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A Format for a Graphical Communication Protocol

STATUS OF THIS MEMO

This paper describes the requirements for a graphical format on which to base a graphical on-line communication protocol. The proposal is an Interactive Graphical Communication Format using the GKSM session metafile. Distribution of this memo is unlimited.

ABSTRACT

This paper describes the requirements for a graphical format on which to base a graphical on-line communication protocol. It is argued that on-line graphical communication is similar to graphical session capture, and thus we propose an Interactive Graphical Communication Format using the GKSM session metafile.

We discuss the items that we believe complement the GKSM metafile as a format for on-line interactive exchanges. One key application area of such a format is multi-media on-line conferencing; therefore, we present a conferencing software architecture for processing the proposed format. We make this format specification available to those planning multi-media conferencing systems as a contribution toward the development of a graphical communication protocol that will permit the interoperation of these systems.

We hope this contribution will encourage the discussion of multimedia data exchange and the proposal of solutions. At SRI, we stay open to the exploration of alternatives and we will continue our research and development work in this problem area.

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I. INTRODUCTION

A. Use of a Graphical Communication Protocol

In the field of computer communications, a protocol is a procedure executed by two cooperating processes in order to attain a meaningful exchange of information. A graphical communication protocol is needed to exchange interactive vector graphics information, possibly in conjunction with other information media like voice, text, and video. Within this multi-media communication environment, computer vector graphics plays a key role because it takes full advantage of the processing capabilities of communicating computers and human users, and thus it is far more compact than digital images which are not generated from data structures containing positional information. Vector graphical communication trades intensive use of storage and processing, at the communicating ends, in return for a low volume of exchanged data, because workstations with graphical hardware exchange graphics commands in conjunction with large data structures at the transmitter and receivers. In this manner, the transmission of a single command can produce extensive changes in the data displayed at the sending and receiving ends.

It is helpful to situate the aforesaid protocol at one of the functional levels of the ISO Open Systems Interconnection Reference Model [1]. Within such a model, a graphical protocol functionality belongs primarily in the application level, though some of it fits in the presentation level. We can distinguish the following components of a communication protocol:

a) a data format
b) rules to interpret transmitted data
c) state information tables
d) message exchange rules

A format for a graphical protocol should provide the layout of the transmitted data, and indicate how the formated data are associated with interpretation rules. The choice of format influences the state tables to be maintained for the correct processing of the transmitted data stream. The graphical format has a minor influence on the exchange rules, which should provide for the efficient use of transmission capacity to transport the data under such a format. Besides the graphical format, there are

other aspects of a graphical protocol that determine state tables and exchange rules. This paper concentrates in the data format, and it does not discuss the message exchange. Nevertheless, we discuss a simple software architecture for generating and interpreting data streams written in our proposed format. Further, we give an example of an application of a proposed format (in Appendix B), and it illustrates the type of message exchanges that are needed for establishing a communication session and exchanging graphical information.

Those in the computer communication field are well aware of the importance of widely accepted protocols in order to achieve meaningful communication. Those who need to implement interactive graphical communications today are confronted with the lack of an standard for computer graphics communication among application programs. Nevertheless, we can use some of the work already done by the computer graphics standard bodies. As a matter of fact, ISO and ANSI have already appended, to the Graphical Kernel System (GKS) standard, the GKSM session metafile specification that has many of the features needed for an on-line graphical protocol.

It is pertinent to mention an example of graphical communication that illustrates the real-time nature of the interaction and also illustrates the use of graphics in conjunction with other information media. With audio-graphics conferencing, a group of individuals at two or more locations can carry on an electronic meeting. They can converse over voice channels and concurrently share a graphics space on which they can display, point at, and manipulate vector graphics pictures [2, 3, 4, 5, 6, 7].

The conference voice channels can be provided by a variety of transmission technologies. The shared graphics space can be implemented on workstations that display the pictures and permit graphical interaction and communication with other locations. The communication of operations upon pictures involves modifications to the underlying data structures, but we are concerned with graphical database updating only to the extent that such updating supports the communication.

In order to play out a recorded graphical session, we will need indications of the rate at which the graphical elements must be shown and the graphical operations recreated. We do not include the means for indicating the timing of a session in a format because our main purpose is to use it in mixed-media communication environments. In these environments, the play-out timing must be compatible across information media in order to coordinate them. Therefore, we leave the timing mechanisms to conference-control

modules. We also leave to conference control processes the manner in which a conferee station emulates a graphical capability that it lacks. One example is the representation of color in monochrome displays.

B. Relationship to Other Work

There are a number of actual, and proposed, standards for graphics information exchange. In the following, we explain the reasons why, at present, none of them can be used as the basis of an on-line protocol. As some of these standards evolve, however, some may become suitable. Moreover, the experience gained with early on-line graphics communication systems will provide insight into the proper standard extensions to support more advanced systems. Such insight could also be used to modify the format proposed in this paper, which we consider an initial approach to the problem. In the future, the format proposed in this paper could be replaced by one of the aforesaid extended standards.

The North American Presentation Level Protocol Syntax, NAPLPS, specifies a data syntax and application semantics for one-way teletext information dissemination and two-way videotex database access and transaction services. The two-way videotex operational model is based on the concept of a consumer and an information provider or service operator. Because of this asymmetry, it is assumed that almost all graphical information will flow from the provider toward the consumer. In the reverse direction, the consumer is expected to manipulate and transmit alphanumeric information, for the most part. Although this standard includes geometric drawing primitives, a user cannot directly modify shapes drawn with the primitives.

At present, NAPLPS does not include interaction concepts like picture transformations or detectability, which are fundamental for attaining a shared graphical workspace. Neither does it allow key graphics input devices like mice, joysticks, stylus, rotating balls, or light pens, which are needed for simple and efficient editing of the shared workspace.

We want to have user-to-user graphical communication that features the level of sophistication and ease of interaction provided by today’s interactive graphics packages. Computer vector graphics can provide both because its paradigm includes an application program that keeps track of a very large number of possible changes of state of the displayed picture. In addition, the application drives a powerful graphics package, like GKS or ACM Core. In the videotex paradigm, the provider application only

allows limited changes to the displayed image, primarily database retrieval requests. Also, the paradigm does not include a separate graphics package. Both the graphics functionality and the data format are collapsed into a coding specification, like NAPLPS.

In this paper we are interested primarily in business and industrial applications where there is a two-way, or multi-way, flow of vector graphics information among the users. The users will have workstations with substantial processing and storage capacities, and high-resolution monitors; moreover, the communication will be on a distributed architecture not depending on a central server host, like the provider application host of videotex.

Currently, the videotex equipment at the consumer end consists of inexpensive microprocessor-based decoders or personal computer boards driving, in most cases, low-resolution standard TV sets and personal computer displays. There is already affordable technology to produce sophisticated decoders and high-resolution graphics devices. The videotex standards need extensive revisions to take advantage of these advances; in particular, they should consider the receiving devices as capable of hosting a programmable customer-application process. When this happens, videotex protocols will be applicable to our intended problem areas [8].

The Computer Graphics Metafile [9] will become an international and North American standard for graphics picture interchange in the near future. However, the CGM, also referred as VDM, is a picture-capture metafile that only records the final result of a graphics session. It is not intended to record the picture-creation process, which is fundamental for the interactive applications that we are addressing. Moreover, the CGM is presently aimed at a minimum support of GKS functionality. It will be some time before the CGM will have some of the elements needed for on-line interaction. If, after these additions, the CGM is augmented for session capture, it would become a logical candidate for a protocol format.

Another future standard is the Computer Graphics Interface, CGI also referred as VDI [10]. The CGI is a standard functional and syntactical specification of the control and data exchange between device-independent graphics software and one or more device-dependent graphics device drivers. A major use of the CGI is for the communication between an application host and a graphics device, but the asymmetry between its intended communicating ends hinders the use of CGI for our purposes.

As previously stated, we want to take advantage of intelligence and storage at the communicating ends in order to achieve powerful information-conveying effects using narrow-bandwidth channels. This requires that the format we seek must have items for communication between two applications. In contrast, the CGI streams are processed by device-dependent drivers, rather than by applications. The CGI specification does include application data elements, but only to be stored in a metafile. These application data elements are not interpreted by the drivers, but by applications that read the metafile, some time after metafile creation.

Furthermore, the CGI has elements for obtaining graphical input, as well as elements for inquiring graphics device capabilities, characteristics, and states. Later, in Section III, we explain why these two classes of elements are unnecessary for the communication protocol we need. As the CGI evolves, it will undergo significant changes, and, in the future, it may become a very suitable kernel for the graphics protocol we seek. As a matter of fact, the CGI will be the communication protocol between graphical application hosts and graphics terminals. At SRI we are tracking its evolution, and we are interested in defining a format based on the CGI.

