ANARI™ 1.1.0 – Provisional Specification

The Khronos® ANARI Working Group

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Chapter 1. Introduction

The fundamental problem being solved by the ANARI standard is to provide application developers with a high-level rendering API that can be used to render images of visualizations containing 3D surface geometry and volumetric data. The API will support rendering techniques such as rasterization and high-fidelity path tracing, and will do so at low application development-time cost.

Although many renderers and APIs already exist, and some of them successfully address the primary requirement above, in practice they are vendor-, hardware platform-, or rendering algorithm-specific, or they provide high-performance building blocks for rendering, but not a complete renderer implementation with a high-level API. ANARI aims to address the limitations of these existing APIs. ANARI fully abstracts vendor-, hardware platform-, and rendering algorithm-specific details behind the API. By doing so, a multiplicity of rendering back-end implementations can be used to their full capability, without the need for renderer-specific code in applications that use ANARI.

Since ANARI provides a high-level API abstraction, significant freedom is provided to back-end renderer implementations. This freedom enables implementations to use any practical rendering algorithm for image generation, although a key focus and interest for ANARI is support for high-fidelity physically based rendering methods.

ANARI applications do not specify the details of the rendering process. Using the ANARI API, applications specify object surface or volume data to be rendered, and any associated parameters that might affect appearance, such as their material properties, texturing, and color transfer functions, as appropriate. ANARI applications retain full responsibility for managing non-rendering attributes of geometry through their own means. ANARI provides rendering-focused functionality only, so higher level scene graphs and other more general functionality must be obtained through other APIs or applications which use ANARI.

Domains which leverage 3D graphics have diverse rendering needs involving trade-offs among quality, speed, and scalability to available hardware resources. It is typical for 3D applications to use both visual and quantitative rendering techniques to satisfy user demands. Furthermore, it is common for an application to need rendering from local CPU or GPU hardware, with parallel scaling through multiple machines in a cluster to exploit additional distributed compute and memory resources. The ANARI API provides the necessary abstractions to allow these needs to be met by back-end renderers, without excessive exposure of hardware or rendering algorithm details to the application. ANARI seeks to standardize extensions for rendering domains including, but not limited to, scientific visualization, professional visualization, visual effects, and engineering CAD.

Multiple ANARI back-ends may be exposed through the API at runtime. The ANARI API provides the application with the means to enumerate available back-ends, methods for querying high-level capabilities of the available back-ends, and the ability to instantiate a back-end and at least one associated renderer, which can then be used to render images.

1.1. Document Conventions

The ANARI specification is intended for use by both implementors of the API and application developers seeking to make use of the API, forming a contract between these parties. Specification text may address either party; typically the intended audience can be inferred from context, though some sections are defined to address only one of these parties. Any requirements, prohibitions, recommendations or options defined by normative terminology are imposed only on the audience of that text.

1.1.1. Informative Language

Some language in the specification is purely informative, intended to give background or suggestions to implementors or developers.

If an entire chapter or section contains only informative language, its title will be suffixed with "(Informative)".

All NOTEs are implicitly informative.

1.1.2. Normative Terminology

Within this specification, the key words **must**, **required**, **should**, **recommended**, **may**, and **optional** are to be interpreted as described in RFC 2119 - Key words for use in RFCs to Indicate Requirement Levels (https://www.ietf.org/rfc/rfc2119.txt). These key words are highlighted in the specification for clarity. In text addressing application developers, their use expresses requirements that apply to application behavior. In text addressing implementors, their use expresses requirements that apply to implementations.

In text addressing application developers, the additional key words **can** and **cannot** are to be interpreted as describing the capabilities of an application, as follows:

can

This word means that the application is able to perform the action described.

cannot

This word means that the API and/or the execution environment provide no mechanism through which the application can express or accomplish the action described.

These key words are never used in text addressing implementors.

Note

There is an important distinction between **cannot** and **must not**, as used in this Specification. **Cannot** means something the application literally is unable to express or accomplish through the API, while **must not** means something that the application is capable of expressing through the API, but that the consequences of doing so are undefined and potentially unrecoverable for the implementation (see Error Handling).

Unless otherwise noted in the section heading, all sections and appendices in this document are normative.

1.1.3. Technical Terminology

The ANARI Specification makes use of common engineering and graphics terms such as **Device**, **Sampler**, and **Frame** to identify and describe ANARI API constructs and their attributes, states, and behaviors. The Specification text provides definitions of the terms. When a term is used in normative language within the Specification, the definitions within the Specification govern and supersede any meanings the terms may have in other technical contexts (i.e., outside the Specification).

1.1.4. Prefixes

Prefixes are used in the API to denote specific semantic meaning of ANARI names, or as a label to avoid name clashes, and are explained here:

ANARI/anari

The ANARI namespace
All types, commands, enumerants and defines in this specification are prefixed with these strings.

The `ANARI_` prefix of named data types and extensions is omitted in tables and itemizations for readability and brevity.

1.1.5. Normative References

References to external documents are considered normative references if the Specification uses any of the normative terms defined in Normative Terminology to refer to them or their requirements, either as a whole or in part.

The following documents are referenced by normative sections of the specification:

IEEE. August, 2008. *IEEE Standard for Floating-Point Arithmetic*. IEEE Std 754-2008. https://dx.doi.org/10.1109/IEEESTD.2008.4610935.

The Khronos® Vulkan Working Group. January, 2020. *Vulkan® 1.2 – A Specification*, Section 16.8. Image Sample Operations, https://registry.khronos.org/vulkan/.

The Khronos® 3D Formats Working Group. *glTF™ 2.0 Specification*, Appendix B: BRDF Implementation https://registry.khronos.org/glTF/.

Chapter 2. API Design Choices

Here we outline several fundamental ANARI API design choices that address key goals of broad application and programming language support, and ease of application development, integration, testing, and distribution.

2.1. C99

The ANARI API is specified as a C99 API in order to provide compiler-independent linkage, thereby supporting easy integration into a broad range of applications based on a variety of compiled languages, including C, C++, Fortran, and dynamic languages such as Python and Julia, among others. C99 provides improved IEEE-754 floating point rounding behavior, integer types in common with C++, and other refinements relative to ANSI C.

2.2. Common Front-end Library

ANARI is specified as a common API header and front-end library (using either static or dynamic linkage) capable of loading available ANARI back-end device implementations at runtime, known as *devices*. ANARI back-end devices are created by standard implementors and are expected to be distributed, installed, or upgraded independently of the standard API header and front-end library.

2.3. Opaque Objects, Parametrization, and Properties

The ANARI API is designed to encapsulate scene data and rendering operations as opaque object handles using string-value pairs to parameterize them. This facilitates a dominantly unidirectional flow of scene information from the application to the instantiated ANARI device. As a result, the vast majority of ANARI API calls have a write-only behavior pattern to minimize imposed implementation requirements.

An application can create ANARI objects and set named inputs on them called *parameters*. However, no mechanism is provided to subsequently query parameter data, since even the existence of a query mechanism would impose additional performance and storage restrictions for back-end renderer implementations (e.g. distributed rendering contexts). Object introspection can be used to query object subtypes and information about their parameters.

Additionally, ANARI objects can publish named outputs called *properties*. Such output is specific to the type and semantics of the object, but has a generic interface function for access.

2.4. Extensions

The ANARI specification defines a set of usable extensions exposed via the C API. Extensions are loosely defined as observable behavior from a particular use of the ANARI API. This most commonly is the existence of usable object subtypes, but also can be pre/post conditions on a function call, specific behavior of an object parameter, or guaranteed availability of a property.

Applications can query extensions made available by a device implementation through queries either on the library or the live device instance. Querying available extensions via the library represents the list of extensions implemented by the vendor at all, while querying extensions on a live device instance will also factor in the runtime environment (i.e. available underlying hardware to the device). In either case, extension queries are intended to be the way an application determines if the device is acceptable in meeting the application's requirements, or if the application wants to adapt itself to what extensions are available.

Vendor extensions are extensions that have not yet made it into the ANARI specification. These extensions are reported in the same list as core extensions, but have vendor specific names, which may exist in more than one device from that vendor. This is a good way for vendors to agree upon and get experience with a extension prior to bring it officially into the specification.

All extensions represent functionality which provides additional capabilities to the application. A reported extension should never represent a reduction in capability.

Testable extension names are inlined in the specification alongside their definition. All extensions follow the prefix convention of `ANARI_[VENDOR]_[NAME]`, where ratified extensions use `KHR` as the vendor string.

