The Industry Foundation Classes (IFC) – Ready for Indoor Cadastre?

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SUMMARY

The term “indoor cadastre” describes an information system that integrates the functional components of acquisition, management, analysis and presentation of building indoor information. In contrast to the term “building information system” (BIM) the focus is set on the data acquisition. From a surveyor’s point of view, the redundant geodetic measurements are the primary data. The measurement results establish the basis for planning and construction. This article figures out how engineering surveyors can use the *Industry Foundation Classes* (IFC) in order to document the survey result.

The *Industry Foundation Classes* (IFC) provide a data model for 3D-Building-Information-Models (BIM) which enables all actors in a planning, construction and management process to exchange information in an integrated data pool. The model is not focused on drawing exchange, like DXF, but considers building components as what they are: objects! ifcXML-files can be used as a software independent model-based exchange format. The objective to use the IFC Model is to improve communication, productivity, delivery time, cost, and quality throughout the whole building life cycle. The IFC model is also interesting from the administrative point of view. For instance Singapore Building and Construction Authority uses the IFC for electronic regulation-checking.

The standard is published by the *International Alliance for Interoperability* (IAI), a non for profit organization, which is organized in Chapters. A Chapter represents a county or a group of countries acting together.

Within the “AEC World” (Architecture, Engineering and Construction) this new ISO standard (ISO 16739) is discussed by experts and implemented by the major CAAD-Software applications. Within the “GIS- and Surveying World” the IFC is widely unknown. This paper gives a short overview on the IFC model and discuses opportunities and limitations of the IFC from a surveyor’s point of view. In doing so, we figure out how topology and geometry is modeled in IFC and have a look at how IFC treats geodetic measurements and coordinate frames.

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1. OBJECTIVE OF THE IFC

The Industry Foundation Classes (IFC) are designed and maintained by the "International Alliance for Interoperability" (IAI). Members of the IAI are architects, engineers, facility managers, academic institutions, government agencies, technical associations and software vendors. The IAI is organized in Chapters. A Chapter represents a country or a group of countries acting together. There are 11 chapters with 19 countries and more than 500 member companies. IFC are a global effort. Most schemas of the IFC are accepted by the ISO as a Public Available Specification and constitute the ISO/PAS 16739.

The Industry Foundation Classes provide a specification of a data model that covers the domain of building information. It can be used as a shared data model or integrated data base by many occupation groups. Any participant of planning and construction process can use the same model which increases transparency of changes done by one actor and let the others know the actual state of the planning. In contrast to exchange plans via drawing files like dxf or dwg, the IFC exchange is strictly model based. A wall is not a set of lines but an object with specified attributes and relations.

2. ARCHITECTURE OF THE IFC

The actual version IFC 2x3 was published in February 2006 [2]. There are four layers in the IFC Model. The layers follow the "gravitation" concept which means that elements of a certain layer can only refer to entities of the same or a lower layer.

1. **Resource Layer**. This layer contains the fundamental concepts expressed as entity types such as geometry (point, line and curve) topology (vertex, edge, face and shell), geometric model (CSG, B-Rep, Geometric Set). The elements of this layer can be referenced by elements of all other layers. In Fig 1. the resource layer is symbolized with octagons.

2. **Core Layer.** This layer declares abstract concepts that are specialized by the layer above. There are abstract concepts like object, group, process, property definition, relationship or root. There is no instance of an abstract entity type. An abstract class provides an interface to the derived (specialized) entity types. The **Core Extensions** specialize the abstract concepts of the kernel concerning to the needs of the modeling domain "building information". In Fig 1. the core layer is symbolized with triangle and rectangles.

