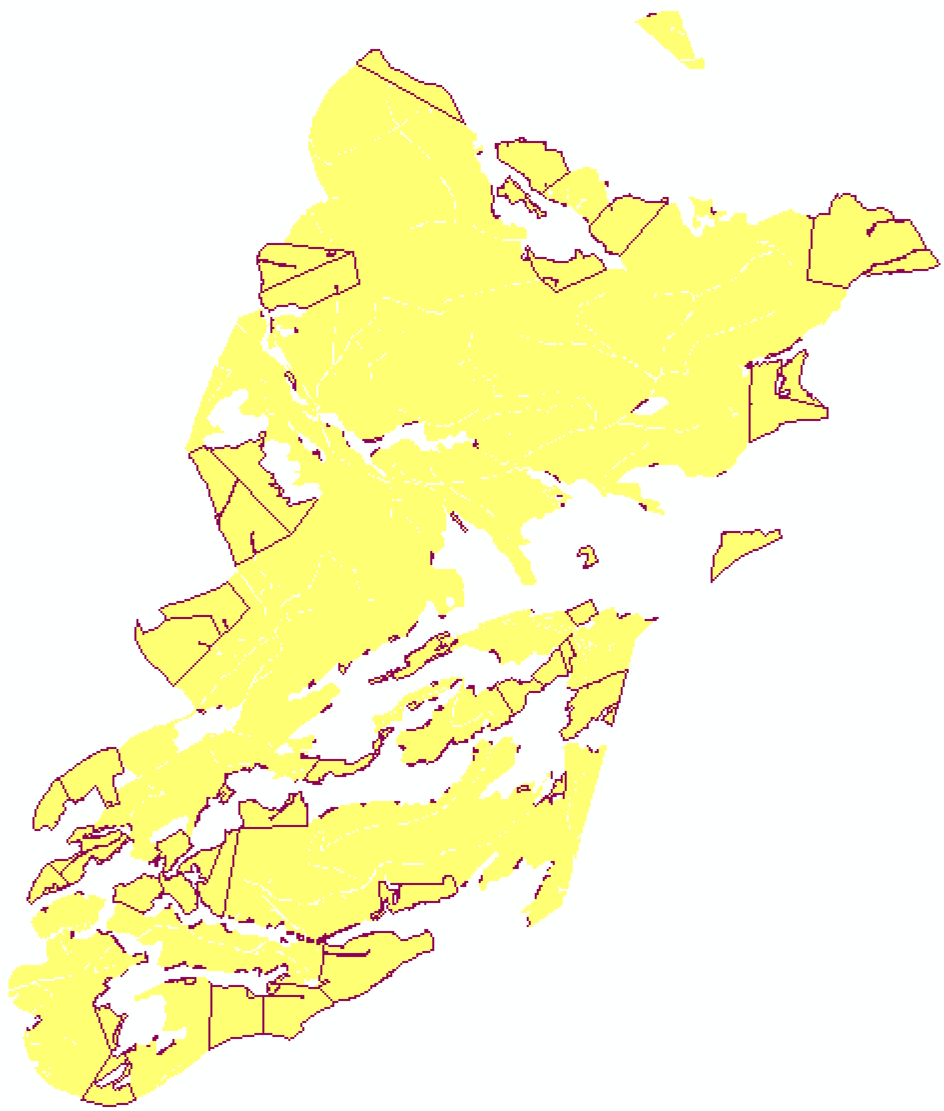

Fig. 41: Partly exported polygons

c) Splines and Arcs

Normally arcs and splines in ArcGIS are transformed to polylines with many vertices. These features can be clipped without problems.