Implemented extensions may be queried via introspection functions. Currently available extensions for instantiated devices and renderers may be queried via the `extension` property.

A full list of ANARI extensions can be found in the Extension Index (Informative) appendix.

2.5. Data-Parallel Distributed Rendering

ANARI is designed to be compatible with applications which are distributed across multiple processes which may reside on multiple machines. The following extensions specify the semantics and required networking to enable rendering in distributed applications.

> *Note*
>
> Distributed rendering define semantics and rules for ANARI usage within distributed *applications*. Some devices *may* use distributed rendering resources behind the API of single-process applications, which is already covered by normal ANARI API usage and does not require additional specification.

2.5.1. MPI

Extension `KHR_DATA_PARALLEL_MPI`

Distributed applications using MPI can leverage ANARI implementations which also use MPI to enable data-parallel rendering. The overall API usage requirements are as follows:

- Applications collectively create the device, frame, and world in lockstep.
- Each rank creates and modifies the local contents of the World it has using the ANARI API normally.
- All ranks collectively render by calling `anariRenderFrame` in lockstep.

Given an MPI distributed application using ANARI, all ANARI concepts apply along with the following additional rules:

- Applications must create Frame and World objects in the same order. Construction order determines how they are collectively identified among all ranks.
- Participating Frame, Renderer, and Camera parameters must match on all ranks. Using different parameters for these objects on different ranks will result in undefined behavior.
- Mapping frame channels is only well-defined on rank 0 of the used MPI communicator (see parameter table below). While it is not an error to map any channel on any other rank, its contents (size, pixel type, and returned data pointer) are undefined.
- Properties queried with `anariGetProperty` are globally synchronizing (collective) operations for Frame and World objects when queried with the `ANARI_WAIT` flag.
- Calling `anariRelease` on the final application held reference of the Device is a globally synchronized (collective) operation.

This extension introduces the following additional parameters:

Table 1. Parameters added to MPI distributed Frame objects.

Name	Type	Default	Description
mpiCommunicator	`VOID_POINTER`	`MPI_COMM_WORLD`	the MPI communicator which the device should treat as the MPI world

> *Note*
>
> A more complete description of the problem, ANARI-based solution, and example implementation results can be found in the freely available paper:
>
> Wald et al.. July, 2024. *Standardized Data-Parallel Rendering using ANARI* https://arxiv.org/abs/2407.00179.

Chapter 3. Common API Concepts

This section describes concepts common to all object types for creation, parametrization, and property queries.

3.1. Thread Safety, Asynchronous Operations

The ANARI API may be called from any thread but calls that share objects must be synchronized and may not overlap. By default, this includes the device. Therefore, calls to the same device must be externally synchronized.

Expensive operations can be implemented asynchronously, which avoids blocking the calling application. Each asynchronous operation is specified as to what API calls are legal to make while the operation has not yet completed.

> *Note*
>
> Making some operations asynchronous complements the thread safety of ANARI, and typically is used for a different purpose. Where a multithreaded application may be trying to work on constructing a scene (which could be many smaller ANARI API calls) while another scene is being rendered in parallel, asynchronous rendering focuses on removing the need for long running operations to cause an application to use multithreading just to avoid blocking on ANARI.

Devices that implement extension `KHR_DEVICE_SYNCHRONIZATION` relax synchronization requirements by excluding the device from the external synchronization requirement if the device is passed as the first argument only. Calls that are operating on the device as the object must still be synchronized with all other calls involving the same device. Likewise `anariRenderFrame` must be synchronized with all other ANARI calls as well. This only applies to the `anariRenderFrame` call itself, not the asynchronous render operations which remain subject to asynchronous rendering restrictions.

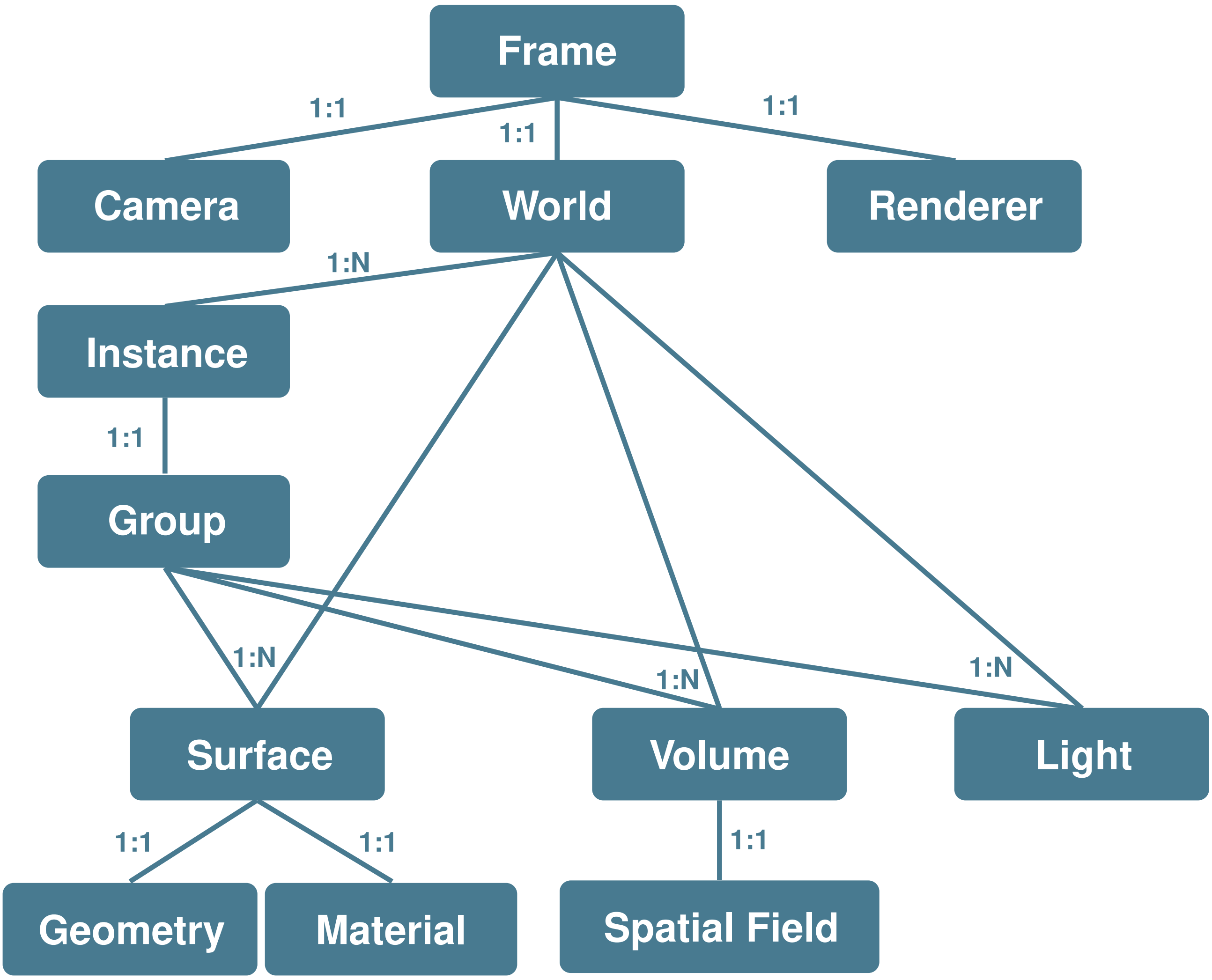
This lowers the scope of required synchronization to individual ANARI objects allowing different threads to operate concurrently on different objects within the same device.

3.2. Scene Hierarchy (Informative)

ANARI scenes are represented as hierarchies of objects. This section describes their relationship to each other.

The Frame is the root object of the scene. It holds the framebuffer configuration and the World, Camera, and Renderer objects. The Camera configures the projection of the rendering used to view the World. The Renderer holds parameters relating to the rendering algorithm. The World holds arrays of the drawable objects of the scene such as Surface, Volume, and Light either directly or via an array of Instance containing Group. A Group holds arrays of Surface, Volume, and Light to be instanced together. An Instance combines a Group with a transform for placement of the same collection of objects at multiple locations within the same World. A Surface represents drawable surfaces containing a Geometry and a Material. A Geometry specifies drawable primitives and data associated with them. A Material specifies the surface's appearance related to the data from the Geometry. A Volume represents volumetric drawable objects and may contain Spatial Field objects. A Spatial Field represents a field of values in 3D space. A Light represents sources of illumination.