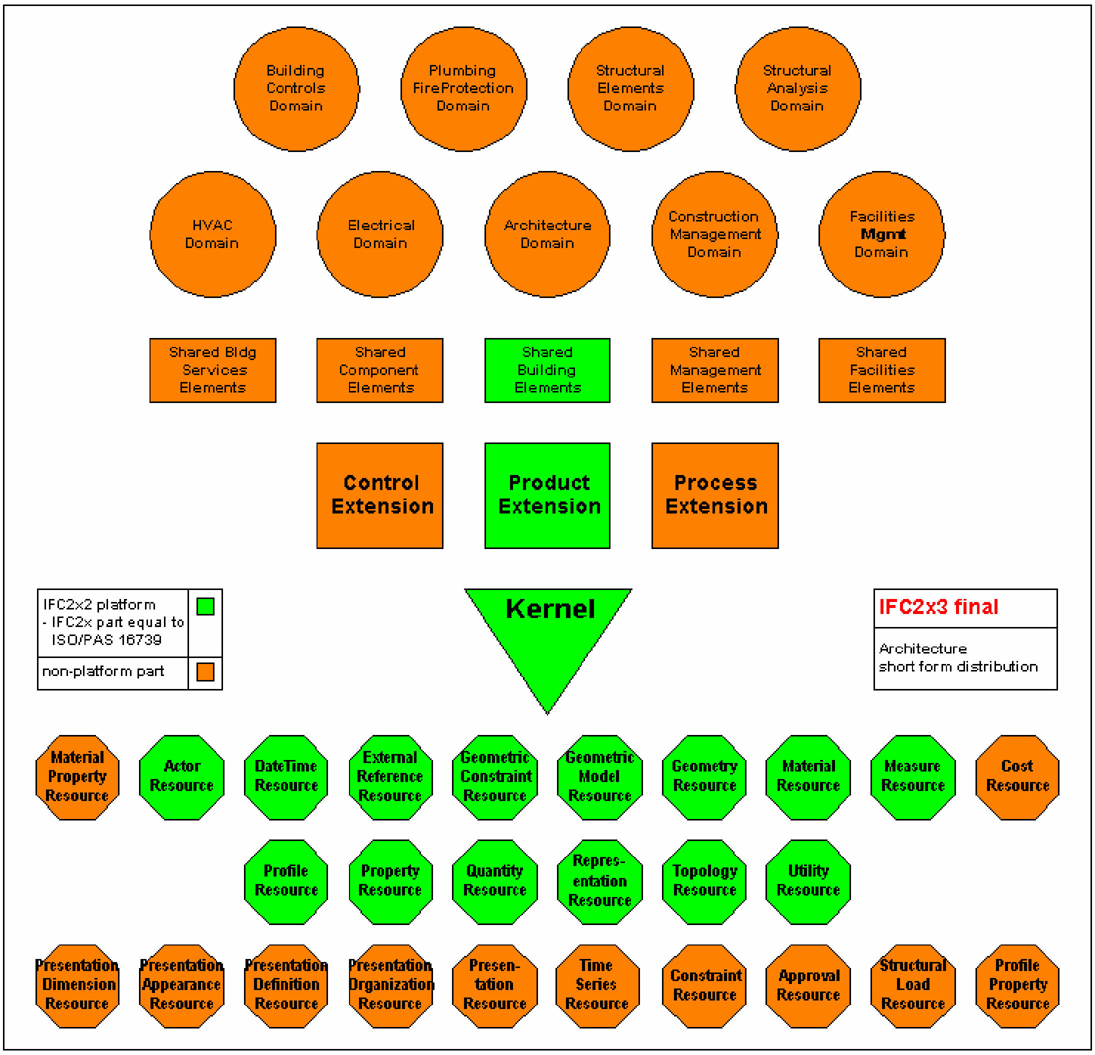

Figure 1. IFC architecture from www.iai-international.org

3. **Interoperability Layer.** This layer defines basic concepts for interoperability between different domain extensions. Shared building elements like beam, door, roof, window or ramp are defined in this layer. In Fig 1. the core layer is symbolized with rectangles.

4. **Domain Layer**. The entity types of the domain layer extend the concepts of the interoperability layer. Elements of one domain are not allowed to reference elements of any other domain. Like in real life every craft has its own vocabulary. There are domains like architecture, facility management, electricity or structural analysis.

3. A WALL SPECIFIED WITH THE IFC

Imagine a room with bounded by walls. First we want to analyse how walls are represented in the IFC concerning to the space they decompose.Thereby we will get to know the concept of inverse and objectified relationships. Afterwards we will examine the geometric and topological representation. The IFC use the object oriented mechanism of specialization extensively. As you can see in Fig.2 the type *ifcWall* is subtyped six times from the root of the entity hierarchy.While descending the specialization tree the entity types gain more and more attributes.