Finally, the Initial Graphics Exchange Specification [11] is not aimed at our primary area of interest. The IGES defines standard file and language formats for storing and transmitting product-definition data that can be used, in part, to generate engineering drawings and other graphical representations of engineering products. Besides the CAD orientation of IGES, the graphical output function may be secondary to other goals like transmitting numerical-control machine instructions.

II. OPERATIONAL REQUIREMENTS AND USABILITY

The main goal of this paper is to lay the groundwork for the development of a vector graphics format to be used as a basis for an on-line graphical communication protocol. We call such a format an "interactive graphical communication format," or IGCF. In this section we describe some operational requirements and usable characteristics for an IGCF.

A. Interoperation of Heterogeneous Systems

A first functional requirement is that an IGCF must permit communication among heterogeneous graphical systems differing both in the hardware used and in the software of their graphics

application interfaces. This is a fundamental for attaining communication among similar graphical application programs running on dissimilar hardware and using dissimilar graphics interface packages. Some examples of such application programs are graphics editors, CAD systems, and graphical database retrieval programs communicating with other editors, CAD programs, and graphical databases, respectively.

B. Picture Capture

A required characteristic of an IGCF is that it must be usable for the exchange of static graphic pictures, i.e. for picture capture; yet, it must not be restricted to final picture recording only. There will be picture exchanges as part of the interactive communication, and we anticipate the need to record the state of a picture at some points during the on-line graphics engagement. We foresee the creation of graphical IGCF libraries containing object definitions and pictures for inclusion in new pictures. Since metafiles have been used for a long time to capture pictures, there is a strong motivation to base an IGCF on a metafile standard in order to secure compatibility with a large number of metafile sources and consumers.

C. Prompt Transmission

In some forms of interactive graphical communication, like audiographics conferencing, it is critical to convey across users the real-time nature of the interaction. This dictates that object creations and manipulations be transmitted as they happen rather than as a final result since a substantial part of the information may be transmitted concurrently with the construction or operation of an object, possibly through associated media like voice. Since both construction and manipulation processes have to be transmitted, there is a limit to the number of intermediate states that can be economically transmitted.

A third requirement is, therefore, that the IGCF elements provide fine "granularity" to convey the dynamics of the constructions and manipulations. We believe that it is sufficient that the IGCF have basic construction elements like polygons, markers, polylines, and text strings and that it transmit them only when they are completed; i.e., it is not necessary to transmit partial constructions of such elements.

The problem for manipulations extends beyond an IGCF. Whereas we know that an IGCF should include segment transformations, segment highlighting and segment visibility on/off, the transmitter must

decide how often to sample an on-going transformation and transmit its current state. The choice of a sampling frequency will depend on the available transmission bandwidth.

D. Low Traffic Volume

In many of the applications we envision, coordinate graphics will be transmitted over narrow bandwidth channels, and thus it is essential to minimize traffic. Accordingly, several requirements are imposed on an IGCF to take advantage of the characteristics of the graphics communication intercourse and architecture in order to minimize traffic.

An IGCF can help reduce traffic by including the basic geometric objects from which so many other objects are built. Moreover, an IGCF should permit the use of objects for the creation of more complex objects; since reuse is very common, the result is a reduction of traffic and storage cost.

E. Preservation of Application Semantic Units

A related requirement is that an IGCF must include elements to represent graphical objects corresponding to real world entities of the intended applications. For example, in a Navy application, the entities of interest are carriers, submarines, planes, and the like. We want to communicate such semantic units across systems and to treat them as unitary objects because, in many applications, communication is based on creating and operating such units. If an IGCF has elements to represent such semantic units, the communication traffic decreases because the entity definitions can be transmitted only once and then reused, and because the entities are manipulated as units rather than separately manipulating their components.

It turns out that there is a small set of primary operations that can be applied to a graphical object, and an IGCF must have elements representing such operations. In contrast to dumb graphics terminals receiving screen refresh information from a host, we foresee graphical communication taking place among intelligent workstations that can exchange encoded operations, interpret them, and apply them to objects stored locally.

F. Transmission Batching

We previously indicated the desirability of conveying to the human users the real-time tempo of interactive graphics exchanges. However, it is possible to do so without having to transmit

immediately all IGCF elements. As a matter of fact, IGCF elements should be divided into those causing a change on a displayed picture and those that do not, although both classes may cause changes to the stored graphical data structures.

It is only necessary to transmit immediately those elements causing a visible change on a displayed picture because they are the ones whose reception and interpretation delivers information to a human user. The second class of elements can be batched and queued for transmission until one element of the first class is submitted. We call the first class update Group-1, and the second, update Group-2.

The aforesaid division is quite important for packet communications because each packet contains a hefty amount of overhead control traffic. It is therefore mandatory to batch, into a packet, as much client data as possible in order to reduce total traffic. The batching units can be varied in size according to the network traffic and response time of conference hosts. During congested periods, the units may have to be increased, thus lowering the number of messages, and then reduced when congestion eases, thus increasing the number of messages.

G. Simple Translation Between IGCF and User Interface

According to the first requirement, an IGCF must permit the interoperation of related heterogeneous graphics applications. Such interoperation has, as an objective, the communication between human users or between a human and a database. Correspondingly, the interoperation involves a mapping between the user interface commands and the IGCF elements. It is not advisable to use the commands themselves as the IGCF elements; otherwise the exchange would depend on the communicating systems, and every pair of communicating systems would require an ad-hoc protocol.

An additional usability characteristic is that there must be a simple mapping between IGCF elements and the actions represented by the user interface commands employed for graphical communications. This simplicity is a must because every communicating graphical system must have a translator that ideally should be very simple. It seems that the inclusion of command sequence delimiters in the IGCF helps the simplicity since the delimiters permit keeping a smaller amount of state information for processing an IGCF stream.

We have verified the mapping from one set of commands for audiographics conferencing to the IGCF proposed in this paper. The

mapping from user interface commands to IGCF can be done in a direct and efficient manner; on the other hand, the reverse mapping, from IGCF to user interface commands, is a more difficult task. We anticipate that, in order to improve performance, we will have to map the IGCF elements to calls to lower level subroutines implementing the user interface actions. Whereas such mapping is conceptually no more complex than translating IGCF to the commands themselves, it will require considerably more programming.

III. ELEMENTS OF AN IGCF

IGCF Element Classes

In this section we list the classes of elements that we believe an IGCF should have in order to exchange vector graphics under the requirements of the previous section. The classes correspond to the common function classes in computer graphics interfaces, and each contains elements corresponding to interface primitives and attributes. We do not list the elements for each class because they are exemplified by the elements in the proposed IGCF.

In the following list, two categories of functions are missing: functions used to query the status of a graphics system, and input functions. As a matter of fact, an IGCF only needs to have elements representing actions that cause a change in the state of the communicating graphical systems, and the inquire functions obviously do not change their state. Even though an input function executed at the transmitting end causes a local change, it is not necessary to transmit the input command itself. The receivers only need to get the data input, in IGCF representation, and they can process the data in any manner, maybe simulating local input actions.

Control

Elements for workstation: initialization, control and transformation; and elements for normalization transformation. (The normalization and workstation transformations can be used to implement zooming.)

Primitive attributes

Elements for primitive, segment, and workstation attributes.

Output primitives

Elements for output primitives.

Segmentation

Elements for basic segmentation and workstation independent segment storage.

Object manipulations can be implemented with segment transformations. Object insertion can be implemented using segment recall and segment visibility. Object deletion can be implemented using segment deletion and segment visibility. Object selection can use segment highlighting as feedback to the user.

Dynamics

A considerable part of the graphical information exchanged through an IGCF will be in the form of pointer movements over a background picture. Pointer tracking is used to transmit points sampled from a graphical pointer trace in order to reproduce, at the receivers, the movement of the pointer at the sender site. This can be done either by just moving the cursor or by tracing its movement with a line. Rubber band echoes are used to signal areas, routes, and scopes in a highly dynamic way. These are indicated by an echo reference point and a feedback point.

Hierarchical object definitions

The requirement for preserving application semantics dictated that an IGCF include the means to represent objects that stand for application entities, and to manipulate such entities as graphical units. Furthermore, the low-traffic-volume requirement called for the use of already existing objects for the creation of new ones.

One way to meet the aforesaid requirements is by including in an IGCF the means to represent object hierarchies. In such a hierarchy an object is a set of output primitives associated with a set of attribute values or a set of lower-level objects, each associated with a composition of transformations [12].

Graphics segments can be used to implement objects in the lowest level of a hierarchy. The definition of a higher-level object can be represented by sequences of IGCF elements describing the definition process. Such a definition can be done by instantiating lower-level objects with specific transformation parameters. Thus an IGCF must incorporate brackets to mark the beginning and end of object definitions, object instantiations, and object redefinitions.