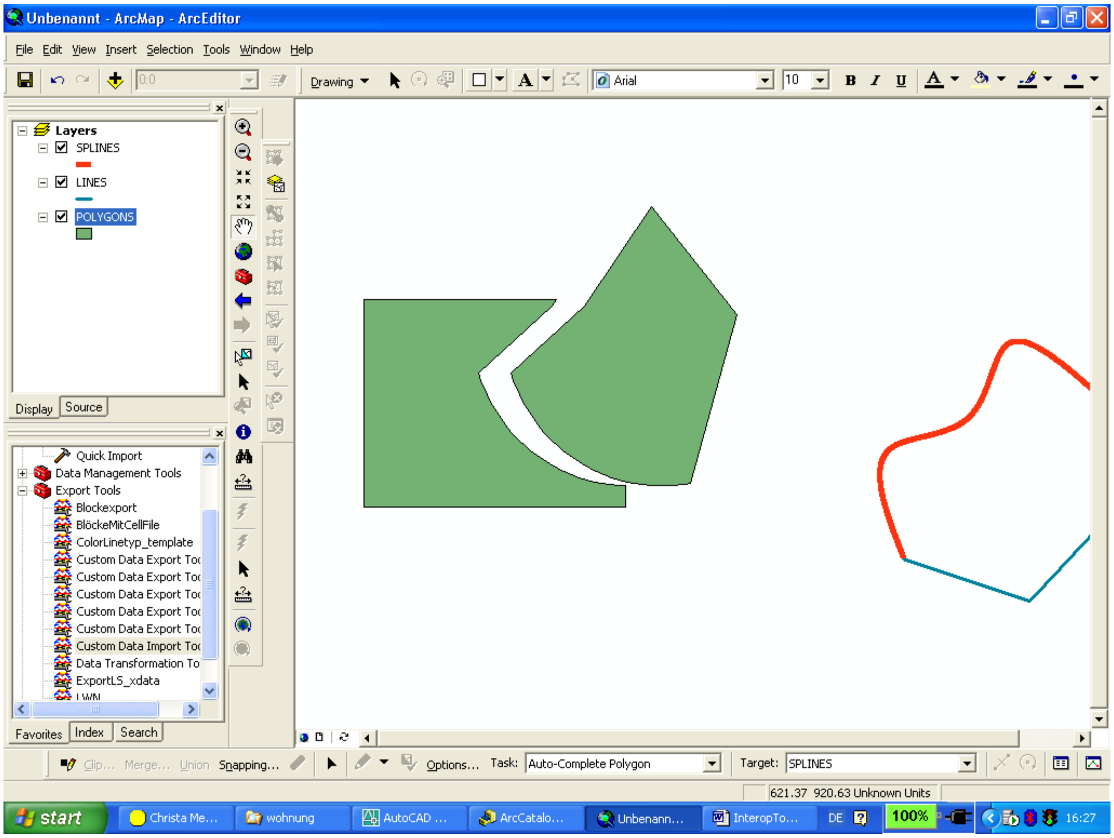

Fig. 42: Polygon features with Arc-borders

But in this use-case the arcs remained arcs when being imported to ArcGIS. And then it was not possible to perform any geoprocessing like clipping. But the features could be edited nevertheless.

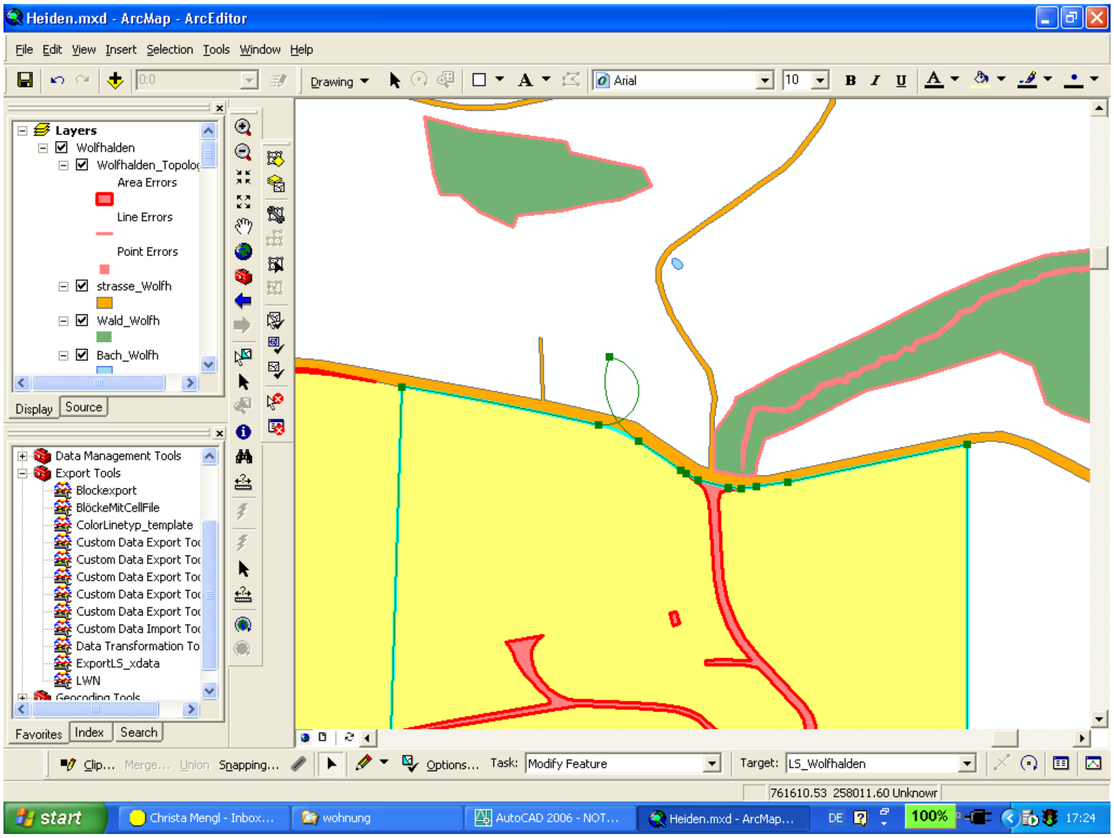

Fig. 43: Arcs in ArcGIS

So the question came up what kind of features are these? In AutoCAD they where defined as polylines.