The following diagram illustrates the relationships described above:



3.3. Object Definition

All objects are characterized by the following items

- Objects are represented as an opaque handle
- Objects must be able to accept parameters
- Objects must be able to post properties
- An object application reference count must only be modifiable by `anariRelease` and `anariRetain`

3.4. Object Handle Representation

Objects and devices in ANARI are represented by opaque 64-bit handles. The `NULL` handle never represents a valid object. Handles are only valid for the device from which they were created, and using handles with other devices leads to undefined behavior.

3.5. Object Creation and Lifetime

Objects are created by calling an `anariNew*` factory function (for example `anariNewGeometry`). Each object type has its own corresponding factory function. All objects, including devices, are only valid in the process in which they are created.

Object lifetime is managed by opaque reference counting. Objects have a public and internal reference count. Objects are created with a public reference count of 1, which can be increased with `anariRetain` and decreased with `anariRelease`. Once the public reference count has been decreased to 0, the object becomes inaccessible to host code, where using its handle in subsequent API calls is invalid and results in undefined behavior.

The signatures to `anariRelease` and `anariRetain` are as follows

```
void anariRelease(ANARIDevice, ANARIObject);

void anariRetain(ANARIDevice, ANARIObject);
```

Calling `anariRelease` with a `NULL` object-handle for the second argument is not an error. The internal reference count is managed by the API and will keep objects alive for as long as the implementation needs them. Therefore, user code may release objects as soon as it no longer requires access to them.

3.6. Parameters, Types, and Commits

Objects are configured by parameters, which are identified by a string name and are set using `anariSetParameter`. Multiple types can be valid for a parameter, but only one type can be set for a particular parameter name at any given time. Setting a parameter with a different type overwrites its previous value and type. Attempting to set a parameter that is unknown to the implementation has no effect on object state, but may cause an ANARI device implementation to emit warnings. The same applies if an unsupported type for a parameter is used.

The signatures to `anariSetParameter` is as follows

```
void anariSetParameter(
  ANARIDevice,
  ANARIObject,
  const char *parameterName,
  ANARIDataType,
  const void *value
);
```

The `ANARI_STRING` valued parameter named `name` on all object types is reserved across all implementations and can optionally be used by applications to inject human readable identifiers into the command stream. This can be useful for debugging purposes, for example.

Implementations are allowed to ignore this parameter and must not emit warnings when it is present.

Changes to parameter values must only take effect once `anariCommitParameters` has been called on the object:

```
void anariCommitParameters(ANARIDevice, ANARIObject);
```

Uncommitted parameters must have no effect on the behavior of the object during rendering operations.

Data types passed to and returned from ANARI are specified using the `ANARIDataType` enum. The enum values identify ANARI object data types and C data types. Types starting with `ANARI` are provided by the ANARI headers. All other types refer to C99 types. See Table 1 below for a complete list.

Values set on objects are passed as a `void *` in `anariSetParameter`, which points to the value to be read. The type is encoded by the passed in `ANARIDataType` enum. For example, this means that, given `ANARI_INT`, the implementation casts the input `void * value` to `int *` and dereferences it accordingly. There are, however, two exceptions: `ANARI_STRING` and `ANARI_VOID_POINTER` (`const char *` and `void *` respectively) are object pointer based types, so they are instead passed by value.

Object parameters can be unset using `anariUnsetParameter`, which returns the named parameter back to a state as if it had not been set. Just like with setting parameters, changes made by `anariUnsetParameter` must only be applied when the object is committed.

The signature to `anariUnsetParameter` is as follows

```
void anariUnsetParameter(
  ANARIDevice,
  ANARIObject,
  const char *parameterName
);
```

Similarly, all parameters on an object can be simultaneously unset using `anariUnsetAllParameters`, which returns the object back to a state as if no parameters had been set at all. Just like with unsetting individual parameters, changes made by `anariUnsetAllParameters` must only be applied when the object is committed.

The signature to `anariUnsetAllParameters` is as follows

```
void anariUnsetParameter(ANARIDevice, ANARIObject);
```

Table 2. Data types.

Name	Closest C99-Type	Description
`DATA_TYPE`	`ANARIDataType` = `int32_t`	describes data types in ANARI

Name	Closest C99-Type	Description
STRING	const char *	0-terminated string
DATA_TYPE_LIST	ANARIDataType*	array of ANARIDataType values terminated by UNKNOWN
STRING_LIST	const char **	array of 0-terminated strings terminated by NULL
PARAMETER_LIST	ANARIParameter*	array of ANARIParameter structs terminated by {NULL, UNKNOWN}
VOID_POINTER	void *	void pointer
BOOL	uint8_t	boolean represented as uint8_t
FUNCTION_POINTER	void(*)(void)	generic function pointer
DELETER_CALLBACK	ANARIDeleterCallback	deleter callback function pointer
STATUS_CALLBACK	ANARIStatusCallback	status callback function pointer
FRAME_COMPLETION_CALLBACK	ANARIFrameCompletionCallback	extension KHR_FRAME_COMPLETION_CALLBACK, frame completion callback function pointer
LIBRARY	ANARILibrary	library object handle
DEVICE	ANARIDevice	device object handle
OBJECT	ANARIObject	generic object handle
ARRAY	ANARIArray	generic array object handle
ARRAY1D	ANARIArray1D	1D array object handle
ARRAY2D	ANARIArray2D	2D array object handle
ARRAY3D	ANARIArray3D	3D array object handle
CAMERA	ANARICamera	camera object handle
FRAME	ANARIFrame	frame object handle
GEOMETRY	ANARIGeometry	geometry object handle
GROUP	ANARIGroup	group object handle
INSTANCE	ANARIInstance	instance object handle
LIGHT	ANARILight	light object handle
MATERIAL	ANARIMaterial	material object handle
RENDERER	ANARIRenderer	renderer object handle
SURFACE	ANARISurface	surface object handle
SAMPLER	ANARISampler	sampler object handle
SPATIAL_FIELD	ANARISpatialField	spatial field object handle
VOLUME	ANARIVolume	volume object handle
WORLD	ANARIWorld	world object handle

Name	Closest C99-Type	Description
INT8	int8_t	8 bit signed integer
INT8_VEC2	int8_t[2]	two element 8 bit signed integer vector
INT8_VEC3	int8_t[3]	three element 8 bit signed integer vector
INT8_VEC4	int8_t[4]	four element 8 bit signed integer vector
UINT8	uint8_t	8 bit unsigned integer
UINT8_VEC2	uint8_t[2]	two element 8 bit unsigned integer vector
UINT8_VEC3	uint8_t[3]	three element 8 bit unsigned integer vector
UINT8_VEC4	uint8_t[4]	four element 8 bit unsigned integer vector
INT16	int16_t	16 bit signed integer
INT16_VEC2	int16_t[2]	two element 16 bit signed integer vector
INT16_VEC3	int16_t[3]	three element 16 bit signed integer vector
INT16_VEC4	int16_t[4]	four element 16 bit signed integer vector
UINT16	uint16_t	16 bit unsigned integer
UINT16_VEC2	uint16_t[2]	two element 16 bit unsigned integer vector
UINT16_VEC3	uint16_t[3]	three element 16 bit unsigned integer vector
UINT16_VEC4	uint16_t[4]	four element 16 bit unsigned integer vector
INT32	int32_t	32 bit signed integer
INT32_VEC2	int32_t[2]	two element 32 bit signed integer vector
INT32_VEC3	int32_t[3]	three element 32 bit signed integer vector
INT32_VEC4	int32_t[4]	four element 32 bit signed integer vector
UINT32	uint32_t	32 bit unsigned integer
UINT32_VEC2	uint32_t[2]	two element 32 bit unsigned integer vector
UINT32_VEC3	uint32_t[3]	three element 32 bit unsigned integer vector

