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Information processing systems — Computer graphics — Programmer's Hierarchical Interactive Graphics System (PHIGS) —

Part 4:
Plus Lumière und Surfaces, PHIGS PLUS

Systèmes de traitement de l'information — Infographie — Interface de programmation du système graphique hiérarchisé (PHIGS) —
Partie 4: Plus Lumière und Surfaces, PHIGS PLUS

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

International Standard ISO/IEC 9592-4 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*.

ISO/IEC 9592 consists of the following parts, under the general title *Information processing systems — Computer graphics — Programmer's Hierarchical Interactive Graphics System (PHIGS)*:

— *Part 1: Functional description*

— *Part 2: Archive file format*

— *Part 3: Clear-text encoding of archive file*

— *Part 4: Plus Lumière und Surfaces, PHIGS PLUS*

Annex D forms an integral part of this part of ISO/IEC 9592. Annexes A, B, C, E and F are for information only.

Introduction

ISO/IEC 9592-1 provides a set of functions for the definition, display and modification of 2D or 3D graphical data. It does not provide support for simulating the effects of lighting, shading, and other properties that are important for the display of multi-dimensional data. This part of ISO/IEC 9592 specifies a basic set of such functionality for use in conjunction with the functionality defined in ISO/IEC 9592-1 and its amendment 1.

To provide this support, PHIGS PLUS defines

a) output primitives specified by rational and non-rational B-spline curves and surfaces;

b) output primitives containing both geometric and non-geometric data in their definition;

c) attributes that control the application of lighting and shading to both the new primitives and the primitives specified in ISO/IEC 9592-1;

d) a generalized mechanism for colour specification to allow non-indexed colour specification.

Information processing systems– Computer graphics– Programmer's Hierarchical Interactive Graphics System (PHIGS)– Part 4—Plus Lumière und Surfaces, PHIGS PLUS

1 Scope

This part of ISO/IEC 9592 specifies an additional set of functionality of the Programmer's Hierarchical Interactive Graphics System. This additional functionality is intended to satisfy basic application requirements in the areas of lighting and shading and defines additional primitives and functionality for controlling the rendering of 3D objects. It relies on the coexistence of the functions and functionality specified in ISO/IEC 9592-1, and is meant to extend that functionality in the above areas.

It is the intent of this part of ISO/IEC 9592 to be compatible with ISO/IEC 9592-1 and its Amendment 1. That is, in a standard conforming PHIGS PLUS implementation all functions defined in ISO/IEC 9592-1 and not altered by ISO/IEC 9592-4 shall perform as specified in ISO/IEC 9592-1, and all functions defined in ISO/IEC 9592-1 but altered in ISO/IEC 9592-4 shall perform as specified in ISO/IEC 9592-1 and ISO/IEC 9592-4, and, an application functionally conforming to ISO/IEC 9592-1 produces the same effect running on a standard conforming PHIGS PLUS implementation as it would produce running on a standard conforming PHIGS ISO/IEC 9592-1 implementation, excepting such differences among implementations as are allowed in ISO/IEC 9592-1. If PHIGS PLUS functions are used, they should only cause the extended effects specified in this part of ISO/IEC 9592.

This part of ISO/IEC 9592 defines a language independent extension to a graphics system for integration into a programming language. PHIGS PLUS is embedded in a language layer obeying the particular conventions of the language. Such language bindings are specified for ISO or ISO/IEC languages in ISO/IEC 9593.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO/IEC 9592. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO/IEC 9592 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO/IEC 646:1991, *Information technology – ISO 7-bit coded character set for information exchange.*

ISO/IEC 7942:1985, *Information processing systems – Computer graphics – Graphical Kernel System (GKS) functional description.*

ISO/IEC 8632:1987, *Information processing systems – Computer graphics – Metafile for storage and transfer of picture description information.*

ISO/IEC 8805:1988, *Information processing systems – Computer graphics – Graphical Kernel System for Three Dimensions (GKS-3D) functional description.*