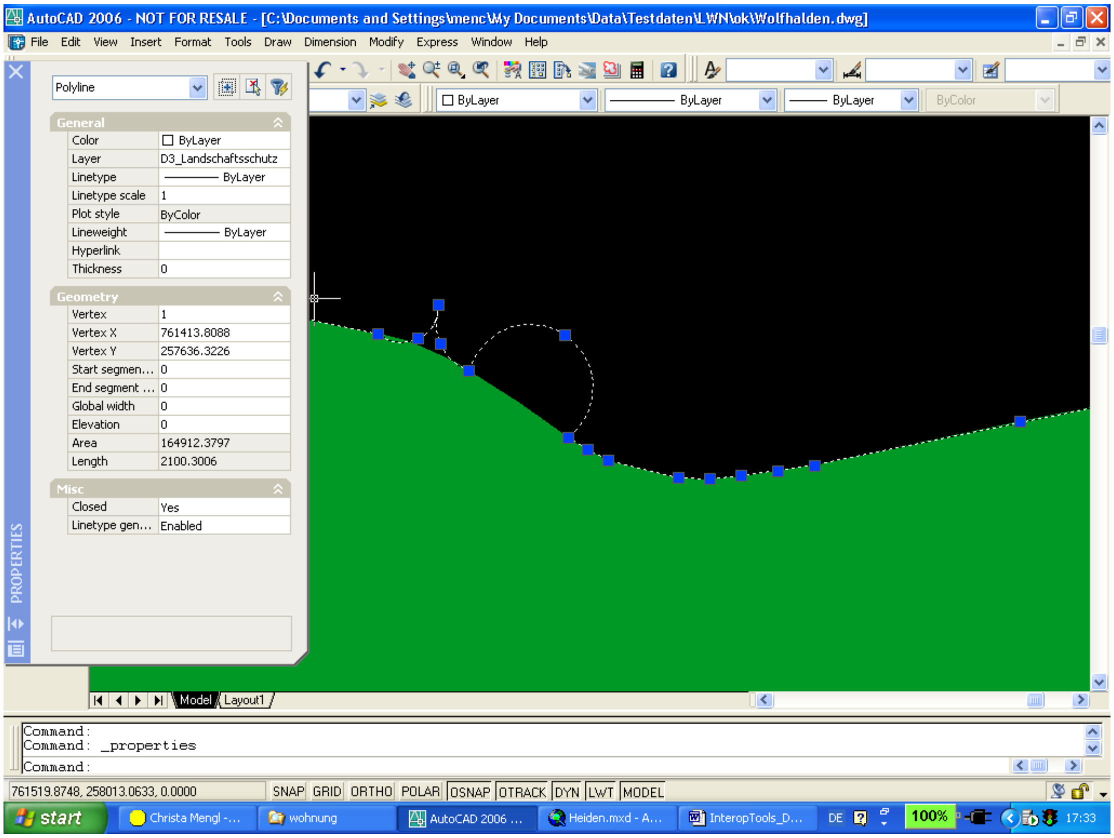

Fig. 44: Polylines in AutoCAD

Further tests in ArcGIS showed that the areas containing such “splines” could not be clipped themselves (red area bottom left in the next picture). But when being copied, the copied feature could be clipped without problems (top left) no matter if the original roads feature was used or if new features where created. In the next test a new road feature was created. This could clip the original red area.