To model the space, that contains the wall objects, the IFC use the entity type *IfcSpace*.*IfcSpcace* is subtyped from *IfcSpatialStructureElement*.

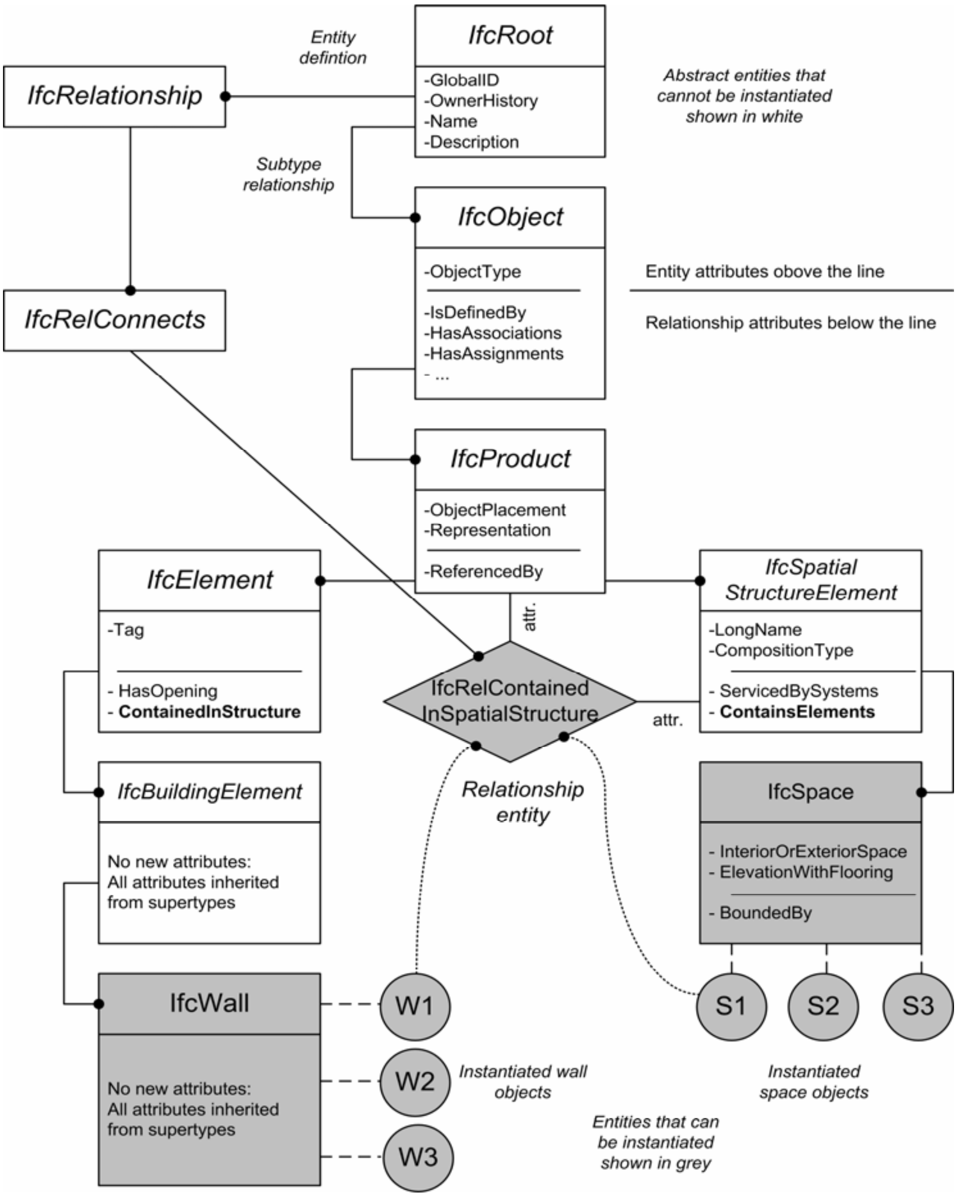

Figure 2. Specialization hierarchy for a wall and the space that contains the walls (cp. with [1])

An IFC Project is decomposed into spatial structers of type: *IfcSite*, *IfcBuilding*, *IfcBuildingStory* and *IfcSpace*. Neither *IfcSpace* has direct attributes that refer the objects it is composed of, nor does *IfcWall* “know” which *IfcSpace* it composes. Please note the way relationships are modelled: Objects don’t refer other object in a direct way but via an objectified relationship entity.The relationship classes are subtyped from the abstract class *IfcRelationship*. “The link from any object class to the relationship is handled via an inverse attribute.