Name	Closest C99-Type	Description
UINT32_VEC4	uint32_t[4]	four element 32 bit unsigned integer vector
INT64	int64_t	64 bit signed integer
INT64_VEC2	int64_t[2]	two element 64 bit signed integer vector
INT64_VEC3	int64_t[3]	three element 64 bit signed integer vector
INT64_VEC4	int64_t[4]	four element 64 bit signed integer vector
UINT64	uint64_t	64 bit unsigned integer
UINT64_VEC2	uint64_t[2]	two element vector 64 bit unsigned integer vector
UINT64_VEC3	uint64_t[3]	three element vector 64 bit unsigned integer vector
UINT64_VEC4	uint64_t[4]	four element 64 bit unsigned integer vector vector
FIXED8	int8_t	8 bit signed normalized fixed point number
FIXED8_VEC2	int8_t[2]	two element 8 bit signed normalized fixed point vector
FIXED8_VEC3	int8_t[3]	three element 8 bit signed normalized fixed point vector
FIXED8_VEC4	int8_t[4]	four element 8 bit signed normalized fixed point vector
UFIXED8	uint8_t	8 bit unsigned normalized fixed point number
UFIXED8_VEC2	uint8_t[2]	two element 8 bit unsigned normalized fixed point vector
UFIXED8_VEC3	uint8_t[3]	three element 8 bit unsigned normalized fixed point vector
UFIXED8_VEC4	uint8_t[4]	four element 8 bit unsigned normalized fixed point vector
FIXED16	int16_t	16 bit signed normalized fixed point number
FIXED16_VEC2	int16_t[2]	two element 16 bit signed normalized fixed point vector
FIXED16_VEC3	int16_t[3]	three element 16 bit signed normalized fixed point vector

Name	Closest C99-Type	Description
FIXED16_VEC4	int16_t[4]	four element 16 bit signed normalized fixed point vector
UFIXED16	uint16_t	16 bit unsigned normalized fixed point number
UFIXED16_VEC2	uint16_t[2]	two element 16 bit unsigned normalized fixed point vector
UFIXED16_VEC3	uint16_t[3]	three element 16 bit unsigned normalized fixed point vector
UFIXED16_VEC4	uint16_t[4]	four element 16 bit unsigned normalized fixed point vector
FIXED32	int32_t	32 bit signed normalized fixed point number
FIXED32_VEC2	int32_t[2]	two element 32 bit signed normalized fixed point vector
FIXED32_VEC3	int32_t[3]	three element 32 bit signed normalized fixed point vector
FIXED32_VEC4	int32_t[4]	four element 32 bit signed normalized fixed point vector
UFIXED32	uint32_t	32 bit unsigned normalized fixed point number
UFIXED32_VEC2	uint32_t[2]	two element 32 bit unsigned normalized fixed point vector
UFIXED32_VEC3	uint32_t[3]	three element 32 bit unsigned normalized fixed point vector
UFIXED32_VEC4	uint32_t[4]	four element 32 bit unsigned normalized fixed point vector
FIXED64	int64_t	64 bit signed normalized fixed point number
FIXED64_VEC2	int64_t[2]	two element 64 bit signed normalized fixed point vector
FIXED64_VEC3	int64_t[3]	three element 64 bit signed normalized fixed point vector
FIXED64_VEC4	int64_t[4]	four element 64 bit signed normalized fixed point vector
UFIXED64	uint64_t	64 bit unsigned normalized fixed point number
UFIXED64_VEC2	uint64_t[2]	two element 64 bit unsigned normalized fixed point vector

Name	Closest C99-Type	Description
UFIXED64_VEC3	uint64_t[3]	three element 64 bit unsigned normalized fixed point vector
UFIXED64_VEC4	uint64_t[4]	four element 64 bit unsigned normalized fixed point vector
FLOAT16	uint16_t	16 bit floating point number
FLOAT16_VEC2	uint16_t[2]	two element 16 bit floating point vector vector
FLOAT16_VEC3	uint16_t[3]	three element vector 16 bit floating point vector
FLOAT16_VEC4	uint16_t[4]	four element vector 16 bit floating point vector
FLOAT32	float	32 bit floating point number
FLOAT32_VEC2	float[2]	two element 32 bit floating point vector vector
FLOAT32_VEC3	float[3]	three element vector 32 bit floating point vector
FLOAT32_VEC4	float[4]	four element vector 32 bit floating point vector
FLOAT64	double	64 bit floating point
FLOAT64_VEC2	double[2]	two element vector 64 bit floating point vector
FLOAT64_VEC3	double[3]	three element vector 64 bit floating point vector
FLOAT64_VEC4	double[4]	four element vector 64 bit floating point vector
UFIXED8_RGBA_SRGB	uint8_t[4]	three component sRGB color with linear alpha
UFIXED8_RGB_SRGB	uint8_t[3]	three component sRGB color
UFIXED8_RA_SRGB	uint8_t[2]	one component sRGB with linear alpha
UFIXED8_R_SRGB	uint8_t[1]	single component sRGB
INT32_BOX1	int32_t[2]	one dimensional 32 bit integer box (inclusive lower and upper bounds)
INT32_BOX2	int32_t[4]	two dimensional 32 bit integer box (inclusive lower and upper bound vector)
INT32_BOX3	int32_t[6]	three dimensional 32 bit integer box (inclusive lower and upper bound vector)

Name	Closest C99-Type	Description
INT32_BOX4	int32_t[8]	four dimensional 32 bit integer box (inclusive lower and upper bound vector)
UINT64_REGION1	uint64_t[2]	one dimensional 64 bit unsigned integer region (inclusive lower and exclusive upper bounds)
UINT64_REGION2	uint64_t[4]	two dimensional 64 bit unsigned integer region (inclusive lower and exclusive upper bound vector)
UINT64_REGION3	uint64_t[6]	three dimensional 64 bit unsigned integer region (inclusive lower and exclusive upper bound vector)
UINT64_REGION4	uint64_t[8]	four dimensional 64 bit unsigned integer region (inclusive lower and exclusive upper bound vector)
FLOAT32_BOX1	float[2]	one dimensional 32 bit float box (inclusive lower and upper bounds)
FLOAT32_BOX2	float[4]	two dimensional 32 bit float box (inclusive lower and upper bound vector)
FLOAT32_BOX3	float[6]	three dimensional 32 bit float box (inclusive lower and upper bound vector)
FLOAT32_BOX4	float[8]	four dimensional 32 bit float box (inclusive lower and upper bound vector)
FLOAT64_BOX1	double[2]	one dimensional 64 bit float box (inclusive lower and upper bounds)
FLOAT64_BOX2	double[4]	two dimensional 64 bit float box (inclusive lower and upper bound vector)
FLOAT64_BOX3	double[6]	three dimensional 64 bit float box (inclusive lower and upper bound vector)
FLOAT64_BOX4	double[8]	four dimensional 64 bit float box (inclusive lower and upper bound vector)
FLOAT32_MAT2	float[4]	two by two 32 bit float matrix in column-major order

Name	Closest C99-Type	Description
`FLOAT32_MAT3`	`float[9]`	three by three 32 bit float matrix in column-major order
`FLOAT32_MAT4`	`float[16]`	four by four 32 bit float matrix in column-major order
`FLOAT32_QUAT_IJKW`	`float[4]`	quaternion

Floating point number (data types with `FLOAT`) layout and behavior are as specified in [ieee-754].

3.6.1. Color

The following data types must be accepted by geometry's `color` attribute parameter and by samplers, which are grouped here for brevity:

- `UFIXED8`
- `UFIXED8_VEC2`
- `UFIXED8_VEC3`
- `UFIXED8_VEC4`
- `UFIXED16`
- `UFIXED16_VEC2`
- `UFIXED16_VEC3`
- `UFIXED16_VEC4`
- `UFIXED32`
- `UFIXED32_VEC2`
- `UFIXED32_VEC3`
- `UFIXED32_VEC4`
- `FLOAT32`
- `FLOAT32_VEC2`
- `FLOAT32_VEC3`
- `FLOAT32_VEC4`
- `UFIXED8_RGBA_SRGB`
- `UFIXED8_RGB_SRGB`
- `UFIXED8_RA_SRGB`
- `UFIXED8_R_SRGB`

3.7. Object Introspection

ANARI supports introspection of objects, i.e., querying supported extensions, object subtypes and information about their parameters, which is particularly useful to enumerate and inspect implementation-specific object extensions. The intended use is to allow for building a graphical user interface for, e.g., specific renderers or materials, and to provide hints for the debug layer to aid in validating extensions.

The information queried with the following functions is static and will reflect what the implementation is capable of supporting. If a extension is unavailable for runtime dependent reasons, for example due to missing hardware support, the device may still advertise the associated parameters and object subtypes. The dynamic runtime extension availability can be queried using properties.

