INTERNATIONAL STANDARD

ISO 19141

First edition
2008-06-01

Geographic information — Schema for moving features

Information géographique — Schéma des entités mobiles

Reference number
ISO 19141:2008(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 19141 was prepared by Technical Committee ISO/TC 211, *Geographic information/Geomatics*.

Introduction

This International Standard specifies a conceptual schema that addresses moving features, i.e., features whose locations change over time. This schema includes classes, attributes, associations and operations that provide a common conceptual framework that can be implemented to support various application areas that deal with moving features, including:

- Location Based Services,
- Intelligent Transportation Systems,
- Tracking and navigation (land-based, marine, or space), and
- Modeling and simulation.

The schema specifies mechanisms to describe motion consisting of translation and/or rotation of the feature, but not including deformation of the feature. The schema is based on the concept of a one parameter set of geometries that may be viewed as a set of leaves or a set of trajectories, where a leaf represents the geometry of the moving feature at a particular value of the parameter (e.g., a point in time) and a trajectory is a curve that represents the path of a point in the geometry of the moving feature as it moves with respect to the parameter.

Geographic information — Schema for moving features

1 Scope

This International Standard defines a method to describe the geometry of a feature that moves as a rigid body. Such movement has the following characteristics.

a) The feature moves within any domain composed of spatial objects as specified in ISO 19107.

b) The feature may move along a planned route, but it may deviate from the planned route.

c) Motion may be influenced by physical forces, such as orbital, gravitational, or inertial forces.

d) Motion of a feature may influence or be influenced by other features, for example:

1) The moving feature might follow a predefined route (e.g. road), perhaps part of a network, and might change routes at known points (e.g. bus stops, waypoints).

2) Two or more moving features may be “pulled” together or pushed apart (e.g. an airplane will be refuelled during flight, a predator detects and tracks a prey, refugee groups join forces).

3) Two or more moving features may be constrained to maintain a given spatial relationship for some period (e.g. tractor and trailer, convoy).

This International Standard does not address other types of change to the feature. Examples of changes that are not adressed include the following:

— The deformation of features.

— The succession of either features or their associations.

— The change of non-spatial attributes of features.

— The feature’s geometric representation cannot be embedded in a geometric complex that contains the geometric representations of other features, since this would require the other features’ representations to be updated as the feature moves.

Because this International Standard is concerned with the geometric description of feature movement, it does not specify a mechanism for describing feature motion in terms of geographic identifiers. This is done, in part, in ISO 19133.

2 Conformance

2.1 Conformance classes

2.1.1 Introduction

This International Standard specifies four conformance classes (Table 1). They are differentiated on the basis of two criteria: purpose and level of complexity.

2.1.2 Purpose

This International Standard may be used in support of data transfer. Operations defined for objects are irrelevant to data transfer, which requires only descriptions of the state of the objects at the time of transfer. Thus, two conformance classes require only the implementation of attributes and associations of the classes specified in the schema. The other two conformance classes support the object-oriented implementation of systems or interfaces; they require implementation of operations as well as implementation of attributes and associations.

2.1.3 Complexity

Many applications do not need a complete description of the geometry of a feature and its orientation at any point in time. Their requirements are satisfied by describing the movement of a single reference point on the feature using its trajectory as specified in Clause 6. One pair of conformance classes supports these simple applications.

Other applications need knowledge of the positions at each time of all points or a significant subset of the points on a moving feature. They require the full description provided by the prism geometry specified in Clause 7.

Table 1 — Conformance classes

Complexity	**Purpose**	
	Data Transfer	Data with operations
Trajectory	**A.1.1**	**A.2.1**
Prism Geometry	**A.1.2**	**A.2.2**

2.2 Requirements

To conform to this International Standard, an application schema shall satisfy the requirements of the Abstract Test Suite in Annex A.