This convention allows encapsulating the object class definitions, which could be distributed without the relationship objects in valid sub models" [2].

Hitherto is no geometric representation. *IfcProduct* refers two entities that specify the geometry of an object.The ObjectPlacement attribute handles the placement of an object in space whereas the RespresentaionObject refers the object's shape. As you can see in Fig. 3 products refer to one *IfcProductRepresenation* Object. The product-representation relationship is of cardinality n:m. A *IfcProduct-Representation* can be referred by different products and a product can have several *IfcRepresentaion*. One representation is composed out of many Items of type *IfcRepresentationItem*. This set of items describes the shape of an object.

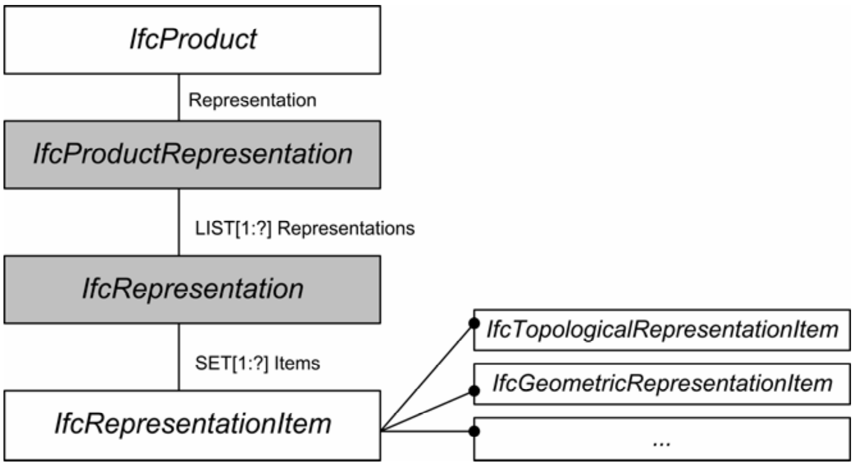

Figure 3. Entity types that model the representation of an object

The IFC differ between topological and geometric representation. Figure 4. shows some of the geometric representation items.

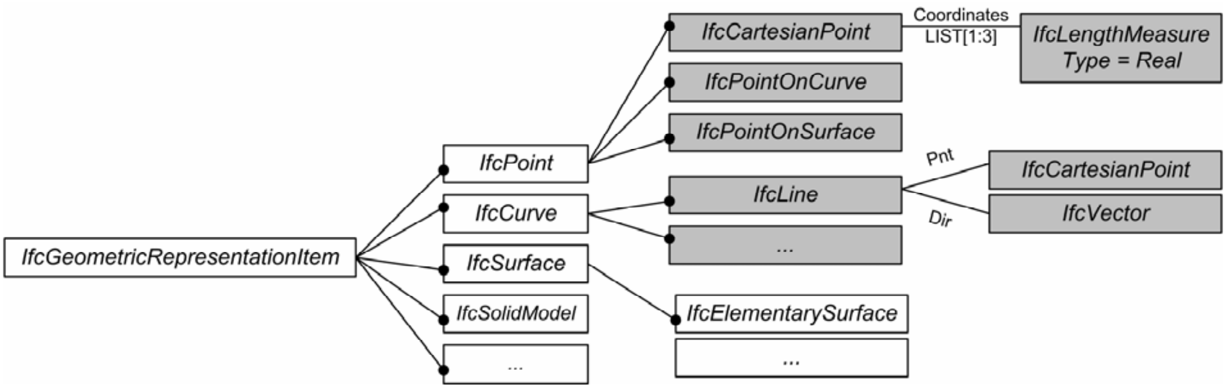

Figure 4. Geometric representation items

In Figure. 5 you can see some of the topological items.