In order to complement the mechanism for object definition, an IGCF must permit the use of a flexible alphabet for creating object identifiers that ensure the uniqueness of an identifier in a hierarchy. The construction of the object identifiers is not part of an IGCF, an IGCF only has to represent the identifiers. Further, an identifier has to be independent of a communication session and a particular graphics system so that identifiers created at a host during one session can be used, in other sessions possibly involving other hosts, to recall the objects they label.

We also leave to the communicating systems the implementation of mechanisms to resolve duplicate identifiers when merging two hierarchies, created in different sessions. In this paper we shall limit ourselves to the warning that segment numbers do not qualify as identifiers because they depend on the session and state of the system in which they are created.

In addition to object definition and instantiation, an IGCF should have elements representing operations on objects. The operations so far identified are: transformation, deletion, display, disappearance, expose, and hide. Expose is used to uncover objects on a screen that are hidden by other objects; hide is used to place an object behind others on a screen.

IV. A PROPOSED IGCF

A. Using the GKSM as a Basis

An IGCF must be usable to transmit all graphical actions in a conference session. This suggests to base an IGCF on a standard session-capture graphics metafile, thus ensuring compatibility with a large user population. We have based the proposed IGCF, PIGCF, on the GKSM session-capture metafile specification because GKSM contains many of the elements identified for an IGCF [14]. In addition, the audit trail orientation of GKSM permits the recording of interactive communication sessions for later play out, and this is a feature that we anticipate will be frequently used.

The GKSM is a proper subset of our PIGCF and thus any graphical system developed to handle the PIGCF, can read a GKSM metafile. Conversely, the applications using the PIGCF should have an option for constraining session recording only to the GKSM part, possibly suppressing some session events. By doing so, we will be able to ship a GKSM metafile to any correspondent who has GKSM

interpretation software. Alternatively, an application with a GKSM interpreter but without an PIGCF interpreter can read a PIGCF file interpreting only the GKSM part and ignoring the rest.

Whereas the GKSM was specified for the GKS system, we believe that the GKSM is a sound and general basis for all of our 2-D applications. We feel that the GKSM specification is not parochial to GKS systems but contains all the most useful items desired in a metafile. In the future, we expect to tackle applications requiring 3-D, like interactive repair and maintenance aids. When GKS be augmented with 3-D capabilities [13], we will extend the PIGCF with any necessary elements.

We are aware that the GKSM specification is not part of the GKS standard itself but is an appendix recommending such a metafile format. Nevertheless, all the GKS vendor implementations that we know of, at the present time, support GKSM metafile output and interpretation. If this trend continues, as we expect, we will be able to exchange graphical files with a large base of GKS installations. There will indeed be many of them since GKS will be adopted as an standard by ISO and by many national standard bodies in the near future.

B. Positional Information Coordinates

Following the GKSM convention, the PIGCF positional information is in normalized device coordinates, NDC. Thus the originator of a conference must indicate the workstation window for the conference. This window is the sub-rectangle of the NDC space enclosing the area of interest for the conference. In most cases, the participating workstations will take this window as their own. However, the graphical systems should provide for the possibility of a workstation choosing a different workstation window, which may contain the conference window or just overlap it. Except for special cases, a conference originator should not state a conference workstation viewport. In this manner, each workstation can display its workstation viewport in the most convenient portion of the screen.

There will be conferences where the participating workstations will maintain the positional information in world coordinates, WC. It might be necessary to reconstruct the world dimensions after transmission because such dimensions have a relevant meaning for the application, like sizes of components or distances. In this case, a workstation will have to map from WC to NDC before transmitting and from NDC to WC after receiving. At the outset, the conference originator has to specify the world window and the

NDC viewport used in the conference in order for the conferencing workstations to do such mappings. These mappings could be done by the presentation layer, in terms of the ISO Open Systems Interconnection Reference Model, in a manner that is transparent to the communicating application programs.

Most often all workstations will have the same world windows and NDC viewports. However, the graphical systems will provide for the possibility of a workstation choosing a different window or viewport, but such workstation will have to record the conference ones for doing the aforesaid mappings. There are graphical systems, like the ACM Core, that do not provide for a workstation transformation. In such systems, the NDC viewport is considered to be the workstation window for the aforesaid mappings.

C. Layers of the PIGCF

There are two levels in the PIGCF a lower level L and an upper one U. The lower level L is just the GKSM metafile specification as defined in Appendix E of the proposed GKS ANSI standard [14]. We have excerpted most of Appendix E of [14] at the end of this RFC as our Appendix A. All level L elements belong to the update Group-1 except: SET DEFERRAL STATE, the output primitive attribute elements, the workstation attribute elements, CLIPPING RECTANGLE, CREATE SEGMENT, CLOSE SEGMENT, RENAME SEGMENT, SET SEGMENT PRIORITY, and SET DETECTABILITY.

The upper level U is those elements that we believe complement the GKSM for general on-line graphical exchanges. This layering conforms to the graphics metafile level-structure described in Enderle et. al [15]. Under such structuring, an application oriented metafile can be based on graphical metafiles.

D. PIGCF Elements in the Level U

The level U items are encoded as GKSM user item elements so that a PIGCF file will conform to the GKSM metafile specification. Accordingly, a PIGCF file will be a GKSM metafile in its entirety. We use the same formatting conventions as the GKSM specification. Those unfamiliar with these conventions should read the beginning of the appendix. The following items belong to the second update group: the two items for object definition, the two items for object redefinition, the two items for object instantiation, the two items for normalization transformation, SELECT COMPONENT, and RECALL LIBRARY. The remaining items belong to the first update group.

Items for Object Definition

BEGIN DEFINITION

| 'GKSM 120' | L |

Indicates beginning of object definition sequence

END DEFINITION

| 'GKSM 121' | L | I |

Indicates end of object definition sequence. I(Nc): object identifier (N preceding c, i, r means an arbitrary number of characters, integers, or reals.) Objects defined interactively are made visible on the screen; i.e. they are automatically instantiated. If only the definition is to be kept but not the image, a DISAPPEAR item must follow.

BEGIN REDEFINITION

| 'GKSM 122' | L | I |

Indicates beginning of object redefinition sequence I(Nc): object identifier

END REDEFINITION

| 'GKSM 123' | L |

Indicates end of object redefinition sequence

Items for Object Instantiation

BEGIN INSTANTIATION

| 'GKSM 124' | L | I |

Indicates beginning of object instantiation sequence I(Nc): Object identifier

END INSTANTIATION

| 'GKSM 125' | L |

Indicates end of object instantiation sequence

Items for Object Manipulation

TRANSFORM OBJECT

| 'GKSM 126' | L | C | I | M |

Apply transformation M to object I
C: number of characters in identifier
I(Nc): object id
M(6r): upper and center rows of a 3x3 matrix representing
a 2D homogeneous transformation [12].
M 11 M 12 M 13 M 21 M 22 M 23

DELETE OBJECT

| 'GKSM 127' | L | I |

I(Nc): object identifier

DISPLAY OBJECT

| 'GKSM 128' | L | I |

Turn on visibility of object I
I(Nc): object identifier

DISAPPEAR OBJECT

| 'GKSM 129' | L | I |

Turn off visibility of object I
I(Nc): object identifier

EXPOSE OBJECT

| 'GKSM 130' | L | I |

Redisplay object I on top of any overlapping objects
I(c): object identifier

HIDE OBJECT

| 'GKSM 131' | L | I |

Redisplay object I behind any overlapping objects
I(c): object identifier

SELECT COMPONENT

| 'GKSM 132' | L | I | P |

Select component P of object I
I(c): object identifier
P(i): pick id of component
This is used to select a group of output primitives identified by P in a segment associated with I.

ERASE COMPONENT

| 'GKSM 133' | L | I | P |

Erase component P of object I
I(c): object identifier
P(i): pick id of component

This erases a group of output primitives identified by P in a segment associated with I. This element can be used only within a REDEFINE OBJECT sequence.

Items for Normalization Transformation

SET WINDOW

| 'GKSM 134' | L | W |

Define boundaries of world window for normalization transformation.
W(4r): limits of world window (XMIN, XMAX, YMIN, YMAX)

SET VIEWPORT

| 'GKSM 135' | L | V |

Define boundaries of NDC viewport for normalization transformation.
V(4r): limits of NDC viewport (XMIN, XMAX, YMIN, YMAX)

Items for Other Operations

ABORT

| 'GKSM 136' | L |

Abort ongoing operation transmitted in PIGCF stream. This provides the means to abort unwanted or erroneous operations. Only the innermost operation of a nested sequence is aborted; successive aborts can be used to get out of several levels of operation nesting.