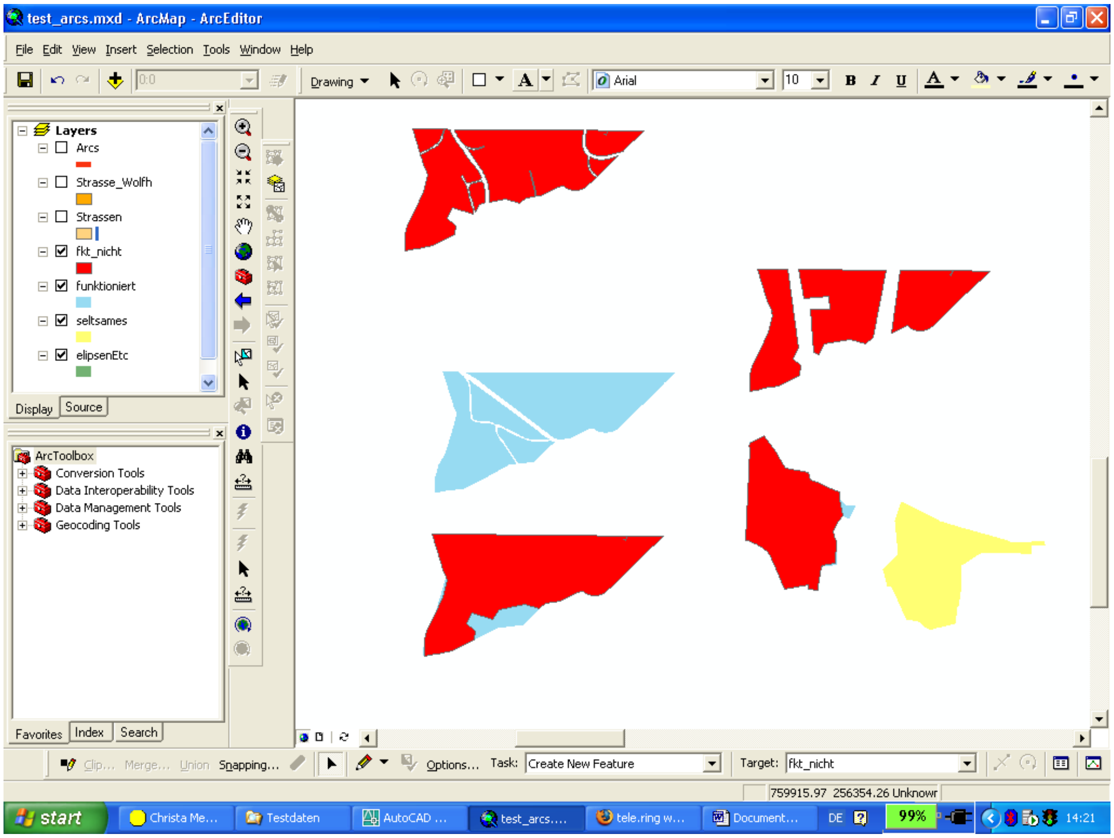

Fig. 45: clipped polygonfeatures in ArcGIS

So the problem with geoprocessing only occurs when the original features from the topology are used. And only in this cases the "splines" remain in ArcGIS. When there is no topology defined, the "splines" are transformed to lines and clipping is no problem.

<u>d) Decentralised data and updating process</u>

Decentralised keeping of data makes interoperability and updating processes difficult. Private companies like surveyors and governmental departments like the department for nature preservation own and update their data independently. But in reality in land use regulation as well as nature preservation concerning special landowners have to rely on the surveyor's data. Updates in the cadastral plan have to be considered in derived plans as well. The main thing is that the concerned departments know about the updates. So at least a process has to be defined who has to be informed in what way about updates. As cited in the chapter "The Soft Dimension" the „willingness to interoperate" is a „prerequisite for interoperability" (Allan Levinsohn, 2005). Then it would be useful to know where the updates are located so that not the whole plan has to be checked. It is also possible to define policies for the update process so that the derived plans could be updated automatically.

4 Conclusions

4.1 Synthesis

4.1.1 Interoperability

Although there is a hot debate about interoperability going on in the GIS world and a lot of efforts are made there is not one single practical solution to be found concerning the CAD - GIS data exchange problem. Specialists are aware of the challenge but still no one has found the formula to solve it completely and simple.

The definition of interoperability by Michael Rose et al. (2005) suggests that the exchange and use of information across different hard- and software has to be without special effort. The practical testing showed that this is not always given. Even if having to use the workbench and different transformers shall not be declared as a special effort, the exchange and use is not always possible. So total interoperability can not be supplied. His principles of interoperability are not fulfilled.

Allan Levinsohn (2005) is correct when he claims that industry standard APIs and tools for data exchange are available. The Data Interoperability extension is one example. The tests did not deliver conclusions concerning data schemas. But with the workbench it can be managed to import or export data to and from special schemas. His level of interoperability called "institutional" containing the willingness to interoperate is indeed variable. Sometimes as proofed in the AutoCAD use-case it is difficult to gain information about what data is available or about what changes have been made. Data creators are unaware that their data is needed and used to create derived data.

Considering the dimensions of interoperability the data format interoperability is satisfied. The metadata interoperability was not tested but experience proofs that there is a shortcoming. Semantic interoperability seems to be a special problem between CAD and GIS systems. Probably W. Kuhn (2005) is not completely right to call semantic interoperability "the only useful form of interoperability" but the emphasis of interoperability problems lies here. Concerning CAD and GIS mainly conceptual heterogeneities made out by Kuhn complicate the semantic interoperability.

The syntactic interoperability as standardization of language and data formats is more or less fulfilled because of efforts from the likes of the OGC.

It is not easy to have standardised tests on subjects like policy, education or coordination but experience and the AutoCAD use-case show that the "soft" dimension is a big barrier towards interoperability.

4.1.2 Solutions

As the focus of this work is not the technical solutions it shall just be said that there are a lot of efforts under way. The Safe Software FME suite is one solution for data transfer. Solutions like keeping data in an Oracle database or the federated GIS could not be tested. Different departments with different software working with data in one common database seems to be a demanding thing. Workflows will have to be defined, which again have to consider the “soft” component.

It is out of question that the OGC is an important organisation. It is not possible to name the concrete influence of the OGC on the practically tested scenarios. But software vendors like ESRI are members of the OGC. Therefore it is assumed that the specifications and other OGC projects have influenced the software development and that without the consensus on standards software like the Data Interoperability Extension would probably not exist. The OGC´s interoperability program ranks interoperability at the top of priority lists of software producers. The technology development program is a precondition for interoperability. The Simple Features Specification exists. But the tests showed that features supported by one specific software are not necessarily supported by another software. This can lead to problems for example when accurately constructed arcs representing for example roadcrossings in AutoCAD are imported to ArcGIS and are then substituted by lines. This reduces the accuracy and can cause problems.

It has to be agreed on the importance of standards. But the mere existence of the countless standardisation organisations shows that there will not be an agreement about “the one” standard. The OGC´s open standard gives a good example for the others. On the contrary to other standardisation organisations the OGC´s open standard has free rights of distribution. As it is based on an international agreement, claims not to discriminate against persons or groups and ensures that specification and license are technology neutral it seems to be one possibility to unit several of the other standards. Even small geodata markets like Switzerland have their own standards like INTERLIS.