ISO/IEC 9592-1:1989, *Information processing systems – Computer graphics – Programmer's Hierarchical Interactive Graphics System (PHIGS) – Part 1: Functional description.*

ISO/IEC 9592-1:1989/Amd.1:1992, *Information processing systems – Computer graphics – Programmer's Hierarchical Interactive Graphics System (PHIGS) – Part 1: Functional description – Amendment 1.*

ISO/IEC 9592-2:1989, *Information processing systems – Computer graphics – Programmer's Hierarchical Interactive Graphics System (PHIGS) – Part 2: Archive file format.*

ISO/IEC 9592-2:1989/Amd.1:1992, *Information processing systems – Computer graphics – Programmer's Hierarchical Interactive Graphics System (PHIGS) – Part 2: Archive file format – Amendment 1.*

ISO/IEC 9592-3:1989, *Information processing systems – Computer graphics – Programmer's Hierarchical Interactive Graphics System (PHIGS) – Part 3: Clear text encoding of archive file.*

ISO/IEC 9592-3:1989/Amd.1:1992, *Information processing systems – Computer graphics – Programmer's Hierarchical Interactive Graphics System (PHIGS) – Part 3: Clear text encoding of archive file – Amendment 1.*

ISO/IEC 9593:1990, *Information processing systems – Computer graphics – Programmer's Hierarchical Interactive Graphics System (PHIGS) language bindings.*

3 Definitions

For the purpose of this part of ISO/IEC 9592 the following definitions apply. This part of ISO/IEC 9592 also makes use of the definitions in ISO/IEC 9592-1. (Terms used within definitions in this clause that are themselves defined in this clause are italicized.)

3.1 ambient light source: A *light source* that contributes to the *reflectance calculation* independently of the orientation or position of the area being illuminated or the location of the viewer's eye.

3.2 ambient reflection coefficient: The fraction of *ambient light* reflected from an area.

3.3 area primitive: Any of the output primitives: fill area, fill area set, cell array, *fill area set with data*, cell array PLUS, *set of fill area sets with data*, *triangle set* with data, *triangle strip* with data, *quadrilateral mesh* with data, non-uniform B-spline surface and non-uniform B-spline surface with data. In addition, some generalized drawing primitives may have this classification.

3.4 attenuation coefficient: A coefficient that determines the decrease in intensity of light as a function of the distance between a *light source* and an illuminated object.

3.5 back facing: A back-facing facet has a *facet normal* that, when transformed to NPC, has a negative Z component. See also *front facing*.

3.6 colour mapping: The conversion of direct colours in the *rendering pipeline* to other colours before they are displayed on the workstation.

3.7 colour spline: The parametric curve or surface in colour space (or homogeneous colour space) defining the colour distribution over an output primitive.

3.8 concentration exponent: A parameter of a *spot light* source that specifies the relative decrease of light as the angle of the light diverges from the centreline of the light source's *cone of influence*.

3.9 cone of influence: A conceptual cone that represents the influence of light from a *spot light* source. The cone of influence is defined by the light source's position, direction and *spread angle*.

3.10 data mapping: The conversion of application-specific data or colour to *intrinsic colour*.

3.11 depth cueing: An effect in which the colours of points on an output primitive are combined with a specified depth cue colour. The degree of combination is dependent on the depth (Z in normalized projection coordinates) of the points.

3.12 depth cue mode: A field in each entry of the *depth cue table* of the workstation state list that indicates whether or not *depth cueing* should be performed.

3.13 depth cue table: A table in the workstation state list that contains information used to control *depth cueing*.

3.14 diffuse reflection: An approximation of the light reflected equally in all directions from an area.

3.15 diffuse reflection coefficient: The fraction of light from non-*ambient light* sources that is diffusely reflecting from an area.

3.16 direct colour specification: A non-indexed method of specifying colour where the components of the colour, i.e., coordinates in colour space, are specified together with the colour model in which those components are expressed.

3.17 directional light source: A *light source* that contributes to the *reflectance calculation* dependent on the orientation of the area being illuminated but independent of the area's position.

3.18 edge visibility flag: An indicator that is part of the specification of some output primitives, such as *fill area set with data*, that controls whether an individual edge is visible.