POINTER TRACKING

| 'GKSM 137' | L | T | P |

Update graphical pointer position to P
T(i): 0 causes only cursor to be moved
1 causes cursor movement to be traced with a line
P(p): a point sampled from graphical pointer movement trace

RUBBER BAND

| 'GKSM 138' | L | T | P |

Echo a rubber band of type T with given reference and feedback points. The first occurrence of this item in a sequence carries the coordinates of the echo reference point. Subsequent occurrences carry updates to a pointer position indicating an echo feedback point.

T(i): echo type
(0 echo reference point;
> 0 echo feedback:
1 = line,
2 = rectangle,
3 = circle)
P(r): echo reference point (T = 0),
or echo feedback point (T > 0)

The reference and feedback points are:
T = 1 - reference is one end of line, feedback is other end.
T = 2 - reference is one corner of rectangle, feedback is opposite corner.
T = 3 - reference is center of circle, feedback is perimeter point.

RECALL LIBRARY

| 'GKSM 139' | L | F |

Recall graphical library in file F
F(i): name of file containing library

The graphical pictures in F and all their components become available for use during the communication session. The pictures are assumed to be recorded with the PIGCF, and their components have to be displayed with DISPLAY OBJECT elements or similar actions so that the pictures become visible.

V. AN ARCHITECTURE FOR PIGCF PROCESSING

This section presents an example software architecture for the generation and interpretation of PIGCF in a multimedia conferencing system using GKS as the underlying programmer's graphics interface. This section should not be interpreted as a definitive statement of such an architecture, but only as an exercise to illustrate how the format proposed in this paper fits within the overall framework of a conferencing system. Choosing GKS simplifies the example architecture; nevertheless, other graphics packages can be used by adding, to the architecture, the modules to interpret and generate the PIGCF level L items.

Figure 1 shows the major software modules charged with graphics interaction and display at a conferencing workstation. This is a familiar programmer's view of the graphics pipeline. A conferencing application program updates data structures and uses device-independent graphics services through a language binding. These services, in turn, use device-dependent graphics services that call on device drivers to accept input and to present graphic pictures. The application performs numerous other functions for conference management and control of other media streams, but we need not consider them in this example.

In Figure 2, the basic graphics pipeline has been augmented with the software modules involved in the generation, transmission, reception, and interpretation of PIGCF streams. The application has a module for interpreting the lower and higher levels of PIGCF and one for generating the upper level U. The device-independent graphics services include modules for generating and interpreting the lower level, L. This reflects the current practice of including the generation and interpretation functions in the graphics package. There is also a module that transmits the outgoing PIGCF streams to remote work stations. Similarly, there is a module that receives incoming streams from remote stations. In actual practice, the transmit and receive modules are decomposed into several processes implementing a layered protocol architecture. A process receives both levels of PIGCF and writes them into a conference record metafile for future use. A router process receives and forwards PIGCF traffic from and to the modules previously referred. This router is likely to be replaced by independent communication interfaces between pairs of modules exchanging PIGCF.

The thick arrows show the flow of outgoing PIGCF, whereas the thin arrows show the incoming PIGCF flow. We first follow the outgoing path, starting at the application. The application processes local user actions which are transformed into data structure updates, level

U PIGCF elements, and executions of device independent graphics subroutines that, among other things, generate level L PIGCF (GKSM) elements.

The router merges both level streams according to generation order and sends them to the local copy of the conference record and to the transmission module. The latter batches Group-2 PIGCF items until it receives a Group-1 item. It also timestamps the PIGCF stream to synchronize its play-back, at the receiver, with the play-back of other media information. The PIGCF may be separated into traffic categories transmitted over diverse communication facilities according to the transport services required by the categories, for example, real-time service for pointer updates, highly reliable transmission for new object definitions, or low-priority service for graphical library transfers. Finally, the transmit module must acknowledge the reception of incoming PIGCF, and of other media traffic as well.

The receive module is the entry point for incoming PIGCF streams that may come within diverse traffic categories requiring merging. It checks the timestamps for synchronizing PIGCF items with related data in other media, for example, voice. It is possible to include here a high-level error-correction function that validates the received streams using state and context information about PIGCF syntax and semantics. The receive module passes the streams to the router which forwards them to three processes: It sends level L items to the GKSM interpreter which produces the corresponding changes on the displayed picture; it sends level L and level U items to the conference record, as well as to the PIGCF interpretation code in the application. The level U items cause updates to both the data structures modeling object hierarchies, and the pictorial representation of the hierarchies, through the execution of graphics services. U items also update graphics cursors and may recall new graphics libraries. The application must process level L items because they could indicate updates to the data structures; this happens if, for example, the structures record attribute value information for the object hierarchies. The application coordinates these actions with other media effects according to the timestamps. Conference record play-back is done in off-line mode. Record items are received by the router and thereafter processed similarly to incoming PIGCF.

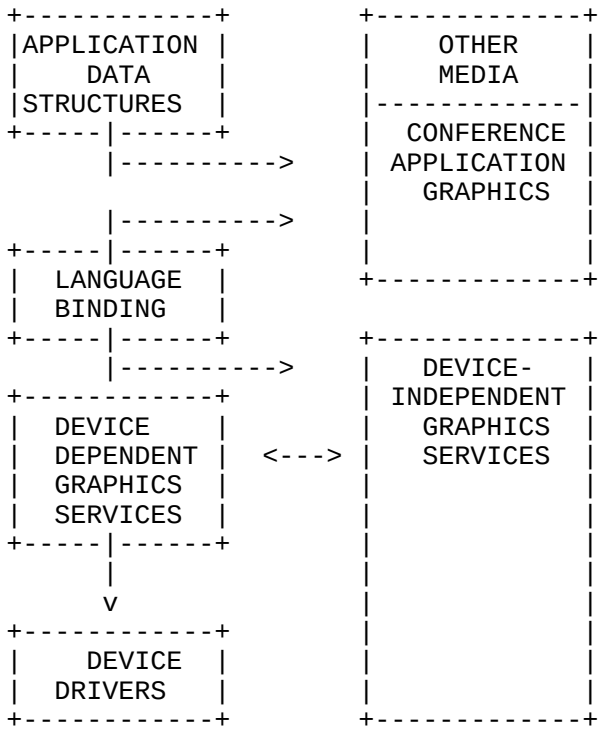


FIGURE 1 - THE BASIC GRAPHICS PIPELINE
IN A CONFERENCING SYSTEM

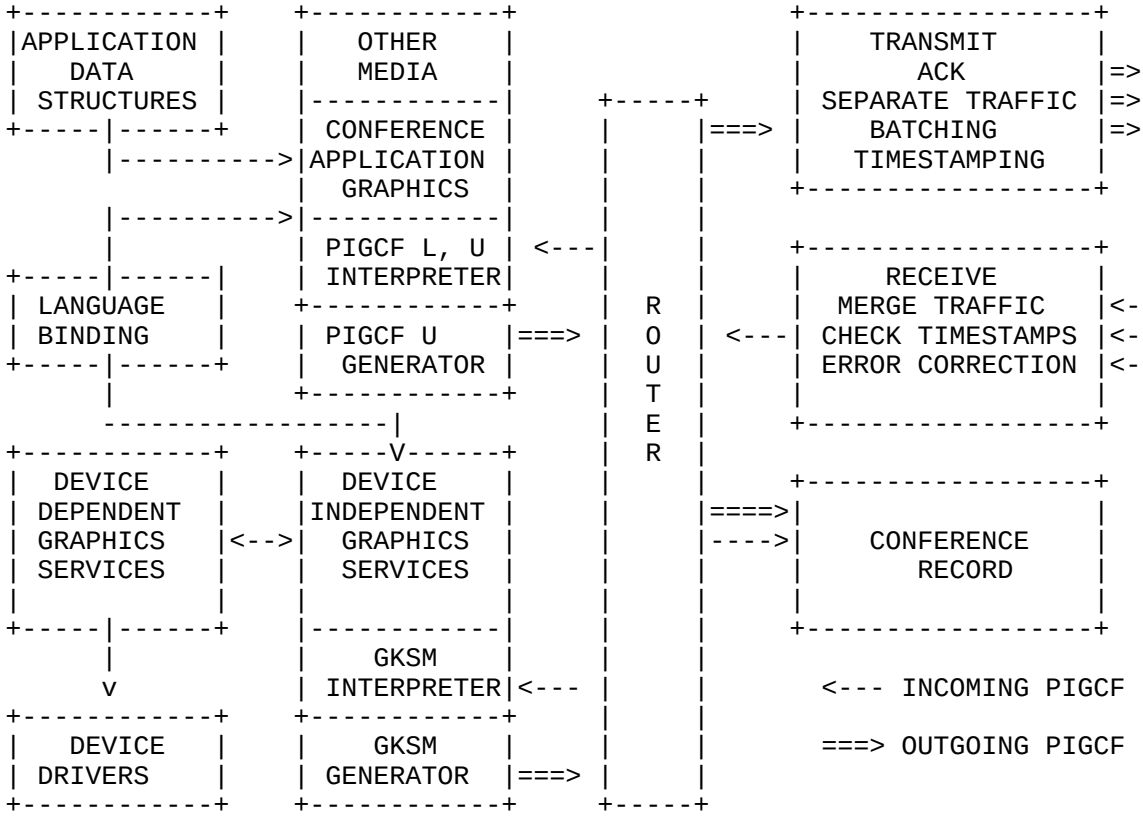


FIGURE 2 - A CONFERENCING SOFTWARE ARCHITECTURE FOR PROCESSING PIGCF

VI. CONCLUSIONS

Teleconferencing and other multi-media applications will be part of the communication resources available to organizations in the near future. This will prompt computer graphics and computer communication practitioners to address the issue of application-to-application graphics communication. A key element of the issue is a protocol, and a key component of the protocol is a data format. We have presented the operational requirements for such a protocol and have proposed a format that fulfills these requirements.