The same amplitude as with standards seems to exist with data models. In the practical testing it was prooved that it is possible, but not simple, to exchange data to and from different data models. Besides of using Data Interoperability Extension it should be possible to map data from one model to another by using GML. The data model in the use-case had several deficiencies like ambiguous codes. The ESRI data models could help unexperienced users to create efficient data models. The OGC´s geometry object model seems not to be fully implemented in the tested software. Obviously CAD and GIS software vendors do not agree on common geometry subclasses.

It has to be fully agreed with Mark Reichardt (2004) when he states that a lot of coordination will be necessary so that, for example, every road department even within one state uses the same attribute schemas, measurement types and data types in describing a road.

4.1.3 CAD versus GIS

The differences between CAD and GIS prooved to be a barrier towards interoperability in the practical testing. The semantic differences, for example the representation of attributes in AutoCAD through colour, layer, linestyle etc. whereas the same attributes are represented in GIS by filling attributes in a database are to be solved laboriously using the workbench. The differences cited in literature do cause data exchange problems in practical application. At the first glance differences in the geometries seem not to matter that much. But as prooved multiple times in the tests these seemingly small problems can trigger others. For example when a polygon with many vertices has to be exported from GIS to CAD. Or when splines contained in a topology in ArcGIS prevent geoprocessing the feature.

There were no integrated GIS or CAD systems tested. But it is hoped that these systems can bridge the gap because otherwise there will be no real interoperability between GIS and CAD.

4.1.4 Data update

Use-case number two highlighted the problems with data update. Again the “soft” component of interoperability is important. People have to be aware of data updates. Otherwise it can happen easily that, for example, the topografic base map can be imported into another system without effort but the problems only start afterwards. Data in the derived map has to be updated. Maybe there are legal restraints against this update. For example updated forest borders do not automatically trigger updates in landuse. So the map has to be published with the old landuse data, which might look weird because the meadow can be on the same location as the forest or there are gaps with no information at all. But even if there are no legal restraints to data updates it is laborious work to update all derived maps when the basis is updated. Processes between all involved parties have to be defined to inform everyone about data updates. In reality this is very seldom done. Sometimes not even the executive department has a list about their mutations. iTRIM could at least set the topic on peoples minds and make them exchange information. For sure a lot of updating could be automated.

4.1.5 Data Interoperability Extension

Most of the software systems nowadays can read the most important formats of their competitors. But simple reading often is not enough as the tests showed. Translation is necessary. In CAD programmes information is encoded in line style or symbology. As these are format specific the information often gets lost when imported to another program. The extension enables semantic interoperability by translating information packed in layer- or linestyle information into attributes. During data export from GIS to CAD systems template- or cell files enable the translation of semantic meaning back.

4.2 Essentials

There is an obvious trend that the future belongs to the Internet. WFS and WMS can provide the requested data. Data integration instead of data conversion seems to be the trend. But there will still exist applications where it is not enough just to view data. Sometimes it will be necessary to convert data to make it available and editable in different software platforms. Ron Lake (2005) correctly names the trends for interoperability.

The main problems of interoperability can be summarized under three categories:

- The “Soft dimension”
  Policy, education, partnerships, coordination and the will to cooperate can be named here. Maybe this is most difficult to solve. The responsible persons must recognize the problem. Most of the times these persons are not involved in GIS and therefore cannot recognise the problem. As the use-cases highlighted people are not aware that others use their data to make derived products. Therefore there are no update processes defined. It is on the user’s side to ask to be informed about updates. But what interest

has the creator of the base data in doing additional effort? A lot of processes would have to be defined between rivalling companies or departments. They definitely sometimes lack the will to cooperate. But the main problem seems to be simply knowing about problems.

- Semantic interoperability

  Different data models and the difference between CAD and GIS make interoperability a challenging topic. Documentation and standardisation of data models is the first step to be done. It still happens very often that data is exchanged without metadata. What use is it to be able to integrate geometries in a map without knowing what these represent? Maybe the differences between CAD and GIS can be levelled through the increasing integration of the two systems by the software vendors. Software products like FME can accomplish semantic translation. There the transformers can do a lot of semantic translation. But also here one big problem seems to be the knowing of what kind of data do I get and what kind of data is needed for the following procedures.

- "Technical" interoperability

  A lot of work has already been done in this field. Data exchange formats like .dxf, languages like GML etc. have been developed. The best-known file formats can be imported and exported without effort to other software formats. Most of the problems are already solved. The user can solve some by programming an import interface. What still can be misleading is for example that in spite of standards like the simple features specification by the OGC there is still confusion about polygons in AutoCAD and in ArcGIS. They are defined differently. Other features well known in one system are not supported in other systems and so on. Standardisation is a very important aspect in this topic.

The OGC works in all three areas of interoperability. It makes the problem public. It promotes cooperation. It sets standards, defines technical solutions and is also occupied with semantic interoperability.