3.19 eye point: A point in world coordinates that transforms to infinite positive Z in normalized projection coordinates. This point is used in the *reflectance calculation* for determining viewing-position-dependent effects of lighting.

3.20 facet: An interior segment of an *area primitive*. Each facet of an output primitive is defined by a subset of the primitive's set of vertices. The subset is dependent on the individual primitive type, and in the case of parametric surfaces, on the approximation of the surface. Facets have an orientation in NPC described as *back-facing* or *front-facing*.

3.21 facet culling: The process of removing *front-facing* or *back-facing facets* of area primitives.

3.22 facet data: *Intrinsic colour* data or a *normal vector* specified with an *area primitive*.

3.23 facet normal: A *normal vector* associated with a *facet* of an *area primitive*. Facet normals are used to determine the orientation of a facet and in some cases for determining the *reflectance normal*.

3.24 fill area set with data: An output primitive consisting of a set of coplanar polygons. It is similar to the fill area set output primitive defined in ISO/IEC 9592-1. The corresponding structure element may include other information such as colours or normals that are conditionally used to colour, light and shade the output primitive.

3.25 front facing: A front-facing facet has a *facet normal* that, when transformed to NPC, has a positive or zero Z component. See also *back facing*.

3.26 general colour: A data type that allows both the direct and indirect specification of colour. General colour specifies a colour type together with a type-dependent colour value. The colour type can either indicate a colour model, in which case the colour values are coordinates in the colour space corresponding to that model, or it can indicate that the colour is being specified indirectly, in which case the single colour value is an index into the workstation-dependent colour table.

3.27 geometry spline: The parametric curve or surface defining the geometry of a *parametric output primitive*.

3.28 indirect colour specification: A method of specifying colour via an index into a workstation dependent colour table.

3.29 intrinsic colour: The colour or colours of an output primitive that are independent of *lighting*, *depth cueing* and *colour mapping*.

3.30 intrinsic colour data: Colour or application-specific data associated with output primitives and specified in the output primitive's structure element. Intrinsic colour data, when specified, is conditionally used to determine the *intrinsic colour* of an output primitive.

3.31 isoparametric curve: A curve on a parametric surface produced by evaluating the surface over the range of one of its independent variables while holding its other independent variable constant.

3.32 knot vector: A non-decreasing sequence of real numbers that is part of the definition of non-uniform B-splines. This vector consists of values of the independent variables and is used in computing the B-spline basis polynomials.

3.33 light source: A simulated source of light.

3.34 light source direction: A unit vector that defines the orientation of oriented *light sources*.

3.35 light source state: A field in the traversal state list that selects which *light sources* in a workstation light source table are active.

3.36 lighting: See *reflectance calculation*.

3.37 normal vector: A unit length vector, typically indicating the orientation of a *facet* or object.

3.38 parameter range: The *parameter space* over which a parametric curve or surface is defined.

3.39 parameter range limits: Minimum and maximum parameter values, specified separately from any knot values, that limit the parameter range over which parametric curves are generated.

3.40 parametric output primitive: Output primitives defined as a mapping from a parameter space to modelling coordinates. Parametric output primitives defined in PHIGS PLUS are non-uniform B-spline curve, non-uniform B-spline curve with colour, non-uniform B-spline surface and non-uniform B-spline surface with data.

3.41 parameter space: The coordinate system of the independent variable(s) of parametric curves and surfaces. The parameter space is one-dimensional for curves and two-dimensional for surfaces.

3.42 polyline set with colour: An output primitive consisting of an unconnected set of polylines. The corresponding structure element may include colour information that is conditionally used to shade the primitive.

3.43 portion: A portion of an area primitive refers to one or more *facets* of the primitive that are distinguished as a group from its other facets by some property such as orientation or position relative to a *trimming loop*. The term can be applied to groups of explicitly defined facets as well as the facets conceptually used to approximate a non-uniform B-spline surface.

3.44 positional light source: A *light source* that contributes to the *reflectance calculation* dependent on the orientation and position of an area being illuminated relative to the light source.