3 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/TS 19103, *Geographic information — Conceptual schema language*

ISO 19107, *Geographic information — Spatial schema*

ISO 19108, *Geographic information — Temporal schema*

ISO 19109, *Geographic information — Rules for application schema*

ISO 19133, *Geographic information — Location-based services — Tracking and navigation*

4 Terms, definitions, and abbreviated terms

4.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

4.1.1
base representation
⟨moving features⟩ representation, using a local origin and local ordinate **vectors**, of a **geometric object** at a given reference time

NOTE 1 A rigid geometric object may undergo translation or rotation, but remains congruent with its base representation.

NOTE 2 The local origin and ordinate vectors establish an engineering coordinate reference system (ISO 19111), also called a local frame or a local Euclidean coordinate system.

4.1.2
curve
1-dimensional **geometric primitive**, representing the continuous image of a line

[ISO 19107:2003, definition 4.23]

NOTE The boundary of a curve is the set of **points** at either end of the curve. If the curve is a cycle, the two ends are identical, and the curve (if topologically closed) is considered to not have a boundary. The first point is called the start point, and the last is the end point. Connectivity of the curve is guaranteed by the "continuous image of a line" clause. A topological theorem states that a continuous image of a connected set is connected.

4.1.3
design coordinate reference system
engineering coordinate reference system in which the **base representation** of a moving object is specified

4.1.4
feature
abstraction of real world phenomena

[ISO 19101:2002, definition 4.11]

NOTE A feature may occur as a type or an instance. Feature type or feature instance shall be used when only one is meant.

4.1.5
feature association
relationship that links instances of one **feature** type with instances of the same or a different feature type

[ISO 19110:2004, definition 4.2]

NOTE Feature associations include aggregation of features.

4.1.6
feature attribute
characteristic of a **feature**

[ISO 19101:2002, definition 4.12]

4.1.7
feature operation
operation that every instance of a **feature** type may perform

[ISO 19110:2004, definition 4.5]

4.1.8
foliation
one parameter set of geometries such that each point in the **prism** of the set is in one and only one **trajectory** and in one and only one **leaf**

4.1.9
geometric object
spatial object representing a geometric set

[ISO 19107:2003, definition 4.47]

4.1.10
geometric primitive
geometric object representing a single, connected, homogeneous element of space

[ISO 19107:2003, definition 4.48]

NOTE Geometric primitives are non-decomposed objects that present information about geometric configuration. They include points, curves, surfaces, and solids.

4.1.11
instant
0-dimensional **geometric primitive** representing position in time

[ISO 19108:2002, definition 4.1.17]

4.1.12
leaf
⟨one parameter set of geometries⟩ geometry at a particular value of the parameter

4.1.13
location-based service
LBS
service whose return or other property is dependent on the location of the client requesting the service or of some other thing, object or person

[ISO 19133:2005, definition 4.11]

4.1.14
network
abstract structure consisting of a set of 0-dimensional objects called junctions, and a set of 1-dimensional objects called links that connect the junctions, each link being associated with a start (origin, source) junction and end (destination, sink) junction

[ISO 19133:2005, definition 4.17]

NOTE The network is essentially the universe of discourse for the navigation problem. Networks are a variety of 1-dimensional topological complex. In this light, junction and topological node are synonyms, as are link and directed edge.

4.1.15
one parameter set of geometries
function f from an interval $t \in [a, b]$ such that f(t) is a geometry and for each **point** $P \in f(a)$ there is a one parameter set of points (called the trajectory of P) $P(t) : [a, b] \rightarrow P(t)$ such that $P(t) \in f(t)$

EXAMPLE A curve C with constructive parameter t is a one parameter set of points c(t).

4.1.16
period
one-dimensional **geometric primitive** representing extent in time

[ISO 19108:2002, definition 4.1.27]

NOTE A period is bounded by two different **temporal positions**.

4.1.17
point
0-dimensional **geometric primitive**, representing a position

[ISO 19107:2003, definition 4.61]

NOTE The boundary of a **point** is the empty set.

4.1.18
prism
⟨one parameter set of geometries⟩ set of points in the union of the geometries (or the union of the **trajectories**) of a **one parameter set of geometries**

NOTE This is a generalization of the concept of a geometric prism that is the convex hull of two congruent polygons in 3D-space. Such polyhedrons can be viewed as a **foliation** of congruent polygons.