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List of abbreviations

AEC	Architecture, Engineering and Construction
CAD	Computer Aided Design
CASE	Computer Aided System Engineering
CEN	European Committee for Standardization
COBRA	Common Object Request Broker Architecture
COM	Component Object Model
DBMS	database management system
ERM	Entity Relationship Model
ERP	Enterprise Resource Planning
ETL	extract, transform, load
FME	Feature Manipulation Engine
FGCD	Federal Geographic Data Committee
GIS	Geographic Information System
GML	Geographic Markup Language
GPS	Global Positioning System
GSDI	Global Spatial Data Infrastructure Association
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
INSPIRE	Infrastructure for Spatial Information in Europe
IPR	Intellectual property rights

ISO	International Organization for Standardization
NSA	NATO Standardization Agency
NSDI	National Spatial Data Infrastructure
OASIS	Organization for the Advancement of Structured Information Standards
OGC	Open Geospatial Consortium
OMA	Open Mobile Alliance
OMG	Object Management Group
SDI	Spatial Data Infrastructure
SDTS	Spatial Data Transfer Standard
SOA	Services-Oriented Architecture
SQL	Structured Query Language
UML	Unified Modeling Language
USGS	U.S. Geological Survey
W3C	World Wide Web Consortium
WFS	Web Feature Service
WMS	Web Map Service
XML	Extensible Markup Language

Appendix

Testscheme AutoCAD

Software:
Acad2006
ArcGIS ArcEditor, 9.0
TESTPLAN IMPORT

Legend (colours):
- not relevant
- open Question
- Test failed
- Test passed
- partly ok

Test ID	Topic	Question: Is Import possible?	Detailed test description (Sheet "Details")	Tested	Comment
1 Objeects	Line				
	Line			p	Annotation: 1 assembled line is imported as multiple polylines.
	3D-Line			p	"Environment" Z-Value Enabled
	assembled Linie		option A	f	is imported as multiple polylines -> try Workbench
	crossed Linie			p	
	closed Linien			p	
1.2	Ray	What happens to the direction?		f, p	heavily shortened, but imported as line. Direction can be declared in Workbench with Orientor.
1.3	Construction Line			p,f	heavily shortened, but imported as line.
1.4	Multi Line			f, p	Multiline is written to database as one single element. But: When editing, every single line can be edited on its own.
1.5	Polyline				
	simple Polylinie			p	
	closed Polylinie			p	Display as Polygon
			option D	p	GeometryFilter, Geometrycoercer, so construction as line instead of polygon is possible.
	assembled Polylinie			p	
	crossed Polylinie			p	
1.6	Curve				Curve Geometry not supported in Shapefiles. But in ACAD: Curve refers to the smoothness of circles etc. Command Viewres.
1.7	3D Polyline			p	"Environment": Z-Value enabled
1.8	Polygon		option A,C **	p	vertical planes not supported in ArcGIS
			option A **	f,p	Workbench
			option D	p	Workbench
1.9	complex Polygon			p	Polygonmeshes not supported in ArcGIS
1.10	Polygon with holes			f,p	is imported, but islepolygon is not clipped but interpreted as superimposed area on ist own.
			option D	p	Workbench:Polygon->Intersector (Intersected) and Selfintersector (Selfinterssected)->Areabuilder (Area; Create Donuts: Drop Holes)->Polygon
1.11	badly smapped polygons		option A, B, C	f	imported as polyline
			option D	p	Workbench:Polygon->Snapper (Snapped)->Polygonbuilder (Polygon)-> Polygon
1.12	Rectangle		see option A	p	
			see option B,C	p, f	imported as polygone (can be copied on Line-shape)
			option D	p	GeometryFilter (not necessary when imported as geomtrytypes instead of layers), Geometrycoercer (fme-line angeben), so display as line instead of polygon can be achieved.
1.13	Arc			p	arc
1.14	Circle		see option A	p	elipse. Only scalable but not editable (only one vertex)
			see option B,C	p, f	imported as polygone (can be copied on Line-shape)
1.15	Donut			f	imported as circle (Polygon)
			option D??		
1.16	Spline			p,f	imported but lines between multiple vertices (Shape: Polyline)
1.17	Elipse		see option A	p	Only scalable but not editable (only one vertex)
			see option B,C	p, f	imported as polygone (can be copied on Line-shape)
1.18	Block		option A	f	block is imported as Feature Class Point (insertion point), Polylines and Polygones. Poblem: Blockcoherence is missing. Only Polylines connect. Circle as Polygon. The inner-Polygon is interpreted as isle. Hatches missing
			option B	f	
			option C	f	only Polylines and Polygons and Blocktext is inserted. No insertion point. Blockcoherence is missing. Hatch missing. Isle not clipped. Blocktext is not readable (only symbols). - block2
			option C	f	only Blocktext and Points are inserted. Blocktext not readable.
1.19	Table				
1.20	Point			p	multiple Punktstiles are imported all the same
1.21	Boundary		option A	p	as Polyline imported
			option B	f, p	as Polyline and as Polygon imported
			option C	f, p	as Polyline and as Polygon imported
1.22	Hatch			f	not imported at all
1.23	Gradient			f	not imported at all
1.24	Region		option A, B, C	f	not imported at all
1.25	Wipeout				
1.26	Revision Clouds				
1.27	Mtext			p, f	is partly invisible (only very small rectangles are imported). Apparently only with Settings: Group By Layer (?) imported but the the whole mText as 1 Object. Is textheight editable?
1.28	Dtext (Single Line)			p	Is textheight editable?