Device subtypes and their implemented extensions can be queried from a library before instantiating a device. Object and parameter specific information can be queried from an instantiated device object.

```
const char **anariGetDeviceSubtypes(ANARILibrary);
```

A list of device subtypes implemented in a library is retrieved by calling `anariGetDeviceSubtypes`. It returns `NULL` if there are no devices, or a `NULL`-terminated list of `0`-terminated C-strings with the names of the devices. The first (if any) device is the default device.

```
const char **anariGetDeviceExtensions(ANARILibrary, const char *deviceSubtype);
```

The list extensions implemented by a device is retrieved by calling `anariGetDeviceExtensions` with a device subtype returned by `anariGetDeviceSubtypes`. It returns a `NULL`-terminated list of `0`-terminated C-strings with the names of the implemented extensions.

```
const char **anariGetObjectSubtypes(ANARIDevice, ANARIDataType objectType);
```

To enumerate the subtypes of type `objectType` supported by device `deviceSubtype` call function `anariGetObjectSubtypes`. It returns `NULL` if there are no subtypes, or a `NULL`-terminated list of `0` -terminated C-strings with the names of the subtypes. The following object types are expected to have subtypes:

- `CAMERA`
- `RENDERER`
- `INSTANCE`
- `LIGHT`
- `GEOMETRY`
- `SAMPLER`
- `MATERIAL`
- `VOLUME`
- `SPATIAL_FIELD`

```
typedef struct
{
  const char *name;
  ANARIDataType type;
} ANARIParameter;

const void *anariGetObjectInfo(ANARIDevice,
    ANARIDataType objectType,
    const char *objectSubtype
    const char *infoName,
    ANARIDataType infoType);
```

An object (sub)type `objectType`/`objectSubtype` can be queried for information with `anariGetObjectInfo` (passing `NULL` or an empty string for `objectSubtype` to query an object type directly that does not have subtypes). The function returns the result for `infoName` of type `infoType`, or `NULL` if the info cannot be retrieved. The following infos of objects can be queried:

Table 3. Info of objects for introspection.

Name	Type	Required	Description
description	`STRING`	No	explanation of the object, e.g., for a tooltip
parameter	`PARAMETER_LIST`	Yes	list of supported parameters (array of `ANARIParameter`)
channel	`STRING_LIST`	for `FRAME`	list of supported channels
extension	`STRING_LIST`	for `RENDERER`s	list of supported extensions

Parameters that can be of multiple types are reported multiple times (once for each supported variant: with the same `name`, but different `type`).

```
const void *anariGetParameterInfo(ANARIDevice,
    ANARIDataType objectType,
    const char *objectSubtype,
    const char *parameterName,
    ANARIDataType parameterType,
    const char *infoName,
    ANARIDataType infoType);
```

Finally, a parameter can be inspected with `anariGetParameterInfo`, returning the result for `infoName` of type `infoType`, or `NULL` if the info cannot be retrieved. The following infos of parameters can be queried:

Table 4. Info of parameters for introspection.

Name	Type	Required	Description
description	`STRING`	No	explanation of the parameter, e.g., for a tooltip
minimum	type	No	set values will be clamped to this minimum
maximum	type	No	set values will be clamped to this maximum
default	type	No	default value, must be in `minimum`..`maximum` if present
required	`BOOL`	Yes	whether the parameter must be set for an object to be valid, must be `FALSE` if a `default` is present
softMinimum	type	No	typical minimum, must be in `minimum`..`maximum` if present (useful, e.g., for a slider widget)
softMaximum	type	No	typical maximum, must be in `minimum`..`maximum` if present (useful, e.g., for a slider widget)
elementType	`DATA_TYPE_LIST`	for `ARRAY`s	array of supported element types of the `ANARIArray` parameter, with last element `UNKNOWN`
value	`STRING_LIST` or `DATA_TYPE_LIST`	No	list of accepted strings or data types for parameters that only recognize specific values
initializer	`BOOL`	No	whether the value is set as a normal parameter or only passable on creation of the object

Note

The `initializer` flag is only present for devices and represents immutable parameters passed during device creation via `anariNewInitializedDevice`.

3.8. Object Properties

Implementations may expose object properties through the object query interface.

```
int anariGetProperty(ANARIDevice,
    ANARIObject,
    const char *propertyName,
    ANARIDataType propertyType,
    void *memory,
    uint64_t size,
    uint32_t waitMask);
```

Properties are identified by a string name and type. The `waitMask` indicates whether the property query will wait for the value to become available or should return instantly.

If the property is available, the value will be written to `memory`, and the function returns `1`. Otherwise, the value is not written to `memory`, and the return value is `0`.

The length of a string property can be queried as an `ANARI_UINT64` by appending `.size` to the property name. The returned length includes space for the zero termination character.

At most `size` bytes will be written to `memory`.

> *Note*
>
> Return value does not replace error handling via the callbacks. A property may be unavailable for various reasons including not being supported by the device, the value not being computed yet, or any other device-specific reason. Errors related to property queries are still returned via the error callback.

3.9. Arrays and Memory Ownership

There are two methods of expressing array data on objects: directly mapping array elements on an object parameter in order to write data elements, or creating array objects represented by a handle.

The first method lets applications directly map a device's internally-managed one, two, or three dimensional array data on any given object using

```
void *anariMapParameterArray1D(ANARIDevice,
    ANARIObject,
    const char *parameterName
    ANARIDataType elementType,
    uint64_t numElements,
    uint64_t *elementStride);

void *anariMapParameterArray2D(ANARIDevice,
    ANARIObject,
    const char *parameterName
    ANARIDataType elementType,
    uint64_t numElements1,
    uint64_t numElements2,
    uint64_t *elementStride);

void *anariMapParameterArray3D(ANARIDevice,
    ANARIObject,
    const char *parameterName
    ANARIDataType elementType,
    uint64_t numElements1,
    uint64_t numElements2,
    uint64_t numElements3,
    uint64_t *elementStride);
```

Each of these functions return a write-only array for the application to fill, where the number of elements `numElementsN` must be positive (there cannot be an empty mapped array). Whenever an array is directly mapped, any previous array configuration (size, dimensionality, etc.) is discarded in favor of the currently mapped array configuration.

Devices are only required to allocate directly mapped arrays for parameters corresponding to extensions that the device implements. In cases where the parameter is unknown by the device, the device is permitted to return `NULL`.

Devices are permitted to have a non-dense element stride, which is returned by writing to `elementStride`. The `elementStride` argument must not be `NULL`.

Once the array has been filled, applications signal that the device is free to consume the data with

```
void anariUnmapParameterArray(ANARIDevice, ANARIObject, const char *parameterName);
```

Directly mapped arrays behave like normal parameters in that the underlying array data will not be used in the next rendered frame until the object itself is committed with `anariCommitParameters`. Furthermore, using `anariUnsetParameter` will subsequently reset the parameter to an unset state, effectively clearing the previously mapped array on the object. Using `anariSetParameter`, `anariMapParameterArray`, or `anariUnsetParameter` on an array that is still mapped is an error – applications must first unmap the array before altering the parameter through other means. Writing to the mapped pointer after calling `anariUnmapParameterArray` is undefined behavior and should be avoided.

The second method of expressing array data on objects uses handles. `ANARIArray` handles represent data arrays in memory, which are shared with device implementations. The memory shared with ANARI can be either owned by the application, have ownership transferred to the device via a deleter callback, or be managed by the device.

The signature of the deleter is provided in `anari.h` as

```
typedef void (*ANARIDeleterCallback)(const void *userPtr, const void *appMemory);
```

To create a data array, use any of the following API calls based on the desired dimension:

```
ANARIArray1D anariNewArray1D(ANARIDevice,
   const void *appMemory,
   ANARIDeleterCallback,
   const void *userPtr,
   ANARIDataType elementType,
   uint64_t numElements);

ANARIArray2D anariNewArray2D(ANARIDevice,
   const void *appMemory,
   ANARIDeleterCallback,
   const void *userPtr,
   ANARIDataType elementType,
   uint64_t numElements1,
   uint64_t numElements2);

ANARIArray3D anariNewArray3D(ANARIDevice,
   const void *appMemory,
```

```
    ANARIDeleterCallback,
    const void *userPtr,
    ANARIDataType elementType,
    uint64_t numElements1,
    uint64_t numElements2,
    uint64_t numElements3);
```

The number of elements `numElementsN` must be positive (there cannot be an empty array object).

In each creation function a deleter can be passed in (with an associated pointer to any needed application data or state), which ANARI will use to free the original pointer passed during construction. If the application passes `NULL`, ANARI will fully rely on the application to free the memory.

When `appMemory` is not `NULL`, then the array is considered to be a *shared* array, where both the application and device observe the same memory. Passing `NULL` in `appMemory` creates a *managed* array. The backing memory of the array is managed by the device and is only writable via mapping.

Applications are permitted to release `ANARIArray` objects even if the device still contains internal references to it. When releasing a shared array object ANARI relinquishes shared ownership of the memory, which may result in the creation of internal copies. When a shared array is created with a deleter callback, it is implementation defined when an implementation frees host memory after the array object has been released. Deleter callbacks are never called for managed arrays.