4.1.19
temporal coordinate system
temporal reference system based on an interval scale on which distance is measured as a multiple of a single unit of time

[ISO 19108:2002, definition 4.1.31]

4.1.20
temporal position
location relative to a **temporal reference system**

[ISO 19108:2002, definition 4.1.34]

4.1.21
temporal reference system
reference system against which time is measured

[ISO 19108:2002, definition 4.1.35]

4.1.22
trajectory
path of a moving **point** described by a one parameter set of points

4.1.23
vector
quantity having direction as well as magnitude

[ISO 19123:2005, definition 4.1.43]

4.2 Abbreviated terms

CRS Coordinate Reference System (ISO 19111)

SLERP Spherical Linear Interpolation

LRS Linear Referencing System (ISO 19133)

OCL Object Constraint Language (ISO/IEC 19501)

UML Unified Modelling Language (ISO/IEC 19501)

5 Package – Moving Features

5.1 Semantics

A moving feature can be modelled as a combination of movements. The overall motion can be expressed as the temporal path or trajectory of some reference point on the object (the "origin"), such as its center of gravity. Once the origin's trajectory has been established, the position along the trajectory can be described using a linear reference system (as defined in ISO 19133). The "parameterization by length" for curves (as defined in ISO 19107) can be used as a simple linear reference if no other is available. The relationship between time (t) and measure value (m) can be represented as the graph of the $t \rightarrow m$ function in a plane with coordinates (t, m). This separation of the geometry of the path and the actual "time to position" function allows the moving feature to be tracked along existing geometry.

Figure 1 illustrates how the concepts of foliation, prism, trajectory, and leaf relate to one another. In this illustration, a 2D rectangle moves and rotates. Each representation of the rectangle at a given time is a leaf. The path traced by each corner point of the rectangle (and by each of its other points) is a trajectory. The set of points contained in all of the leaves, and in all of the trajectories, forms a prism. The set of leaves also forms a foliation.

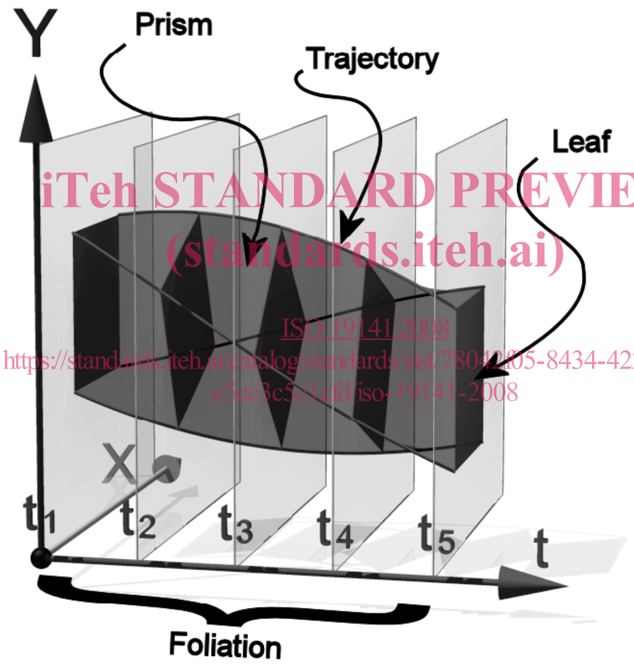

Figure 1 — Feature movement as foliation

These two object representations, of the path and the position along that path, give the general position of the moving feature. The other variable in describing the position of the feature is the rotation about the chosen reference point. To describe this, a local engineering coordinate system is established using the object reference point as its origin. The geometry of the feature is described in the engineering coordinate system and the real-world orientation of the feature is given by mapping of the local coordinate axes to the global coordinate system (the CRS of the trajectory of the reference point). This can be given as a matrix that maps the unit vectors of the local coordinate system to vectors in the global CRS.

If the global CRS and local CRS have the same dimension, then each point within the local CRS can be traced in time through the global CRS by combinations of these various mappings. The map would trace from time (t) to the measure (m) to a position on the reference point's path using the LRS. Then using the rotation matrix, the calculated offset from this point gives a direct position in the global CRS.