Software:
Acad2006
ArcGIS ArcEditor, 9.0
TESTPLAN IMPORT

- not relevant
- open Question
- Test failed
- Test passed
- partly ok

Test ID	Topic	Question: Is Import possible?	Detailed test description (Sheet "Details")	Tested	Comment
1.29	Surfaces				
1.30	Solids				3dim solids not supported in ArcGIS
1.31	Dimensions		option A, B, C	f	not imported at all
1.32	Groups		option A, B	f	Not supported in ArcGIS. Only some objects are imported (no splines)
			option C	f	Not recognized as group but all objects are imported
1.33	Brake Line Symbol				
1.34	Super Hatch				
1.35	rounded edge		option A	p	Polyline (rounded edgeds stay round)
			option B	f	imported as polygon
			option C	f, p	wird als Polyline importiert. Rounded edgeds become a lot of short lines.
1.36	chamferred edge		option A, C	p	
			option B	f	imported as polygon
2 Formats	Linetyp	Is the linetype persisting?	see option A, C	f/p	Linetype is not visible but is written to the attribute table
			see option B	f	
2.2	Textstyle	Is the textstyle persisting?	option C, D	f	best case: Import Data, Textstyle in attribute table, but is not editable. no Acad .shx files (use TrueType).With Quick Import the attribut Textstyle is always substituted with Arial.
2.3	Dimensionstyle			f	no CAD Dimension Entities in Arc GIS
2.4	Tablestyle				
2.5	Pointstyle	What happens if the point is defined as "x"? - pointstyle question		f,p	Pointstyle gets lost. No matter what pointstyle is defined in ACAD, it looks all the same in ArcGIS.
2.6	Color		see option A, C	f/P	Colour is not directly displayed but is written to the attribute table -> can be regained with queries.
			see option B	f	
2.7	Thickness			f	
2.8	Units			p	
2.9	Array 2D				
2.10	Array 3D				
3 Export	Export to .wmf				
3.2	Export to .sat				
3.3	Export to .stl				
3.4	Export to .bmp				
3.5	Export to .dxx				
3.6	Export to .eps				
3.7	Export to .3ds				
3.8	Export to .dwg				
4 Insert	Block				
4.2	Xref				
4.3	Raster				
4.4	Field				
4.5	.3ds				
4.6	.sat				
4.7	.dxb				
4.8	.wnf				
4.9	OLE				
4.10	Markups				
5 div	frozen layers		option A, C		are displayed nevertheless
5.2	turned off layers		option A, C		are displayed nevertheless
5.3	Nested Blocks (=blocks consisting of other blocks)			f	
5.4	Shapes				
5.5	Save as .dxf				
5.6	user defined coordinate system			p	In Workbench with Coordinate Fetcher and Affiner: Features can be moved. on the contrary to Acad not the coordinatesystem but the features are moved. With "Environments" the Coordinatesystem can be precised. With the Wizzard for Custom Formats one can select in Select Exposed Parameters - Ignore UCS. Then in Workbench in Workspace - .dwg the parameter can be selected whether UCS shall be ignored or not.
5.7	projection				no reprojection?
5.8	badly assembled .dwg (all objects on one layer)				Differentiation during Import because of multiple Geometries possible
5.9	joining of lines disconnected because of text				Workbench: Snapper
5.10	because of symbols disconnected lines (in linear networks)				Workbench: Snapper
5.11	Templates	Do the templates have consequences?			
6 Daten	AutoCAD SQL Extension (ASE)				
6.2	blocks with attribuet tags		optionA, C*	p	no XML-Tags supported in ArcGIS
6.3	Excel				
6.4	dBase				
6.5	Access				
6.6	Oracle				
6.7	Paradox				
6.8	MS Visual Fox Pro				
6.9	SQL Server				
	Inserts				
	Extended Entity Data				
	List Format (Attribute)				
	structure Format				
	Interpreted Format				
	Proxy Data				
	Leaders				
	Face				
	Traces				
	True Annotation				not supported by the Interop., Text features are represented by labelled lines. In ArcMap, users see only the labels, because the Interop automatically makes the lines invisible and turns on labelling. In ArcCatalog, users see the lines.

Detailed Testdescription Import:
A
1) Create a new Geodatabase in Mobile Matrix Data Manager
2) re Click -> Import -> choose Feature Class
3) Environments: Output has z-Value: same as Input
or B (Direct Read -> not editable):
1) in Datamanager Dobleclick on Add Interoperability Connection -> choose CAD file
2) add Data -> choose Cad Layer in Interoperability
or C (Translating Data using Quick Import) -> editing possible:
1) in Datamanager Toolbox -> Data Interoperability Tools
2) Quick Import
3) Settings: Group Entities by Layer Name
4) Environments: Output has z-Value: same as Input
or D (with Workbench):
1) Quick Import
2) Input Dataset -> in ... adjacent Format -> choose Custom Formats "New"

Where there is no option named, Quick Import (C) works

option C* - Blocks with Attributes:
Quick Import -> Import Dataset ... -> Settings choose the following:
Group Entities By: Attribut Schema
Blocks: Expand Into Entities - Do NOT choose
Visible Attributes: Expand Into Entities - Do NOT choose

options A** and C** with Polygonen: (see F:\Data\Testdaten\Acad_To_Esri\Line.dwg as example)
Acad recognises Polygon only as regular features (equilateral polygones)
otherwise Polygons have to be created as CLOSED polylines
If this happens, an import as polygon is easily possible.
Was the polygon in ACAD created from more polylines or even from one or more lines,
it will be imported as polylines.
In this connection for lines and polylines can be applied:
In Acad Lines with multiple vertices can be drawn. But in ArcGIS they will be
interpreted as multiple single polylines.