Applications are only permitted to write to the memory visible to `ANARIArray` objects if all array objects involved are mapped. Mapping a shared array object indicates that the device should not execute any rendering operations (or internal state updates, such as building acceleration structures) of any parent objects to the mapped array object which is directly referencing mapped memory.

Array objects are mapped using

```
void *anariMapArray(ANARIDevice, ANARIArray);
```

Mapped array objects are unmapped using

```
void anariUnmapArray(ANARIDevice, ANARIArray);
```

Mapping a shared array will always result in the same address originally used when constructing the array object. Mapping a managed array may return a different pointer each time it is mapped. The contents of memory mapped from managed arrays is undefined until written to and the entire mapped range must be specified before unmapping to avoid populating the array with undefined values.

`ANARIArray` objects containing object handles increase the ref count of all objects in the array. Reference counts are updated on creation of the array object and when unmapping the array.

Use of the arrays inside ANARI may cause accesses at indices derived from parameters or other arrays (for example when drawing an indexed geometry). Out of bounds accesses caused this way have undefined behavior.

> *Note*
>
> Array parameters of objects that are accessed by the same index (because they represent an "array of structures") have per naming convention a common prefix followed by a period. An example are the vertex attributes of the triangle geometry, which all start with `vertex.` followed by the attribute name.

Arrays define a valid region of elements, which by default is always the full capacity of the array. Implementations can allow applications to keep a singular allocation of data, but use a parameter to tell the implementation only to use a subset of elements. This gives applications the ability to more efficiently change the number of elements used by parent objects at the cost of memory size efficiency.

Implementations provide this functionality by implementing extension `KHR_ARRAY1D_REGION`, which adds the following parameter to `ANARIArray1D`:

Table 5. Parameters understood by the 1D array.

Name	Type	Description
region	`UINT64_REGION1`	extension `KHR_ARRAY1D_REGION`, region of elements currently in use

If `region` is not set, all elements are used as specified when the array was constructed. When `region` is set, it is clamped to the range of the array's constructed size respectively and warnings should be emitted by the debug layer if `region.upper` is larger than capacity.

The values specified by `region` are clamped such that the array will always be a valid range containing at least one element. Thus `region` is clamped according to the following:

- `region.upper` is clamped from below by `region.lower + 1`
- `region.upper` is clamped from above by the array's capacity
- `region.lower` is clamped from above by `region.upper - 1`

Mapping an array always returns the full capacity, regardless of the elements specified by `region`. Object handles within `region` must always be valid. Object arrays can be constructed with invalid handles, as long as the array `region` contains only valid handles by the time the array is used in a render operation.

> *Note*
>
> As with all `REGION` types, the element from `region.lower` is *inclusive*, while `region.upper` is *exclusive*. This is intended to mimic C++ begin/end iterators on containers.

> *Note*
>
> Directly mapped arrays from object parameters maximizes the device's

> opportunity to be efficient in its underlying implementation. This is preferred method applications should use to set array data on objects. However, if the array data needs to be set on more than one object, then applications should prefer using array objects also detailed in this section so that a single array handle can be set on more than one parent object.

3.10. Libraries

ANARI libraries are the mechanism that applications use to manage API device implementations. Libraries are solely responsible for creating instances of devices. Implementors may use a library to cache data or objects which are truly global to their device implementations, such as contexts from underlying APIs. Libraries are generally the first thing loaded by an application and the last thing cleaned up. While libraries are represented by an opaque handle, they are not considered an object per the given definition of an object and are thus only usable in API calls which explicitly take `ANARILibrary` handles.

To load a library, use

```
ANARILibrary anariLoadLibrary(const char *name,
  ANARIStatusCallback defaultStatusCallback,
  const void *defaultStatusCallbackUserData);
```

This will look for a shared library named `anari_library_[name]`, open it, and look for entry points for (implementation defined) initialization. The status callback passed is used as the default value for the `statusCallback` parameter on devices created from the returned library object. Similarly, the user pointer passed is used as the default value for the `statusCallbackUserData` device parameter.

To unload a library (where library resource cleanup occurs), use

```
void anariUnloadLibrary(ANARILibrary);
```

It is undefined behavior to unload a library while instances of devices from that library have not been released.

> *Note*
>
> Vendors are also permitted to implement direct device creation functions to allow an application to directly link their ANARI library at compile time. Please reference your vendor's documentation for whether direct linking is supported by their ANARI library.

3.11. Devices

ANARI coordinates the use of one or more *devices*. A device is an object which provides the implementation of all ANARI API calls outside of libraries. Devices represent the global state which an implementor may reuse between different objects to render images. It is common for applications to only use one device at a time, but the API permits concurrent use of multiple devices to independently render from each other.

> *Note*
>
> ANARI devices are a *software* construct. Because ANARI abstracts away the details of an entire rendering system, the underlying hardware which a device may use is entirely up to the implementation. Please read your vendor's device documentation to see what parameters are available to configure and what underlying hardware is both available and used to render frames.

The ANARI device is responsible for coordinating the sharing of execution resources with the calling application, such as a CPU thread pool or GPU kernel queues.

ANARI devices are represented by an `ANARIDevice` handle and created using

```
ANARIDevice anariNewDevice(ANARILibrary, const char *subtype);
```

Some devices may have device parameters that can only be set once: for example, choosing a particular GPU used for rendering on a machine with more than one. Devices should always be usable with `anariNewDevice` having sensible defaults, but applications seeking to set immutable parameters on a device during device creation should instead use

```
struct ANARIParameterValue
{
  const char *name;
  ANARIDataType type;
  const void *value;
};

ANARIDevice anariNewInitializedDevice(
  ANARILibrary,
  const char *subtype,
  ANARIParameterValue *initializers
);
```

The last element in `params` is indicated with `name` being `NULL`, `type` being `ANARI_UNKNOWN`, and `value` being `NULL`.

Version information can be queried as properties on the `ANARIDevice` using `anariGetProperty`.

Table 6. Properties queryable on a device.

Name	Type	Required	Description
version	`INT32`	Yes	unique device version number guaranteed to increase between versions
version.major	`INT32`	No	semantic device version major value (major.minor.patch)
version.minor	`INT32`	No	semantic device version minor value (major.minor.patch)
version.patch	`INT32`	No	semantic device version patch value (major.minor.patch)
version.name	`STRING`	No	human readable device name/title
anariVersion.major	`INT32`	Yes	targeted ANARI specification version major value (major.minor)
anariVersion.minor	`INT32`	Yes	targeted ANARI specification version minor value (major.minor)
geometryMaxIndex	`UINT64`	Yes	largest supported index into vertex arrays in geometries
extension	`STRING_LIST`	Yes	list of supported extensions

3.12. Error Handling

Errors and other messages (warnings, validation messages, debug information etc.) from the device are reported via a status callback. The status callback function can be set using

```
typedef void (*ANARIStatusCallback)(const void *userPtr,
    ANARIDevice,
    ANARIObject source,
    ANARIDataType sourceType,
    ANARIStatusSeverity,
    ANARIStatusCode,
    const char *message);
```

The following values for `ANARIStatusCode` are defined:

- `STATUS_NO_ERROR`
- `STATUS_UNKNOWN_ERROR`
- `STATUS_INVALID_ARGUMENT`
- `STATUS_INVALID_OPERATION`
- `STATUS_OUT_OF_MEMORY`
- `STATUS_UNSUPPORTED_DEVICE`
- `STATUS_VERSION_MISMATCH`

The following values for ANARIStatusSeverity are defined:

- SEVERITY_FATAL_ERROR
- SEVERITY_ERROR
- SEVERITY_WARNING
- SEVERITY_PERFORMANCE_WARNING
- SEVERITY_INFO
- SEVERITY_DEBUG

Table 7. Parameters understood by all devices.

Name	Type	Description
statusCallback	STATUS_CALLBACK	callback used to report information to the application
statusCallbackUserData	VOID_POINTER	optional pointer passed as the first argument of the status callback

Statuses may be reported at an undefined time after the API call causing them is made. Furthermore, these callbacks must themselves be thread safe as they can be called on any thread.

3.13. Attributes

Attributes are quantities that are passed between objects during rendering. Attributes are identified by strings.

Surface attributes are passed from geometries and instances to materials and samplers. Attributes are either set explicitly by user-provided data as array parameters (and may be interpolated in a geometry-specific way) or implicitly by the surface. Unspecified (components of) attributes default to zero for the first three components and to one for the fourth component.