3.45 quadrilateral mesh: An output primitive in which an array of quadrilaterals is specified by a two-dimensional array of vertices.

3.46 reflectance calculation: The computation of the effect of *light sources* on the colour of an area primitive's facets.

3.47 reflectance model: An aspect that selects the *reflectance calculation* and thereby specifies which lighting effects are to be displayed.

3.48 reflectance formulae: Formulae that model the light reflected by an *area primitive*.

3.49 reflectance normal: A vector used in the *reflectance calculation* and indicating the orientation of a primitive at a point on the primitive. The vector is conceptually perpendicular to the surface of an object being represented by an *area primitive*. It is derived from the *vertex normals* of the primitive, if specified, or the *facet normal*.

3.50 reflectance properties: An aspect of *area primitives* that indicates how a primitive reflects light.

3.51 rendering colour model: The colour model used for performing colour interpolation during *shading* and *depth cueing*.

3.52 rendering pipeline: A sequence of operations that performs *data mapping*, *lighting*, *shading*, *depth cueing*, and *colour mapping* of output primitives. Each of these operations is considered a stage in the rendering pipeline.

3.53 rigid-body transformation: A modeling transformation composed of at most translation, rotation, and scaling transformations, where translation transformations move every point of an object an equal distance in the same direction, the rotation transformations maintain relative angles, and the scaling transformations apply equal scaling in all coordinate dimensions.

3.54 set of fill area sets with data: An output primitive in which a number of possibly non-coplanar fill area sets are defined by indices into a single list of vertex data. The fill area sets are not required to form a closed or connected surface.

3.55 shading: The interpolation stage of the *rendering pipeline*.

3.56 specular colour: A *reflectance property* indicating the effect of a primitive on the colour of *specular reflections* from that primitive.

3.57 specular exponent: A non-negative number indicating the shininess of an area. The higher the specular exponent, the shinier the area. A specular exponent of 0 indicates a minimum relative degree of shininess.

3.58 specular reflection: An approximation of the unequal reflection of light in different directions from an *area primitive*, dependent on the relationship of the viewer to the primitive and the *light source*.

3.59 specular reflection coefficient: The fraction of non-*ambient light* contributing to *specular reflection*.

3.60 spot light source: A *light source* that contributes to the *reflectance calculation* dependent on the orientation and relative position of the area being illuminated. Light from such a source is restricted to a semi-infinite cone of influence and its intensity may decrease as it deviates from the centreline of this cone. (See *concentration exponent* and *spread angle*.)

3.61 spread angle: An angle that determines the shape of the *cone of influence* of a *spot light* source. Spread angle is the angle between the center of the cone of influence and the limit of the cone of influence measured at the position of the spot light source.

3.62 triangle set: An output primitive in which a number of possibly unrelated triangular facets are defined by indices into a single list of vertex data.

3.63 triangle strip: An output primitive comprised of a group of adjacent triangles formed by connecting a list of vertices such that the second and third vertices of each triangle are used as the first and second vertices of the next triangle.

3.64 trimming curve: A parametric curve in the parameter space of the surface to which it applies. Trimming curves are combined to form *trimming loops* which limit the *parameter range* over which a parametric surface is evaluated.

3.65 trimming loop: A sequence of connected and similarly oriented *trimming curves* that form a closed path. Trimming loops are used to limit the *parameter range* over which a parametric surface is evaluated.

3.66 vertex colour: A *general colour* associated with each vertex of some output primitives. This colour is conditionally used within the *rendering pipeline* to colour and shade the primitive.

3.67 vertex data: Geometric, *intrinsic colour data*, or *vertex normal* data specified at vertices of certain output primitives.

3.68 vertex normal: A *normal vector* optionally supplied with the *vertex data* of some area primitives.

3.69 with-data primitives: Any of the output primitives: *fill area set with data*, *set of fill area sets with data*, *triangle set* with data, *triangle strip* with data, *quadrilateral mesh* with data and non-uniform B-spline surface with data. In addition, some generalized drawing primitives may have this classification.