This means that the 'prism' of the moving feature (defined as all the points which part of the feature passes through) can be viewed (and calculated to whatever degree of accuracy needed) as a bundle of trajectories of points on the local engineering representation of the feature's geometry. If viewed in a 4 dimensional spatio-temporal coordinate system, the points on the feature at different times are different points. Then the pre-image of the prism (points on the trajectories augmented by a time coordinate) is a foliation, meaning that there is a complete and separate representation of the geometry of the feature for each specific time (called a “leaf”). These names come from a 3D metaphor of a book, where each page or leaf is a slice of time in the “folio”.

This might form the basis for an extension of this standard to non-rigid, mutable objects. Each leaf in the 4D foliation is a separate representation of the object, and by creating methods to describe the change through time of the shape and form of the feature, the existing machinery in this International Standard can be used to place those representations in positions with respect to the global coordinate system.

5.2 Package structure

This clause presents a conceptual schema for describing moving features that is specified using the Unified Modelling Language (UML) [ISO/IEC 19501], following the guidance of ISO/TS 19103. Annex B describes UML notation as used in this International Standard.

The schema is contained in the UML package Moving Features. Names of classes included in this package carry the prefix "MF_". The package is subdivided into two leaf packages (Figure 2), Geometry Types and Prism Geometry. The classes in these two packages are derived from classes included in the Geometry Package specified in ISO 19107. Classes from the packages Basic Types [ISO/TS 19103], Geometry [ISO 19107], Temporal Objects, and Temporal Reference System [ISO 19108] are used as data types in the schema.

5.3 Class hierarchy

The classes of the moving features schema form an inheritance hierarchy that has its source in the classes GM_Object and GM_Curve specified in ISO 19107 (Figure 3). This allows the subclasses specific to this schema to be used as feature attributes in compliance with the General Feature Model specified in ISO 19109. The second level of the hierarchy consists of a set of classes that describe a one-parameter geometry. These might be used to describe the movement of a feature with respect to any single variable such as pressure, temperature, or time. The third level specializes these classes to describe motion in time. The classes are specified fully in Clauses 6 and 7.