Software:	
ArcGIS Arc Editor 9.0	
Export into:	
Acad2006	

Legend: not relevant (orange); open question (blue); Test failed (red); Test passed (green); partly ok (yellow)

Test ID	Topic	Question: Is Import possible?	Detailed test description (Sheet "Details")	Tested	Comment
1 Objekte	Line				
	Line		Variante B	p	
	3D-Line		Variante B	p	Environments: Z-Value Enabled angeben
	zusammengesetzte Linie		Variante B	p	
	gekreuzte Linie		Variante B	p	
	geschlossene Linien		Variante B	p	
1.2	Ray	Was passiert mit der Richtung?	Variante B	f	wird zu 2D Polyline; wegen der starken Verkürzung beim Import nicht weiter getestet.
1.3	Construction Line				
1.4	Multi Line		Variante B	f	wird als Block importiert. Wenn man den explodiert, entstehen 2 2D-Polylinien aus der einen Multilinie
1.5	Polyline				
	einfache Polylinie		Variante B	p	
	geschlossene Polylinie		Variante B	p	
	zusammengesetzte Polylinie		Variante B	p	
	gekreuzte Polylinie		Variante B	p	
1.6	Curve				
1.7	3D Polyline		Variante B	p	Environments: Z-Value Enabled angeben
1.8	Polygon		Variante B	p	
1.9	complex Polygon		Variante D	p	im Autocad können komplexe Polygone (mit Inseln und vielen Vertices) z.B. nicht mehr schraffiert werden. Daher ist Bearbeitung mit Workbench nötig. Trotzdem: Import als 2D-Polylines und als Block (wenn Inseln vorhanden?) - Nachbearbeitung im Acad nötig.
1.10	Polygon containing isle		Variante B	p, f	comes as Block in Acad
1.11	badly snapped Polygons		Variante B	p	
1.12	Rectangle			p	
1.13	Arc			p	
1.14	Circle			p	
1.15	Donut				
1.16	Spline				
1.17	Elipse			p	
1.18	Block			f, p	
1.19	Table				
1.20	Point			p	
1.21	Boundary			p, f	as Polyline in Acad
1.22	Hatch				
1.23	Gradient				
1.24	Region				
1.25	Wipeout				
1.26	Revision Clouds				
1.27	Mtext			p, f	although after Import into GIS it can be hardly seen any more, export back works. But mText becomes SingleLineText
1.28	Dtext (Single Line)			p	
1.29	Surfaces				
1.30	Solids				
1.31	Dimensions				
1.32	Groups				
1.33	Brake Line Symbol				
1.34	Super Hatch				
1.35	Abgerundete Ecken				
1.36	Abgeschrägte Ecken				
2 Formats	Linetyp	Is the linetype persisting?			
2.2	Textstyle	Is textstyle persisting?		f	
2.3	Dimensionstyle				
2.4	Tablestyle				
2.5	Pointstyle	What happens if a point is defined as "x"?			
2.6	Color				

	2.7	Thickness			
	2.8	Units			
	2.9	Array 2D			
	2.10	Array 3D			
3 Export		Export to .wmf			
	3.2	Export to .sat			
	3.3	Export to .stl			
	3.4	Export to .bmp			
	3.5	Export to .dxx			
	3.6	Export to .eps			
	3.7	Export to .3ds			
	3.8	Export to .dwg			
4 Insert		Block			
	4.2	Xref			
	4.3	Raster			
	4.4	Field			
	4.5	.3ds			
	4.6	.sat			
	4.7	.dxb			
	4.8	.wnf			
	4.9	OLE			
	4.10	Markups			
5 div		What happens to frozen layers?			
	5.2	what happens to turned off layers?		p, f	objects from turned off/invisible layers/feature classes are not exportet when using Quick Export -> Input Layer -> choosing layers from the actual .mxd. Are the same objects chosen directly from the geodatabase (Folder Icon) also the turned off ones are exported.
	5.3	Nested Blocks (=Blocks consisting of blocks)			
	5.4	Shapes			
	5.5	Save as .dxf			
	5.6	userdefined coordinate system			
	5.7	Projection			
	5.8	badly assembled .dwg (all objects on one layer)			
	5.9	joining of lines disconnected because of text			
	5.10	because of symbols disconnected lines (in linear networks)			
	5.11	Templates	what are the effects of templates?		
6 Daten		AutoCAD SQL Extension (ASE)			
	6.2	blocks with attribute tags			
	6.3	Excel			
	6.4	dBase			
	6.5	Access			
	6.6	Oracle			
	6.7	Paradox			
	6.8	MS Visual Fox Pro			
	6.9	SQL Server			

Details for Export

Option A
Mouse - right click on single layer - Data -> Export Data

Option B
Quick Export
Consider: In Settings a template dwg can be chosen in which linetypes etc.
are already defined. Before starting, this .dwg file must be saved as Acad 2000 format version
otherwise the failure reply says that the file does not exist or can not be read.