At present, none of the existing or emerging graphics standards can be used as the needed protocol or as a format for the protocol, but this may change as the standards evolve. We are monitoring the standards development and will study the use of some of them as a format basis, in particular the CGI. Nevertheless, the computer

communication community badly needs experience with multi-media conferencing implementations. In order for these applications to happen, one can base a graphics communication protocol on an official or on a de-facto standard that is likely to gain wide use thus assuring interoperability with a broad user base. We believe that, by using the GKSM session metafile, we are moving in the proper direction.

Planning the software architecture for generating and interpreting the proposed PIGCF has brought up some problems we will confront as we continue our work toward the development of a complete graphics protocol. This is being done as part of the SRI on-going program in multimedia communications. Within this program, we are implementing a simple multi-media conferencing prototype and will design a more complete one. The experience from both exercises will be a valuable input to the protocol architecture design.

APPENDIX A

Excerpt from "Draft Proposal: Graphical Kernel System" [14]

E.2 Metafile Based on ISO DIS7942

This metafile may be categorized as one which aims to provide a means of recording the exact sequence of function calls made to GKS. Its functional capability covers the entire range of GKS output functions, from level m to level 2. It is, therefore, suitable for applications where the individual graphics actions need to be 'played back', perhaps with selective graphical editing being done by the interpreter.

Two encodings have been specified for this metafile. One encoding is inefficient for many applications. The second allows an unspecified binary format. The remainder of this IGCF appendix gives full details of these metafile structures and encodings.

E.2.1 File Format and Data Format

The GKS metafile is built up as a sequence of logical data items. The file starts with a file header in fixed format which describes the origin of the metafile (author, installation), the format of the following items, and the number representation. The file ends with an end item indicating the logical end of the file. In between these two items, the following information is recorded in the sense of an audit trail:

a) workstation control items and message items;

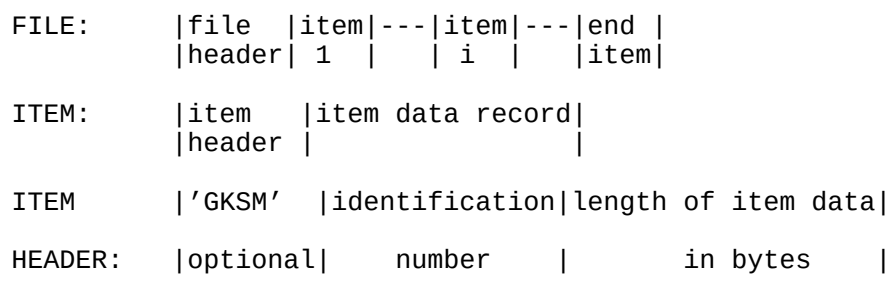
b) output primitive items, describing elementary graphics objects;

c) attribute information, including output primitive attributes; segment attributes, and workstation attributes;

d) segment items, describing the segment structure and dynamic segment manipulations;

e) user items.

The overall structure of the GKS metafile is as follows:



All data items except the file header have an item header containing:

a) the character string 'GKSM' (optional) which is present to improve legibility of the file and to provide an error control facility;

b) the item type identification number which indicates the kind of information that is contained in the item;

c) the length of the item data record.

The lengths of these fields of the item header are implementation dependent and are specified in the file header. The content of the item data record is fully described below for each item type.

The metafile contains characters, integer numbers, and real numbers marked (c), (i), (r) in the item description. Characters in the metafile are represented according to ISO 646 and ISO 2022. Numbers will be represented according to ISO 6093 using format F1 for integers and format F2 for reals. (Remark: Formats F1 and F2 can be written and read via FORTRAN formats I and F respectively.)

Real numbers describing coordinates and length units are stored as normalized device coordinates. The workstation transformation, if specified in the application program for a workstation writing a metafile of this format, is not performed but WORKSTATION WINDOW and WORKSTATION VIEWPORT are stored in data items for later usage. Real numbers may be stored as integers. In this case transformation parameters are specified in the file header to allow proper transformation of integers into normalized device coordinates.

For reasons of economy, numbers can be stored using an internal binary format. As no standard exists for binary number representation, this format limits the portability of the metafile. The specification of such a binary number representation is outside the scope of this document.

When exchanging metafiles between different installations, the physical structure of data sets on specific storage media should be standardized. Such a definition is outside the scope of this standard.

E.3 Generation of Metafiles

Table E1 contains a list, by class, of all GKS functions which apply to workstations of category MO, and their effects on this GKSM. In the table, GKSM-OUT is a workstation identifier indicating a workstation writing a metafile of this format.

The concepts of clipping rectangle and clipping indicator are encapsulated in one metafile item which specifies a clipping rectangle. This item is written to the metafile on activate workstation with the values (0, 1, 0, 1), if the clipping indicator is OFF, or the viewport of the current normalization transformation, if the clipping indicator is ON. If the viewport of the current normalization transformation is redefined or a different normalization transformation is selected when the clipping indicator is ON, a further clipping rectangle item is written. If the clipping indicator is changed to OFF, a clipping rectangle item (0, 1, 0, 1) is written. If the clipping indicator is changed to ON, an item containing the viewport of the current normalization transformation is written. This is analogous to the handling of clipping in segments (see 4.7.6 [14]).

GKS functions which apply to workstations of category MO	GKSM item created or effect
Control functions	
OPEN WORKSTATION (GKSM-OUT,...)	- (file header) 1 (CONDITIONAL)
CLOSE WORKSTATION (GKSM-OUT)	0 (end item)
ACTIVATE WORKSTATION (GKSM-OUT)	(61, 21-44) ensure attributes current; enable output

DEACTIVATE WORKSTATION (GKSM-OUT)	disable output
CLEAR WORKSTATION (GKSM-OUT,...)	1
	2
REDRAW ALL SEGMENTS ON WORKSTATION (GKSM-OUT)	
UPDATE WORKSTATION (GKSM-OUT,...)	3
SET DEFERRAL STATE (GKSM-OUT,...)	4
MESSAGE (GKSM-OUT,...)	5 (message)
ESCAPE	6

Output Primitives

POLYLINE	11
POLYMARKER	12
TEXT	13
FILL AREA	14
CELL ARRAY	15
GENERALIZED DRAWING PRIMITIVE	16

Output Attributes

SET POLYLINE INDEX	21
SET LINETYPE	22
SET LINEWIDTH SCALE FACTOR	23
SET POLYLINE COLOUR INDEX	24
SET POLYMARKER INDEX	25
SET MARKER TYPE	26
SET MARKER SIZE SCALE FACTOR	27
SET POLYMARKER COLOUR INDEX	28
SET TEXT INDEX	29
SET TEXT FONT AND PRECISION	30
SET CHARACTER EXPANSION FACTOR	31
SET CHARACTER SPACING	32
SET TEXT COLOUR INDEX	33
SET CHARACTER HEIGHT	34
SET CHARACTER UP VECTOR	34
SET TEXT PATH	35
SET TEXT ALIGNMENT	36
SET FILL AREA INDEX	37
SET FILL AREA INTERIOR STYLE	38
SET FILL AREA STYLE INDEX	39
SET FILL AREA COLOUR INDEX	40
SET PATTERN SIZE	41
SET PATTERN REFERENCE POINT	42

SET ASPECT SOURCE FLAGS	43
SET PICK IDENTIFIER	44

Workstation Attributes

SET POLYLINE REPRESENTATION (GKSM-OUT,...)	51
SET POLYMARKER REPRESENTATION (GKSM-OUT,...)	52
SET TEXT REPRESENTATION (GKSM-OUT,...)	53
SET FILL AREA REPRESENTATION (GKSM-OUT,...)	54
SET PATTERN REPRESENTATION (GKSM-OUT,...)	55
SET COLOUR REPRESENTATION (GKSM-OUT,...)	56

Transformation Functions

SET WINDOW of current normalization transformation	34, 41, 42
SET VIEWPOINT of current normalization transformation	61, 34, 41, 42
SELECT NORMALIZATION TRANSFORMATION	61, 34, 41, 42
SET CLIPPING INDICATOR	61
SET WORKSTATION WINDOW (GKSM-OUT,...)	71
SET WORKSTATION WINDOW VIEWPORT (GKSM-OUT,...)	72

Note: item 61 (CLIPPING RECTANGLE) is described more fully in E.2.2.