Table 8. Attributes

Identifier	Internal Type	Description
color	FLOAT32_VEC4	color
worldPosition	FLOAT32_VEC4	world space position
worldNormal	FLOAT32_VEC4	world space shading normal
objectPosition	FLOAT32_VEC4	object space position
objectNormal	FLOAT32_VEC4	object space shading normal
attribute0	FLOAT32_VEC4	generic attribute 0
attribute1	FLOAT32_VEC4	generic attribute 1
attribute2	FLOAT32_VEC4	generic attribute 2
attribute3	FLOAT32_VEC4	generic attribute 3

Identifier	Internal Type	Description
`primitiveId`	`UINT32` / `UINT64`	geometry specific primitive identifier, at most device limit `geometryMaxIndex` large

Chapter 4. Rendering Frames

Rendering is asynchronous (non-blocking), and is done by combining a framebuffer, renderer, camera, and world. The process of rendering a frame is known as a *frame operation*. Frame operations are invoked with

```
void anariRenderFrame(ANARIDevice, ANARIFrame);
```

This call may not block, and the ANARIFrame itself can be used to synchronize with the application, cancel, or query for progress of the running task. When `anariRenderFrame` is called, there is no guarantee when the associated task will begin execution.

Applications can query for the status of or wait on a running frame with

```
int anariFrameReady(ANARIDevice, ANARIFrame, ANARIWaitMask);
```

If `ANARI_NO_WAIT` is passed as the wait mask, then the function returns true if the frame has completed. Alternatively, passing `ANARI_WAIT` will block the calling thread until the frame has completed and will always return true.

Applications can query how long an async task ran with the `duration` property on the `ANARIFrame`. If available, this returns the wall clock execution time of the task in seconds. This is useful for applications to query exactly how long an asynchronous task executed without the overhead of measuring both task execution & synchronization by the calling application.

Note

The use of `anariRenderFrame` requires that all objects in the scene being rendered are valid before rendering occurs.

Applications can signal that an in-flight frame should be canceled if possible using

```
void anariDiscardFrame(ANARIDevice, ANARIFrame);
```

This call is not required to block until the frame completes, rather it only signals to the implementation to attempt canceling the currently rendered frame instead of going all the way to completion. The contents of a mapped frame which has been discarded is undefined.

The application can map the given channel of a frame – and thus access the stored pixel information – via

```
const void *anariMapFrame(ANARIDevice,
                          ANARIFrame,
                          const char *channel,
                          uint32_t *width,
                          uint32_t *height,
```

```
                        ANARIDataType *pixelType);
```

Only channels that have been set as parameters to the frame can be mapped, the type of the pixels matches the corresponding parameter value. The arguments `width`, `height`, and `pixelType` are output parameters for the application to validate the exact dimensions and per-pixel data type in the mapped image.

> *Note*
>
> ANARI makes a clear distinction between the *external* format of channels of the frame and the internal one: The external format is the format the user specifies as `DATA_TYPE` parameter for channels, which corresponds to the element type of the returned buffer when calling `anariMapFrame`. Implementations may do significant amounts of reformatting, compression/decompression, …, in-between the generation of the *internal* frame and the mapping of the externally visible one.

The origin of the screen coordinate system in ANARI is the lower left corner (as in OpenGL), thus the first pixel addressed by the returned pointer is the lower left pixel of the image.

A previously mapped channel of a frame can be unmapped calling

```
void anariUnmapFrame(ANARIDevice, ANARIFrame, const char *channel);
```

Chapter 5. Object Types and Subtypes

This section describes the object types (and subtypes where available) which are used to compose a scene in ANARI and which are involved in rendering it.

5.1. Frame

The frame contains all the objects necessary to render and holds the resulting rendered 2D image (and optionally auxiliary information associated with pixels). To create a new frame, use

```
ANARIFrame anariNewFrame(ANARIDevice);
```

The frame uses parameters to encode size, color format, and which channels to use. Channels are identified by string channel names beginning with `channel.`. The frame object has an identically named parameter for each reported channel. Setting these parameters to one of the allowed data types enables the channel and determines the data type it can be mapped as. The same channel names are used to map the channel contents with `anariMapFrame`. Each channel has its own associated extension name.

Table 9. Parameters understood by the frame.

Name	Type	Description
world	WORLD	required world to be rendered
camera	CAMERA	required camera used to render the world
renderer	RENDERER	required renderer which renders the frame
size	UINT32_VEC2	required size of the frame in pixels (width × height)
accumulation	BOOL	extension KHR_FRAME_ACCUMULATION, whether additional internal buffers are created to potentially improve the image quality when multiple subsequent calls to anariRenderFrame are made, default FALSE
frameCompletionCallback	FRAME_COMPLETION_CALLBACK	extension KHR_FRAME_COMPLETION_CALLBACK, callback to invoke as continuation when the rendered frame is complete
frameCompletionCallbackUserData	VOID_POINTER	extension KHR_FRAME_COMPLETION_CALLBACK, optional user pointer passed as the first argument of the frame completion callback

The `world`, `camera`, `renderer`, and `size` parameters are required, `size` must be positive.

The extension `KHR_FRAME_ACCUMULATION` indicates that implementations use progressive rendering techniques like Monte Carlo integration. If enabled via parameter `accumulation`, multiple subsequent calls to `anariRenderFrame` without changes to Frame improve the image quality (e.g., reduce noise levels).

Devices which implement extension `KHR_FRAME_COMPLETION_CALLBACK` add two parameters to Frame: a callback invoked as a continuation after the frame completes, and an associated pointer to application state to be passed to the invoked continuation. This continuation must be complete before returning from `anariFrameReady()` when called with `ANARI_WAIT`.

The signature of the continuation is provided in `anari.h` as

```
typedef void (*ANARIFrameCompletionCallback)(const void *userPtr, ANARIDevice,
ANARIFrame);
```

> *Note*
>
> Implementations are strongly encouraged to invoke the continuation on a background thread. This helps physically maintain asynchronous behavior with calling application API threads. ANARI API calls are legal within the continuation, except for calling `anariFrameReady()` with `ANARI_WAIT`, as this will incur a deadlock.

Table 10. Frame channel enabling parameters and their associated extension names.

Name	Type	Description
channel.color	`DATA_TYPE`	enable mapping the `color` channel and specify its observable type; RGB color including alpha; possible values: `UFIXED8_VEC4`, `UFIXED8_RGBA_SRGB`, `FLOAT32_VEC4`
channel.depth	`DATA_TYPE`	enable mapping the `depth` channel and specify its observable type; euclidean distance to the camera (*not* to the image plane), for multiple samples per pixel their minimum is taken; possible values: `FLOAT32`
channel.normal	`DATA_TYPE`	extension `KHR_FRAME_CHANNEL_NORMAL`, enable mapping the `normal` channel and specify its observable type; average world-space normal of the first hit; possible values: `FIXED16_VEC3`, `FLOAT32_VEC3`
channel.albedo	`DATA_TYPE`	extension `KHR_FRAME_CHANNEL_ALBEDO`, enable mapping the `albedo` channel and specify its observable type; average material albedo (color without illumination) at the first hit; possible values: `UFIXED8_VEC3`, `UFIXED8_RGB_SRGB`, `FLOAT32_VEC3`
channel.primitiveId	`DATA_TYPE`	extension `KHR_FRAME_CHANNEL_PRIMITIVE_ID`, enable mapping the `primitiveId` channel and specify its observable type; `primitiveId` attribute of the first hit; possible values: `UINT32`
channel.objectId	`DATA_TYPE`	extension `KHR_FRAME_CHANNEL_OBJECT_ID`, enable mapping the `objectId` channel and specify its observable type; user defined Surface / Volume `id`, possible values: `UINT32`
channel.instanceId	`DATA_TYPE`	extension `KHR_FRAME_CHANNEL_INSTANCE_ID`, enable mapping the `instanceId` channel and specify its observable type; user defined Instance `id`, possible values: `UINT32`

The following information can be queried as properties on the `ANARIFrame` using `anariGetProperty`.

Table 11. Properties queryable on a frame.

Name	Type	Required	Description
duration	`FLOAT32`	Yes	time (in seconds) between start and completion of the frame
renderProgress	`FLOAT32`	No	progress of the current frame task since the last call to `anariRenderFrame`, in [0..1]
refinementProgress	`FLOAT32`	No	extension `KHR_FRAME_ACCUMULATION`, progress of frame refinement, in [0..1]

5.2. Camera

Cameras express viewpoint and viewport projection information for rendering a scene. To create a new camera of given type `subtype` use

```
ANARICamera anariNewCamera(ANARIDevice, const char *subtype);
```

All cameras accept the following parameters:

Table 12. Parameters understood by cameras.