3.70 workstation light source. A *light source* entry in a workstation light source table.

4 The PHIGS PLUS system

4.1 About this part of ISO/IEC 9592

4.1.1 Specification and conformance

The set of functions known as PHIGS PLUS shall be as described in clauses 4, 5, and 6 of this part of ISO/IEC 9592 in addition to the functions described in clauses 4, 5, and 6 of ISO/IEC 9592-1. A conforming implementation of PHIGS PLUS shall be a conforming implementation of ISO/IEC 9592-1, as amended by amendments to that part, and in addition correctly implement all the functions described in clauses 4, 5, and 6 of this part of ISO/IEC 9592. Minimum support criteria for the additional functionality are specified in 4.10. A conforming implementation of PHIGS PLUS shall provide the additional information described in annex D as well as annex D of ISO/IEC 9592-1, and the minimum support specified in 4.10 as well as 4.14 of ISO/IEC 9592-1. In a conforming implementation all graphical capabilities that can be addressed by PHIGS PLUS shall be used only via PHIGS PLUS.

4.1.2 Registration

For certain parameters of the functions, PHIGS PLUS defines value ranges as being reserved for registration.[1] The meanings of such values and ranges will be defined in the Register. These procedures do not apply to values and value ranges defined as being workstation or implementation dependent; such values and ranges are not standardized.

4.1.3 Notational conventions

This part of ISO/IEC 9592 uses the following typographical conventions.

a) The names of primitive attributes appear in upper case.

b) Geometric aspects of primitives appear in upper case. Non-geometric aspects appear in lower case except when the corresponding individually specified attributes are being used, in which case they appear in upper case.

c) The names of entries in the PHIGS data structures, including those defined by PHIGS PLUS, appear in lower case surrounded by single quotation marks.

d) The names of structure elements appear in lower case surrounded by double quotation marks.

e) The names of PHIGS PLUS functions appear in upper case.

f) The values of an enumeration data type appear in upper case.

g) The names of data types appear in upper case.

1) For the purpose of this part of ISO/IEC 9592 and according to the rules for the designation and operation of registration authorities in the ISO/IEC Directives, the ISO and IEC Councils have designated the following as the registration authority: National Institute of Standards and Technology (National Computer Systems Laboratory), The Registration Authority for Graphical Items, A-266 Technology Building, Gaithersburg, MD 20899, USA

4.2 Overview and concepts

4.2.1 Overview

The Programmer's Hierarchical Interactive System (PHIGS) Plus Lumière Und Surfaces (PHIGS PLUS) provides a functional interface between an application program and a configuration of graphical input and output devices. The functional interface contains all of PHIGS, the basic functions for interactive graphics on a wide range of graphics equipment, and adds new facilities for the specification of curved lines and curved and facetted surfaces. Lighting and other effects such as depth modulation can be specified to allow realistic presentation of the geometry. There is direct support for the visualization of data that can be associated with the geometry.

The interface is at such a level of abstraction that hardware peculiarities are shielded from the application program. As a result, a simplified interface presenting the additional primitives is obtained.

Some PHIGS PLUS concepts are described as being workstation dependent. This means the implementation is allowed to specify the characteristics of these concepts on a workstation by workstation basis. All workstation dependent concepts are explicit in the standard. Other PHIGS concepts are described as being implementation dependent. This means that an implementation is allowed to determine the effect (rather than having the effect mandated by the standard). However such effects shall be the same on all workstations in a single implementation.

Annex D (taken with annex D of ISO/IEC 9592-1) describes the permitted differences between PHIGS PLUS implementations.

4.2.2 Concepts

PHIGS PLUS defines a set of output primitives whose definitions contain, in addition to the geometry of the primitive, information that further specifies certain characteristics of the primitive and influences its appearance on the display surface. These output primitives are called *with-data primitives*.[2] The data defined for these with-data primitives is used to colour and shade the primitive, and in the case of *area primitives*, to indicate the primitive's apparent orientation and control the visibility of its edges. Depending on the output primitive, the information that can be specified in addition to geometry is *intrinsic colour data* that indicates a colour distribution across the primitive, *normal vectors* that indicate the primitive's apparent orientation, and *edge visibility flags* that control the visibility of an area primitive's edges. This data is optionally specified and conditionally used when rendering the primitive. Some of the with-data primitives are the output primitive types defined in ISO/IEC 9592-1 extended to include the additional information. Some other with-data primitives offer data compaction and other advantages.