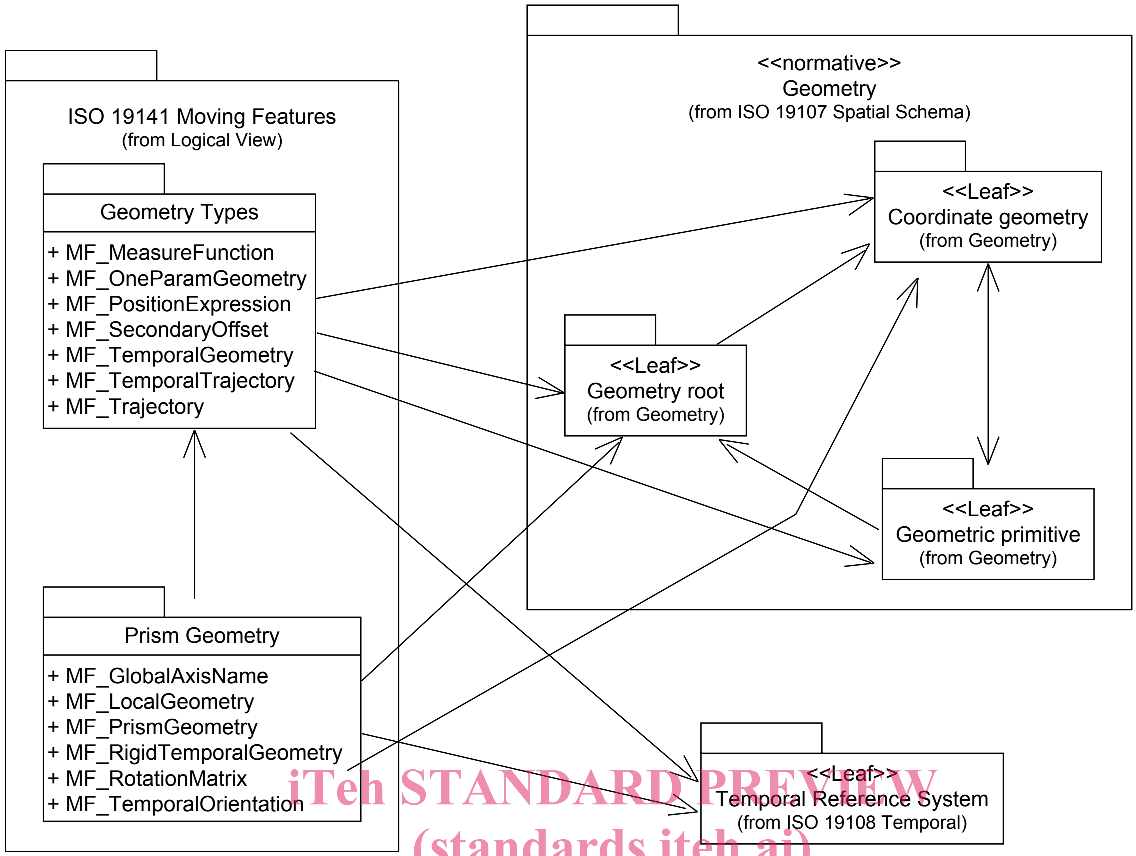

Figure 2 — Moving Feature Package

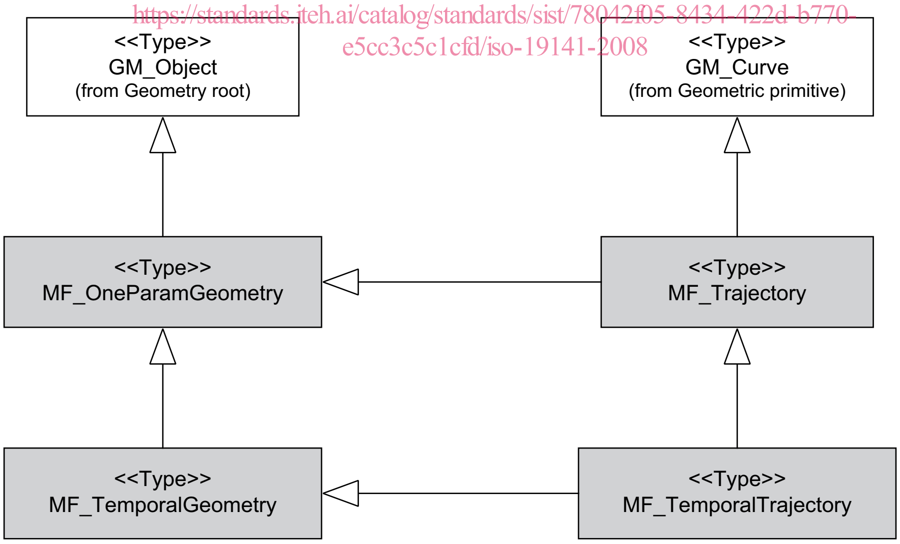

Figure 3 — Components of the Geometry Types Package

6 Package – Geometry Types

6.1 Package semantics

The Geometry Types package contains seven types. Two classes – MF_OneParamGeometry and MF_Trajectory – specify one-parameter geometry types based on the geometric objects specified in ISO 19107 (see Figure 3). Two other classes – MF_TemporalGeometry and MF_TemporalTrajectory – specialize the first classes in order to specify a one-parameter set of geometries in which the parameter is time. The other three classes – MF_MeasureFunction, MF_SecondaryOffset and MF_PositionExpression (Figure 4) – are used to extend the concepts of linear reference systems as defined in ISO 19133. Description of movement in terms of geographic identifiers is out of scope, and is partly covered in ISO 19133.