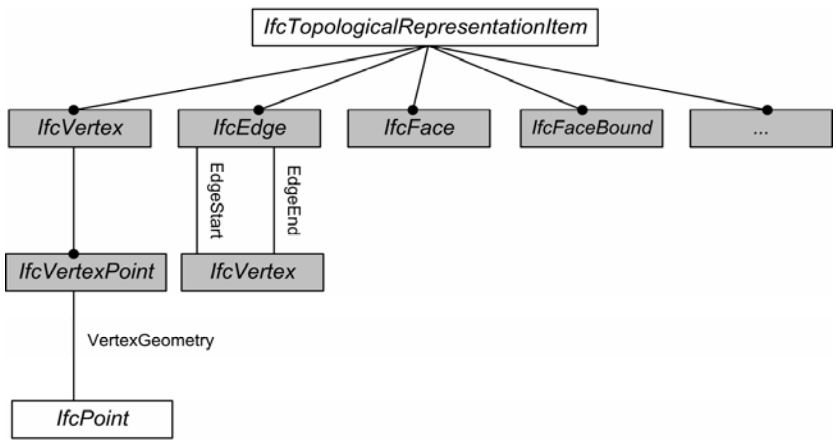

Figure 5. Topological representation items

The shape of physical objects is represented by the elements that are referred by the representation attribute. Their placement is given by the attribute ObjectPlacement where the Translation is modeled by the LocalPlacement Attribute of the abstract type *IfcPlacement* and the rotation is given by the two attributes of *IfcAxisPlacement*. Thereby the Axis attribute describes the exact direction of the local z-axis and the RefDirection describes the direction of the local x-axis. The transformation of the local coordinate system is not restricted to maps where the WCS (world coordinate system) is involved. The *IfcLocalPlacement* entity type has an optional attribute called PlacementRelTo which is itself of type *IfcObjectPlacement*. So it is possible to model a chain of transformations within the IFC.

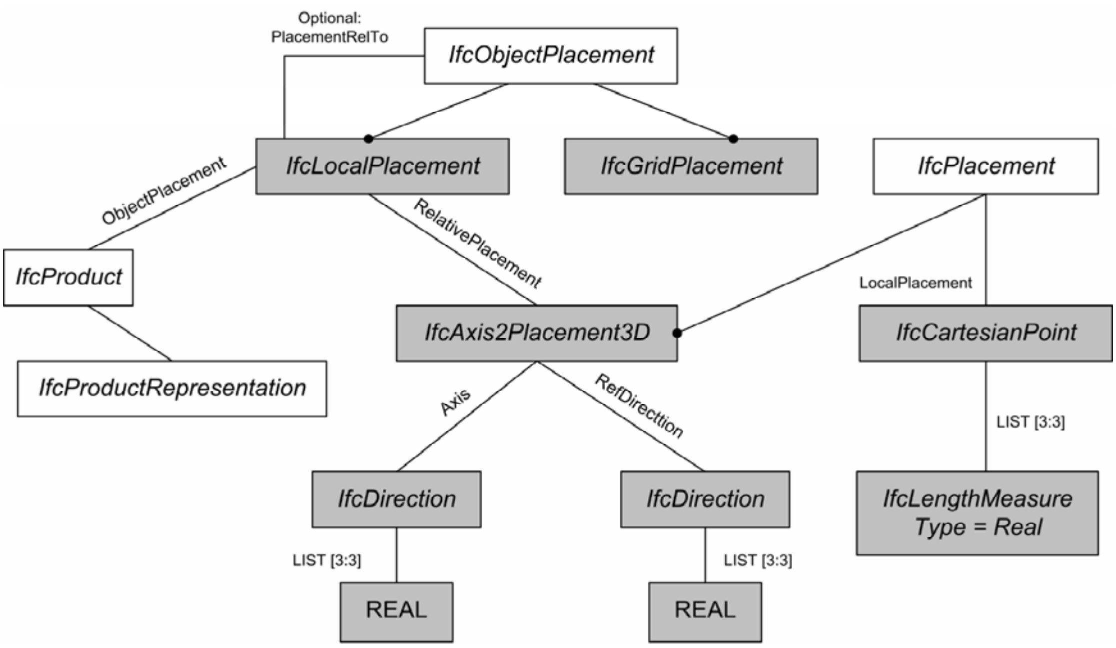

Figure 6. Relative placement (translation, rotation) of an IfcProduct.