A colour is specified in PHIGS PLUS as a *general colour*, which consists of a colour type and a type-dependent colour value. The colour type can indicate any one of a number of colour models, in which case the corresponding colour value is interpreted as a value in that colour space. Alternatively, the colour type can indicate an indirect colour, in which case the colour value is an index into the workstation colour table. PHIGS PLUS thus supports the indirect colour specification of ISO/IEC 9592-1 as a subset of a more general colour specification mechanism. PHIGS PLUS defines general colour extensions to most areas of ISO/IEC 9592-1 where colours are specified.

PHIGS PLUS has the concept of a *rendering pipeline*. Conceptually, all output primitives pass through this pipeline as they are displayed. Operations are performed in the pipeline that affect the colour and appearance of each facet of a primitive. These operations include, for most primitives, the mapping of application-specific data to colour (*data mapping*), the calculation of reflectance effects (*lighting*), data interpolation (*shading*), and *depth cueing*. Output primitive attributes and any data attached to the primitives are conditionally used in these operations. The last stage of the rendering pipeline is a *colour mapping* that maps the resultant colours from the earlier stages into workstation dependent colours. The application may have control over which of these stages are active and what methods are used within each stage.

2) In this subclause, terms in the glossary are italicized when first used.

Data mapping in PHIGS PLUS provides a mechanism to convert application-specific data to colour within the rendering pipeline. Data such as temperature, pressure or other scalar or multi-dimensional information can be specified for most area primitives. Selected portions of this data may then be used during traversal to determine the *intrinsic colour* of the primitive, which is the colour or set of colours associated with a primitive before the effects of lighting are applied. The method to use to convert the data to intrinsic colour is under application control. More data can be specified than is used during any single rendering of a primitive.

Explicitly specified and implicitly specified aspects control the operations of the rendering pipeline. Explicitly specified aspects are *facet normals*, used to determine facet orientation, and *vertex normals* used to determine *reflectance normals* in *reflectance calculations*. When not supplied, facet normals are implicitly determined from the geometry of the facet.

PHIGS PLUS defines the *light sources* and suggests their interaction with output primitives. Several types of light sources are defined: *ambient*, *directional*, *positional* and *spot*. *Workstation light sources* are associated with workstations and are defined as entries in the 'light source table' in the workstation state list.[3] Active light sources are selected from this table by the 'current light source state' in the traversal state list.

Each *facet* of an area primitive has an orientation, either *front facing* or *back facing* as determined in normalized projection coordinates from the facet normal. PHIGS PLUS defines separate attributes for front and back facing facets of area primitives and provides controls for determining when they should be applied. PHIGS PLUS also defines an attribute to control whether individual facets are removed prior to viewing based on their orientation.

PHIGS PLUS defines non-uniform B-spline curve and surface output primitives. These output primitives are specified by a series of control points and parameter values that define non-uniform B-spline curves and surfaces in terms of the B-spline representation. This interface allows the exact specification of commonly required shapes including conics, conic sections such as circles, ellipses, parabolae, spheres, and spheroids without resorting to special cases. The curves and surfaces are represented by non-rational and rational splines using the mathematically robust B-spline representation. Variants of these primitives are defined that allow specification of an intrinsic colour data distribution over the primitive.

PHIGS PLUS replaces some fields of some of the data structures defined in ISO/IEC 9592-1 and adds a number of fields to these data structures. Replacements and additions have been made to the PHIGS description table, traversal state list, workstation state list and workstation description table, and are listed in clause 6.

3) Light sources with their specification included directly in the CSS are not defined by this part of ISO/IEC 9592, but their inclusion as GSEs or GDPs is not prohibited.