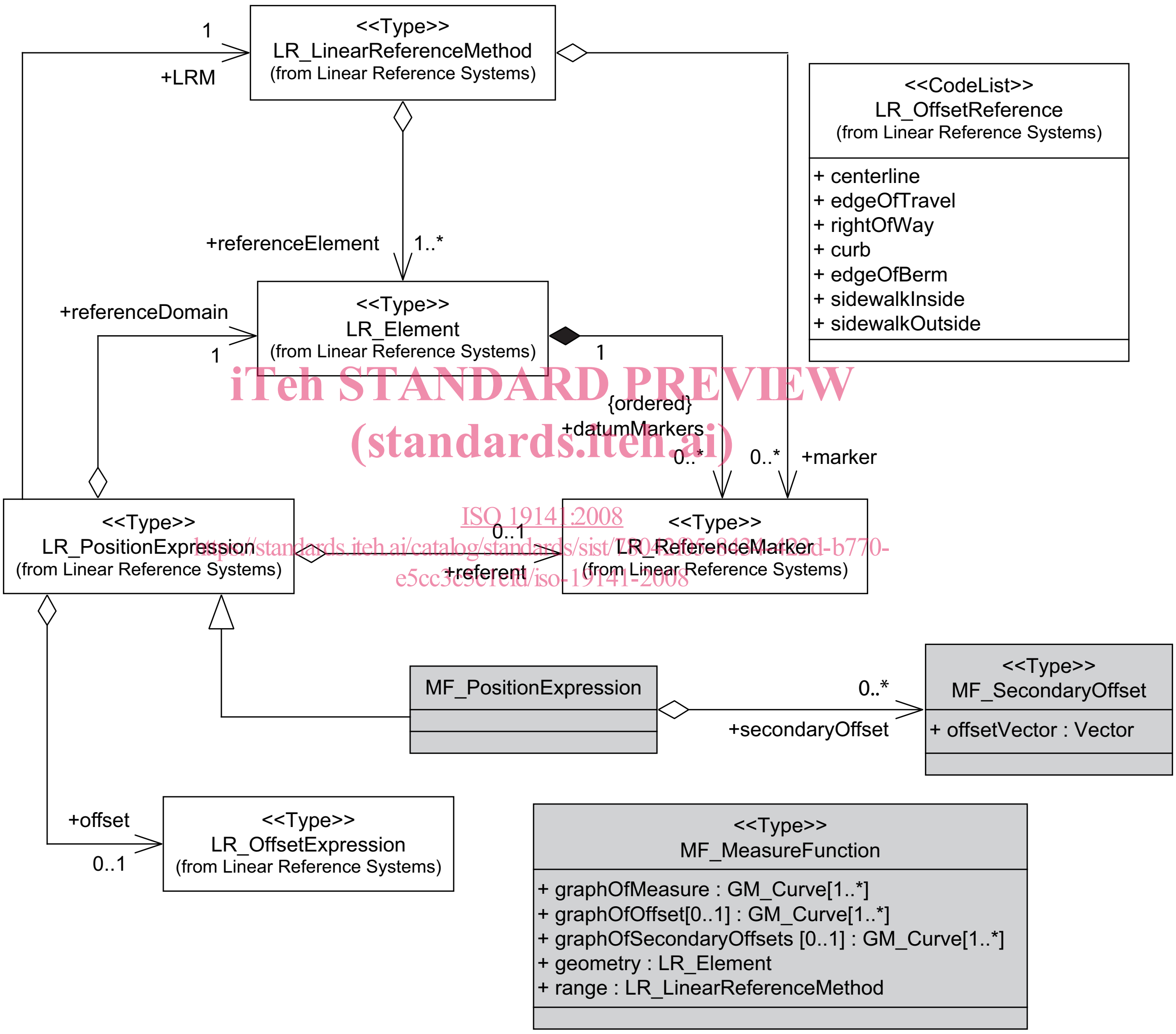

Figure 4 — Use of Linear Reference System by Moving Features

6.2 Type – MF_OneParamGeometry

6.2.1 Class semantics

A one parameter set of geometries is a function f from an interval $t \in [a, b]$ such that f(t) is a geometry and for each point $P \in f(a)$ there is a one parameter set of points (called the trajectory of P) $P(t) : [a, b] \rightarrow P(t)$ such that $P(t) \in f(t)$. A leaf of a one parameter set of geometries is the geometry f(t) at a particular value of the