Note: When the current normalization transformation is altered, items corresponding to attributes containing coordinate information are sent (items 34, 41, and 42).

Segment Functions

CREATE SEGMENT	81
CLOSE SEGMENT	82
RENAME SEGMENT	83
DELETE SEGMENT	84
DELETE SEGMENT FROM WORKSTATION (GKSM-OUT,...)	84
ASSOCIATE SEGMENT WITH WORKSTATION (GKSM-OUT,...)	81, (21-44), (11-16), (61), 82
COPY SEGMENT TO WORKSTATION (GKSM-OUT,...)	(21-44), (11-16), (61)
INSERT SEGMENT	(21-44), (11-16), (61)

Segment Attributes	
SET SEGMENT TRANSFORMATION	91
SET VISIBILITY	92
SET HIGHLIGHTING	93
SET SEGMENT PRIORITY	94
SET DETECTABILITY	95

Metafile Functions	
WRITE ITEM TO GKSM	> 100

E.4 Interpretation of Metafiles

E.4.1 Introduction

The interpretation of metafiles in GKS is described in 4.9 [14]. The effects of INTERPRET ITEM for all types of metafile item are described in the following sections. Items are grouped by class of functionality.

E.4.2 Control Items

Interpretation of items in this class is described under the definitions of each item in E.5. ([14] reads "E.2.4" instead of "E.5" which we believe is an error).

E.4.3 Output Primitives

Interpretation of items in this class generates output corresponding to the primitive functions, except that coordinates of points are expressed in NDC. Primitive attributes bound to primitives are those which have originated from interpretation of primitive attribute items in this particular metafile (see E.4.4).

E.4.4 Output Primative Attributes

Interpretation of items in this class sets values for use in the display of primitives subsequently originating from this particular metafile (see E.4.3). No changes are made to entries in the GKS state list.

E.4.5 Workstation Attributes

Interpretation of items in this class has the same effect as invocation of the corresponding GKS functions shown in Table E1. The GKS functions are performed on all active workstations.

E.4.6 Transformations

Interpretation of a clipping rectangle item sets values for use in clipping output primitives subsequently originating from this particular metafile. No changes are made to entries in the GKS state list. Interpretation of other items in this class (WORKSTATION WINDOW and WORKSTATION VIEWPORT) causes the invocation of the corresponding GKS functions on all active workstations.

E.4.7 Segment Manipulation

Interpretation of items in this class has the same effect as invocation of the corresponding GKS functions shown in Table E1. (Item 84 causes an invocation of DELETE SEGMENT.)

E.4.8 Segment Attributes

Interpretation of items in this class has the same effect as invocation of the corresponding GKS functions shown in Table E1.

E.5 Control Items

FILE HEADER

| GKSM | N | D | V | H | T | L | I | R | F | RI | ZERO | ONE |

All fields in the file header item have fixed length. Numbers are formated according to ISO 6093 - Format F1.

General Information:

GKSM	4 bytes	containing string 'GKSM'
N	40 bytes	containing name of author/installation
D	8 bytes	date (year/month/day, e.g., 79/12/31)
V	2 bytes	version number: the metafile described here has version number 1
H	2 bytes	integer specifying how many bytes of the string 'GKSM' are repeated at the beginning of each record. Possible values: 0, 1, 2, 3, 4

T	2 bytes	length of item type indicator field
L	2 bytes	length of item data record length indicator field
I	2 bytes	length of field for each integer in the item data record (applied to all data marked (i) in the item description)
R	2 bytes	length of field for each real in the item data record (applies to all data marked (r) in the item description).

Specification of Number Representation:

F	2 bytes	Possible values: 1, 2. This applies to all data in the items marked (i) or (r) and to item type and item data record length: 1: all numbers are formatted according to ISO 6093 2: all numbers (except in the file header) are stored in an internal binary format
RI	2 bytes	Possible values: 1, 2. This is the number representation for data marked (r): 1 = real, 2 = integer
ZERO	11 bytes	integer equivalent to 0.0, if RI = 2
ONE	11 bytes	integer equivalent to 1.0, if RI = 2

After the file header, which is in fixed format, all values in the following items are in the format defined by the file header. For the following description, the setting:

H = 4; T = 3; F = 1

is assumed. In addition to formats (c), (i) and (r), which are already described, (p) denotes a point represented by a pair of real numbers (2r). The notation allows the single letter to be preceded by an expression, indicating the number of values of that type.

{Explanatory comments have been added to some item specifications; these are not part of the GKS Appendix E and they are enclosed in braces {}. A complete definition of the generation and interpretation of the GKSM items is given by the definition of the corresponding GKS functions [14].}

END ITEM

| ’GKSM 0’ | L |

Last item of every GKS Metafile. Sets condition for the error.

CLEAR WORKSTATION

| 'GKSM 1' | L | C |

Requests CLEAR WORKSTATION on all active workstations.

C(i): clearing control flag
(0 = CONDITIONAL, 1 = ALWAYS)

REDRAW ALL SEGMENTS ON WORKSTATION

| 'GKSM 3' | L | R |

Requests UPDATE WORKSTATION on all active workstations.

R(i): regeneration flag
(0 = PERFORM, 1 = SUSPEND)

DEFERRAL STATE

| 'GKSM 4' | L | D | R |

Requests SET DEFERRAL STATE on all active workstations.

D(i): deferral mode
(0 = ASAP, 1 = BNIG, 2 = BNIL, 3 = ASTI)

R(i): implicit regeneration mode
(0 = ALLOWED, 1 = SUPPRESSED)

{This item provides control over the occurrence of the visual effect of GKS functions in order to optimize the use of workstation capabilities according to application needs.}

MESSAGE

| 'GKSM 5' | L | N | T |

Requests MESSAGE on all active workstations.
N(i): number of characters in string
T(Nc): string with N characters.

{The message is not part of a metafile output primitives; the message is only for interpretation by workstation operators.}

ESCAPE

| 'GKSM 6' | L | FI | L | M | I | R |

Requests ESCAPE

FI(i): function identifier
L(i): length of integer data in data record
M(i): length of real data in data record
I(Li): integer data
R(Mr): real data.

{This item permits the invocation of a specific non-standard escape function FI. The execution of the function with the given parameters must not alter the GKS state list nor produce geometrical output.}

E.6 Items for Output Primitives

POLYLINE

| 'GKSM 11' | L | N | P |

N(i): number of points of the polyline
P(Np): list of points

POLYMARKER

| 'GKSM 12' | L | N | P |

N(i): number of points
P(Np): list of points.

TEXT

| 'GKSM 13' | L | P | N | T |

P(p): starting point of character string
N(i): number of characters in string T
T(Nc): string with N characters from the set of ISO 646

FILL AREA

| 'GKSM 14' | L | N | P |

N(i): number of points
P(Np): list of points.

CELL ARRAY

| 'GKSM 15' | L | P | Q | R | N | M | CT |

P(p),Q(p),R(p): coordinates of corner points of pixel array (P and Q are the images of the points P and Q specified in the function CELL ARRAY and R is another corner)
M(i): number of rows in array
N(i): number of columns in array
CT(MNi): array of colour indices stored row by row

{This item permits passing raster images to GKS. The raster image is defined by the colour index matrix CT, and its World Coordinate position given by points P and Q.}

GENERALIZED DRAWING PRIMITIVE

| 'GKSM 16' | L | GI | N | P | L | M | I | R |

GI(i): GDP identifier
N(i): number of points
P(Np): list of points
L(i): length of integer data in data record
M(i): length of real data in data record
I(Li): integer data
R(Mr): real data.