4. IFG = IFC FOR GIS

The gab between the GIS and the AEC world has often been mentioned. The IFC offer a data model to the AEC world whereas the GML offers a data model to the GIS world. "The IFC for GIS (IFG) project proposes solutions for the passage of information to from GIS to AEC/FM about terrains, land parcels, local planning, road access etc. and from AEC/FM to GIS about building configuration and use." [IFG Outline] From a "GIS point of view" there are important entity types introduced to the model: Specifically geographic element, coordinate system mapping, qualified geometry (including contur lines, sight lines, survey points etc.).The IFG group works on an interface, that allows to transfer information across GIS and AEC/FM in a bidirectional way. Due to the different model domain, only subsets of the model can be exchanged.

5. INDOOR CADASTRE

We would like to introduce the term "indoor cadastre" to describe the surveyor's point of view. The functional components of a building information system seen as "indoor cadastre" can be classified by conclusion of analogy to GIS [see table 1.]. The main difference is that there is no data model that specifies geodetic observations in the AEC world. In IFG the entity "survey point" exists, but it is not intended to model the relative geometry and the observation topology that describe the geodetic survey. Why do we need the independent surveying measurements as primary data? The only way to provide and to document a correct engineering survey is to measure redundant observations. The absolute geometry can be determinated with the geodetic adjustment technique and additionally you receive the specification of accuracy and correctness. In [3] you can find more information about CAD compared to GIS and adjustment techniques in building information models.

	Geodetic observation as primary data	**Representation of the absolute geometry**	**Thematic attributes**
Land registration	Cadastral measures and computations. Format: LandXML, GML (GPS, terr.survey, Photogrametry)	Analogue maps, shape files or GML including geometry, topology and specification of accuracy	GIS Database, GML application schema (land use, parcel number)
Building Information System (BIM)	There is no standard that models geodetic observations as primary data (Photgrammetry, measurement with laser distomat, terr survey)	Analogue plans, dxf/dwg, IFC including geometry, topology but no specification of accuracy	IFC domain layer (lodger, rental, material)

Table 1. Land registration vs. BIM

A consistent data model that covers the surveyor domain is a great effort. The scope of this article is not to give a detailed data model. We want to outline which entity types should be specified by an IFC survey domain. Please note that a geodetic survey can be seen as an observation topology, which is a set of nodes and edges. Don't mix up the object topology, like it is described in the IFC building model, with the observation topology. Here a measurement can be seen as an edge in a topological graph. The edge connects two physical entities which are seen as nodes. On this level of generalization it makes no difference whether a node is a total station on a survey point or a node is a target like a wall surface. Within the observation topology the attributes of an edge are measurement values like distance, direction or height difference.

The following concepts should be modelled within a IFC indoor cadastredomain:

- Units: clockwise, counter clockwise, angle (radiant grad, degree), right hand system, left hand system
- Raw Observation Value (direction, distance, zenith angle, target height, uncertainty)
- Observation Node (topological: vertex, edge, face, solid ; geometric: point, line, surface, volume, geodetic: measured point)
- Observation Edge (connects two targets with each other and attaches a set of raw observation values, depending on dimension)
- Observation Group (set of observation edges with the same translation, orientation and time stamp e.g. local coordinate system of a total station or measurement line)

The geometric features of the observation group and the observation nodes are unknowns in the adjustment whereas the observations are the given quantity. In order to integrate this observation topology as a domain layer to the IFC it is necessary to figure out which entity types are already specified in the IFC and which are not. The observation nodes and the raw observations should be modelled with the existing entity types of the IFC. If the observation nodes are building elements they should be modelled with entity types lower than the interoperability layer because these quantities are used to determine the building's geometry.

6. CONCLUSION

The IFC are a complex data model with plenty of entity types and consequent modeling rules. This model is good for a topological and geometric representation of buildings. It is strictly object oriented and hence extensible. From a surveyor's point of view it is not possible to integrate survey data as primary data to the model. Nevertheless it is right now possible to pre-process the measurements and export the surveys result, including thematic information, to IFC files. Further work should be done on creating an IFC survey domain, which is a data model based on the IFC types and modeling rules. This would make engineering surveyors being part of the IFC community.

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BIOGRAPHICAL NOTES

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