{This item provides a standard way for drawing additional non-standard output primitives. The generalized drawing primitive GI is drawn according to the point list P and the data record in I and R.}

E.7 Items for Output Primitive Attributes

POLYLINE INDEX

| 'GKSM 21' | L | LT |

LT(i): linetype

LINEWIDTH SCALE FACTOR

| 'GKSM 23' | L | LW |

LW(r): linewidth scale factor

{In GKS, the line width is not affected by GKS transformations. However, the effective line width is calculated as the product of the nominal line width times the line width scale factor in effect when a line is drawn.}

POLYLINE COLOUR INDEX

| 'GKSM 24' | L | CI |

CI(i): polyline colour index

POLYMARKER INDEX

| 'GKSM 25' | L | I |

I(i): polymarker index

MARKER TYPE

| 'GKSM 26' | L | MT |

MT(i): marker type

MARKER SIZE SCALE FACTOR

| 'GKSM 27' | L | MS |

MS(r): marker size scale factor

{In GKS, the marker size is not affected by GKS transformations. However, the effective marker size is calculated as the product of the nominal marker size times the marker size scale factor in effect when a marker is drawn.}

POLYMARKER COLOUR INDEX

| 'GKSM 28' | L | CI |

CI(i): polymarker colour index

TEXT INDEX

| 'GKSM 29' | L | I |

I(i): text index

TEXT FONT AND PRECISION

| 'GKSM 30' | L | F | P |

F(i): text font
P(i): text precision
(0 = STRING, 1 = CHAR, 2 = STROKE)

CHARACTER EXPANSION FACTOR

| 'GKSM 31' | L | CEF |

CEF(r): character expansion factor

{This item allows the manipulation of the width/height of the character body. The width of the character body is scaled by the CEF factor.}

CHARACTER SPACING

| 'GKSM 32' | L | CS |

CS(r): character spacing

TEXT COLOUR INDEX

| 'GKSM 33' | L | CI |

CI(i): text colour index

CHARACTER VECTORS

| 'GKSM 34' | L | CH | CW |

CH(2r): character height vector
CW(2r): character width vector

Note: These vectors are the height and width vectors described in 4.4.5 of [14].

{The character height vector is parallel to the character up vector and has a length equal to character height. The character height specifies the height of a capital letter. The character width vector is perpendicular to the height vector, in the direction of the character baseline, and has the same length.}

TEXT PATH

| 'GKSM 35' | L | P |

P(i): text path
(0 = LEFT, 1 = RIGHT, 2 = UP, 3 = DOWN)

TEXT ALIGNMENT

| 'GKSM 36' | L | H | V |

H(i): horizontal character alignment
(0 = NORMAL, 1 = LEFT, 2 = CENTRE, 3 = RIGHT)
V(i): vertical character alignment
(0 = NORMAL, 1 = TOP, 2 = CAP, 3 = HALF, 4 = BASE,
5 = BOTTOM)

FILL AREA INDEX

| 'GKSM 37' | L | I |

I(i): fill area index

FILL AREA INTERIOR STYLE

| 'GKSM 38' | L | S |

S(i): fill area interior style
(0 = HOLLOW, 1 = SOLID, 2 = PATTERN, 3 = HATCH)

FILL AREA STYLE INDEX

| 'GKSM 39' | L | SI |

SI(i): fill area style index

FILL AREA COLOUR INDEX

| 'GKSM 40' | L | CI |

CI(i): fill area colour index

PATTERN SIZE

| 'GKSM 41' | L | PW | PH |

PW(2r): pattern width vector
PH(2r): pattern height vector

{One style for filling areas is with a pattern of color cells. Such a pattern is defined by an array of color indices which is mapped into a pattern rectangle with dimensions given by PW and PH.}

PATTERN REFERENCE POINT

| 'GKSM 42' | L | P |

P(p): reference point

{One style for filling areas is with a pattern of color cells. Such a pattern is defined by an array of color indices which is mapped into a pattern rectangle whose lower left corner is given by P.}

ASPECT SOURCE FLAGS

| 'GKSM 43' | L | F |

F(13i): aspect source flags
(0 = BUNDLED, 1 = INDIVIDUAL)

{An application can set an output primitive attribute to either bundled or individual. Bundled attributes are workstation-dependent, their binding is delayed, and their values can change dynamically. Individual attributes are global attributes, they are bound immediately, and their value is static and cannot be manipulated.}

PICK IDENTIFIER

| 'GKSM 44' | L | P |

P(i): pick identifier

E.8 Items for Workstation Attributes

POLYLINE REPRESENTATION

| 'GKSM 51' | L | I | LT | LW | CI |

I(i): polyline index
LT(i): linetype number
LW(r): linewidth scale factor
CI(i): polyline colour index

POLYMARKER REPRESENTATION

| 'GKSM 52' | L | I | MT | MS | CI |

I(i): polymarker index
MT(i): marker type
MS(r): marker size scale factor
CI(i): polymarker colour index

TEXT REPRESENTATION

| 'GKSM 53' | L | I | F | P | CEF | CS | CI |

I(i): text index
F(i): text font
P(i): text precision
(0 = STRING, 1 = CHAR, 2 = STROKE)
CEF(r): character expansion factor
CS(r): character spacing
CI(i): text colour index

FILL AREA REPRESENTATION

| 'GKSM 54' | L | I | S | SI | CI |

I(i): fill area index
S(i): fill area interior style
(0 = HOLLOW, 1 = SOLID, 2 = PATTERN, 3 = HATCH) SI(i): fill area style index
CI(i): fill area colour index

PATTERN REPRESENTATION

| 'GKSM 55' | L | I | N | M | CT |

I(i): pattern index
N(i): number of columns in array*
M(i): number of rows in array
CT(MNi): table of colour indices stores row by row

{* The ANSI document reads "area" instead of "array".}

{One style for filling areas is with a pattern of color cells. Such a pattern is defined by a pattern representation.}

COLOUR REPRESENTATION

| 'GKSM 56' | L | CI | RGB |

CI(i): colour index
RGB(3r): red, green, blue intensities

E.9 Items for Transformations

CLIPPING RECTANGLE

| 'GKSM 61' | L | C |

C(4r): limits of clipping rectangle (XMIN, XMAX, YMIN, YMAX)

WORKSTATION WINDOW

| 'GKSM 71' | L | W |

W(4r): limits of workstation window (XMIN, XMAX, YMIN, YMAX)

{GKS includes a workstation transformation that maps a rectangle of the NDC space (a workstation window) into a rectangle of the device coordinate space (a workstation viewport).}

WORKSTATION VIEWPORT

| 'GKSM 72' | L | V |

V(4r): limits of workstation viewport (XMIN, XMAX, YMIN, YMAX)

E.10 Items for Segment Manipulation

CREATE SEGMENT

| 'GKSM 81' | L | S |

S(i): segment name

CLOSE SEGMENT

| 'GKSM 82' | L |

indicates end of segment

RENAME SEGMENT

| 'GKSM 83' | L | SO | SN |

SO(i): old segment name
SN(i): new segment name

DELETE SEGMENT

| 'GKSM 84' | L | S |

S(i): segment name

E.11 Items for Segment Attributes

SET SEGMENT TRANSFORMATION

| 'GKSM 91' | L | S | M |

S(i): segment name
M(6r): transformation matrix
upper and center rows of a 3x3 matrix representing
a 2D homogeneous transformation [9]
M 11 M 12 M 13 M 21 M 22 M 23

{This differs from the ANSI X3.124 Jan. 5 1984 document, in the matrix elements indicated. We believe there is an error in such document.}

SET VISIBILITY

| 'GKSM 92' | L | S | V |

S(i): segment name
V(i): visibility
(0 = VISIBLE, 1 = INVISIBLE)

SET HIGHLIGHTING

| 'GKSM 93' | L | S | H |

S(i): segment name
H(i): highlighting
(0 = NORMAL, 1 = HIGHLIGHTED)

SET SEGMENT PRIORITY

| 'GKSM 94' | L | S | P |

S(i): segment name
P(r): segment priority

SET DETECTABILITY

| 'GKSM 95' | L | S | D |

S(i): segment name
D(i): detectability
(0 = UNDETECTABLE, 1 = DETECTABLE)

E.12 User Items

USER ITEM

| 'GKSMXXX' | L | D |

XXX > 100
D: user data (L bytes)

{The PIGCF level U items are encoded as GKSM USER ITEM elements so that a PIGCF file will conform to the GKSM metafile specification.}

APPENDIX B

Example of PIGCF Use in Conferencing

This section presents an example illustrating the proposed PIGCF graphical component in an audio-graphics conference exchange. We present only the graphical part of the conference exchange, which actually would be complemented with speech. For the sake of briefness the example does not contain all the parameter negotiation that a conference set-up would require.

The example is about an on-line audio-graphics conference between a Navy command and control center and a Navy task force. The PIGCF items shown do not belong to a single transmission stream. The stream they belong to is determined by the station that transmits them, and the identification of the transmitter belongs to lower level communication protocols. We use the character encoding, rather than the binary one, for this PIGCF example. We illustrate just a few of the possible groups of items that could be batched in this example. The plot of the example is as follows.

The command center (center) establishes a conference with some ships in a task force (platforms) to coordinate the interception of an unidentified ship that has been sighted in a conflict area. After recalling graphical libraries, all conference sites can see in their screens a map of the sighting area as well as iconic representations of the task force ships. Then the center interactively draws an iconic representation of the unidentified vessel, scales it, and places it in the sighting location.

The platforms explain possible courses of action using graphical pointers. The center draws the expected trajectory of the unidentified ship and the platforms situate the task force icons at the expected points of interception. Then the center zooms into the interception area and the platforms use rubber bands to discuss interception maneuvers.

Now we proceed to list the PIGCF items exchanged. The center initiates the conference graphical set-up with the FILE HEADER item to set basic representation parameters for the graphical information to be exchanged. This item can be interpreted according to its definition in E.5 [14]. The most important parameter selections for this example are:

i) The items contain 0 characters of the "GKSM" string in the identification field of the item header.
ii) The item type indicator field containing the PIGCF

item number is three bytes long in each item.
iii) The integers are 4 bytes long, and the reals 6 bytes long.
iv) The item data record length indicator is 2 bytes long.

We will obey the PIGCF specification field lengths and the aforesaid field length settings. However, we will add one space before and after the "|" separator to improve legibility. Also, every item will be preceded with its name to help identification.

FILE HEADER:

| GKSM | center | 84/11/10 | 1 | 0 | 3 | 2 | 4 | 6 | 1 | 1
| | |

The center states the boundaries of the work station window for the conference.

WORKSTATION WINDOW: | 71 | 24 | 0.0 0.5 0.0 0.375 |

In this example, we assume that the conferencing work stations use world coordinates for the internal representation of positional information. Accordingly, the center states the boundaries of the world window for the normalization transformation used in the conference.

SET WINDOW: | 134 | 28 | 0.0 320.0 0.0 240.0 |

The center informs the location of its local NDC viewport, however, other conferees can choose different NDC viewports for the same transformation, but their work station window should include the conference's. All systems record the conference: world window, NDC viewport, and work station widow.

SET VIEWPORT: | 135 | 28 | 0.0 0.5 0.0 0.375 |

The center recalls graphical libraries containing geographical maps of the crisis area and icons of the task forces in the area. It also displays a graphical object that provides a background picture.

RECALL LIBRARY: | 139 | 9 | caribbean |
DISPLAY OBJECT: | 128 | 11 | coast_lines |
RECALL LIBRARY: | 139 | 10 | task_units |

The center proceeds to instantiate one of the task forces in the task_units library. This is done by recalling some of the library objects and applying transformations to the objects, later. Since set window, set viewport, and recall library belong to the update

Group-2, they can be batched until display object, from update Group-1, is entered. The second recall library can be batched together with the following begin instantiation until display object is produced. The rest of the example contains more cases of item sequences which can be batched; however, for briefness we do not indicate any more of them.

```
BEGIN INSTANTIATION:  | 124 | 15 | US_CONSTITUTION |
DISPLAY OBJECT:       | 128 | 15 | US_CONSTITUTION |
TRANSFORM OBJECT:     | 126 | 55 |   15 | US_CONSTITUTION |
                        0.1   0.0   0.0   0.0   0.1   0.0 |
TRANSFORM OBJECT:     | 126 | 55 |   15 | US_CONSTITUTION |
                        0.1   0.0  0.312   0.0   0.1  0.078 |
END INSTANTIATION:    | 125 |  0 |

BEGIN INSTANTIATION:  | 124 | 13 | US_NEW_JERSEY |
DISPLAY OBJECT:       | 128 | 13 | US_NEW_JERSEY |
TRANSFORM OBJECT:     | 126 | 53 |   13 | US_NEW_JERSEY |
                        0.1   0.0  0.0   0.0   0.1   0.0 |
TRANSFORM OBJECT:     | 126 | 53 |   13 | US_NEW_JERSEY |
                        0.1   0.0  0.312   0.0   0.1  0.093 |
END INSTANTIATION:    | 125 |  0 |
```

Next the center sets values for two output primitive attributes in preparation for drawing a new icon on the screens. We assume that all the other attributes have been assigned default values as a result of the conference set-up.

```
POLYLINE INDEX:         |  21 |  4 |   20 |
POLYLINE COLOUR INDEX:  |  24 |  4 |  200 |
```

The following items correspond to the interactive definition of the unidentified vessel. Since the definition is done interactively, the vessel image remains visible on the screens after definition.

```
BEGIN DEFINITION:  | 120 |  0 |
POLYLINE:          |  11 | 64 |    5 |
0.047  0.063  0.063  0.047  0.125  0.047  0.14  0.063  0.047  0.047 |
POLYLINE:          |  11 | 52 |    3 |
              0.078 0.063  0.078  0.078  0.109  0.078  0.109  0.063 |
END DEFINITION:    | 121 |  8 | sighting |
```

Then the unidentified vessel "sighting" is scaled and placed at the sighting site.

```
BEGIN INSTANTIATION:  | 124 |  8 | sighting |
TRANSFORM OBJECT:     | 126 | 48 |    8 | sighting |
                        0.2   0.0   0.0
                        0.0   0.2   0.0 |
TRANSFORM OBJECT:     | 126 | 48 |    8 | sighting |
                        0.1   0.0 0.156
                        0.0   0.1  0.016 |
END INSTANTIATION:    | 125 |  0 |
```

The center and the platforms use graphical pointer movements to discuss possible routes the unidentified vessel might follow. We only show a few pointer updates. In practice, there would typically be a large number of points transmitted to convey the movement of the pointers over the screens.

from the center:

```
POINTER TRACKING:  | 137 | 16 |    0 |  0.39  0.032 |
POINTER TRACKING:  | 137 | 16 |    0 |  0.388 0.035 |
POINTER TRACKING:  | 137 | 16 |    0 |  0.388 0.039 |
POINTER TRACKING:  | 137 | 16 |    0 |  0.386 0.04  |
```

from one of the platforms:

```
POINTER TRACKING:  | 137 | 16 |    0 |  0.22  0.016 |
POINTER TRACKING:  | 137 | 16 |    0 |  0.222 0.159 |
POINTER TRACKING:  | 137 | 16 |    0 |  0.233 0.157 |
POINTER TRACKING:  | 137 | 16 |    0 |  0.24  0.155 |
```

The center now draws the expected route to be followed by the unidentified ship. This time the pointer trace is recorded on the screen by drawing a line.

```
POINTER TRACKING:  | 137 | 16 |    1 |  0.388 0.038 |
POINTER TRACKING:  | 137 | 16 |    1 |  0.386 0.038 |
POINTER TRACKING:  | 137 | 16 |    1 |  0.386 0.052 |
POINTER TRACKING:  | 137 | 16 |    1 |  0.375 0.078 |
POINTER TRACKING:  | 137 | 16 |    1 |  0.369 0.105 |
POINTER TRACKING:  | 137 | 16 |    1 |  0.361 0.125 |
POINTER TRACKING:  | 137 | 16 |    1 |  0.352 0.144 |
POINTER TRACKING:  | 137 | 16 |    1 |  0.351 0.156 |
POINTER TRACKING:  | 137 | 16 |    1 |  0.35  0.16  |
```

A platform moves the two US ship icons to interception positions.

```
TRANSFORM OBJECT:  | 126 | 55 |   15 | US_CONSTITUTION |
                     1.0   0.0 0.16
                     0.0   1.0 -0.046 |
TRANSFORM OBJECT:  | 126 | 53 |   13 | US_NEW_JERSEY |
                     1.0   0.0 0.113
                     0.0   1.0 -0.034 |
```

The center zooms into the interception area in order to obtain a larger view for further discussion.

```
WORKSTATION WINDOW:  |  71 | 24 | 0.286 0.403 0.077 0.177 |
```

The two platforms indicate their striking ranges using circular rubber bands centered at each ship. For each platform, we show first the echo reference point and then two echo feedback points. Typically there will be a large number of feedback points.

```
RUBBER BAND:  | 138 | 10 |   0 | 0.335 0.125 |
RUBBER BAND:  | 138 | 10 |   3 | 0.35  0.128 |
RUBBER BAND:  | 138 | 10 |   3 | 0.37  0.128 |

RUBBER BAND:  | 138 | 10 |   0 | 0.384 0.13  |
RUBBER BAND:  | 138 | 10 |   3 | 0.367 0.128 |
RUBBER BAND:  | 138 | 10 |   3 | 0.346 0.129 |
```

Once the interception strategy has been agreed upon, the center zooms out to the original, larger picture.

```
WORKSTATION WINDOW:  |  71 | 24 |    0.0   0.5   0.0 0.375 |
```

The center terminates the conference

```
END ITEM:  |   0 |  0 |
```

At the end of a conference, the final pictures remain visible on the screens. In addition, the PIGCF items will be recorded in its entirety in order to play back the conference session if necessary. The conference record could also be sent to other locations as part of a multi-media message.

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