Name	Type	Default	Description
position	FLOAT32_VEC3	(0, 0, 0)	position of the camera in world-space
direction	FLOAT32_VEC3	(0, 0, -1)	main viewing direction of the camera
up	FLOAT32_VEC3	(0, 1, 0)	up direction of the camera
imageRegion	FLOAT32_BOX2	((0, 0), (1, 1))	region of the sensor in normalized screen-space coordinates
apertureRadius	FLOAT32	0	extension KHR_CAMERA_DEPTH_OF_FIELD, size of the aperture, controls the depth of field
focusDistance	FLOAT32	1	extension KHR_CAMERA_DEPTH_OF_FIELD, distance at where the image is sharpest when depth of field is enabled
stereoMode	STRING	none	extension KHR_CAMERA_STEREO, possible values: none, left, right, sideBySide, topBottom (left eye at top half)
interpupillaryDistance	FLOAT32	0.0635	extension KHR_CAMERA_STEREO, distance between left and right eye when stereo is enabled
shutter	FLOAT32_BOX1	[0.5, 0.5]	extension KHR_CAMERA_SHUTTER, start and end of shutter time, clamped to [0, 1]
rollingShutterDirection	STRING	none	extension KHR_CAMERA_ROLLING_SHUTTER, rolling direction of the shutter, possible values: none, left, right, down, up
rollingShutterDuration	FLOAT32	0	extension KHR_CAMERA_ROLLING_SHUTTER, the "open" time per line, clamped to [0, shutter.upper-shutter.lower]

The camera is placed and oriented in the world with `position`, `direction` and `up`. ANARI uses a right-handed coordinate system.

The region of the camera sensor that is rendered to the image can be specified in normalized screen-space coordinates with `imageRegion`. This can be used, for example, to crop the image, to achieve asymmetrical view frusta, or to horizontally flip the image to view scenes which are specified in a left-handed coordinate system. Note that values outside the default range of [0–1] are valid, which is useful to easily realize overscan or film gate, or to emulate a shifted sensor.

The extension `KHR_CAMERA_DEPTH_OF_FIELD` indicates that cameras support depth of field via the `apertureRadius` and `focusDistance` parameters.

The extension `KHR_CAMERA_STEREO` indicates that a renderer permits 3D stereo rendering, which is enabled by setting `stereoMode` and `interpupillaryDistance`.

Table 13. Additional parameters understood by all cameras with extension `KHR_CAMERA_MOTION_TRANSFORMATION`.

Name	Type	Default	Description
motion.transform	`ARRAY1D` of `FLOAT32_MAT4`		uniformly distributed world-space transformations
motion.scale	`ARRAY1D` of `FLOAT32_VEC3`		uniformly distributed scale, overridden by `motion.transform`
motion.rotation	`ARRAY1D` of `FLOAT32_QUAT_IJKW`		uniformly distributed quaternion rotation, overridden by `motion.transform`
motion.translation	`ARRAY1D` of `FLOAT32_VEC3`		uniformly distributed translation, overridden by `motion.transform`
time	`FLOAT32_BOX1`	[0, 1]	time associated with first and last key in `motion.*` arrays

Extension `KHR_CAMERA_MOTION_TRANSFORMATION`: Uniformly (in `time`) distributed transformation keys can be set with `motion.transform` to achieve camera motion blur (in combination with extension `KHR_CAMERA_SHUTTER`). Alternatively, the transformation keys can also be given as decomposed `motion.scale`, `motion.rotation` and `motion.translation`.

The extension `KHR_CAMERA_ROLLING_SHUTTER` provides more control over the type of shutter implemented. It depends on extension `KHR_CAMERA_SHUTTER`.

5.2.1. Perspective

Extension `KHR_CAMERA_PERSPECTIVE`

The perspective camera represents a simple thin lens camera for perspective rendering. It is created by passing the type string `perspective` to `anariNewCamera`. In addition to the general parameters understood by all cameras the perspective camera supports the special parameters listed in the table below.

Table 14. Additional parameters understood by the perspective camera.

Name	Type	Default	Description
fovy	`FLOAT32`	π/3	the field of view (angle in radians) of the frame's height
aspect	`FLOAT32`	1	ratio of width by height of the frame (and image region)
near	`FLOAT32`		near clip plane distance
far	`FLOAT32`		far clip plane distance

Note that when computing the `aspect` ratio a potentially set image region (using `imageRegion`) needs to be regarded as well.

If `near` and/or `far` are explicitly set they need to fulfill 0 < `near` < `far`. If they are not set they are determined by the renderer.

Note

Some rasterization based rendering algorithms intrinsically require near and far planes. The choice of these may also affect depth precision. By default ANARI devices using such algorithms will try to determine appropriate values from the scene contents and internal heuristics. When the algorithm does not require clip planes and `near`/`far` are not set it may opt to perform no clipping (effectively setting them to 0 and infinity).

5.2.2. Omnidirectional

Extension `KHR_CAMERA_OMNIDIRECTIONAL`

The omnidirectional camera captures the complete surrounding It is is created by passing the type string `omnidirectional` to `anariNewCamera`. It is placed and oriented in the scene by using the general parameters understood by all cameras.

Table 15. Additional parameters understood by the omnidirectional camera.

Name	Type	Default	Description
layout	`STRING`	`equirectangular`	pixel layout, possible values: `equirectangular`

The image content outside of [0–1] of `imageRegion` is undefined for the omnidirectional camera.

5.2.3. Orthographic

Extension `KHR_CAMERA_ORTHOGRAPHIC`

The orthographic camera represents a simple camera with orthographic projection. It is created by passing the type string `orthographic` to `anariNewCamera`. In addition to the general parameters understood by all cameras the orthographic camera supports the following special parameters:

Table 16. Additional parameters understood by the orthographic camera.

Name	Type	Default	Description
aspect	`FLOAT32`	1	ratio of width by height of the frame (and image region)
height	`FLOAT32`	1	height of the image plane in world units
near	`FLOAT32`		near clip plane distance
far	`FLOAT32`		far clip plane distance

Note that when computing the `aspect` ratio a potentially set image region (using `imageRegion`) needs to be regarded as well.

If `near` and/or `far` are explicitly set they need to fulfill 0 ≤ `near` < `far`. If they are not set they are determined by the renderer.

Note

Some rasterization based rendering algorithms intrinsically require near and far planes. The choice of these may also affect depth precision. By default ANARI devices using such algorithms will try to determine appropriate values from the scene contents and internal heuristics. When the algorithm does not require clip planes and `near`/`far` are not set it may opt to perform no clipping (effectively setting them to 0 and infinity).

5.3. Renderer

A renderer is the central object for rendering in ANARI. Different renderers implement different extensions, rendering algorithms, and support different materials. To create a new renderer of given subtype `subtype` use

```
ANARIRenderer anariNewRenderer(ANARIDevice, const char *subtype);
```

Every ANARI device offers a default renderer, which works without setting any parameters (i.e., all parameters, if any, have meaningful defaults). Thus, passing `default` as subtype string to anariNewRenderer will result in a usable renderer. Further renderers and their parameters can be enumerated with the Object Introspection API. The default renderer is an alias to an existing renderer that is returned first in the list by `anariGetObjectSubtypes` when queried for `RENDERER`. Also refer to the documentation of ANARI implementations.

Extension support information can be queried as properties on the `ANARIRenderer` using `anariGetProperty`.

Table 17. Properties queryable on a renderer.

Name	Type	Required	Description
extension	`STRING_LIST`	Yes	list of supported extensions

Even though renderers (and their parameters) are highly implementation specific, some typical parameters are specified by the following extensions.

Table 18. Parameters understood by some renderers.

Name	Type	Default	Description
background	FLOAT32_VEC4	(0, 0, 0, 1)	extension KHR_RENDERER_BACKGROUND_COLOR, the background color
background	ARRAY2D of Color		extension KHR_RENDERER_BACKGROUND_IMAGE, the background image, rescaled to the size of the Frame by linear filtering
ambientColor	FLOAT32_VEC3	(1, 1, 1)	extension KHR_RENDERER_AMBIENT_LIGHT, ambient light color
ambientRadiance	FLOAT32	0	extension KHR_RENDERER_AMBIENT_LIGHT, the amount of light emitted by a point on the ambient light source in a direction, in W/sr/m^2
denoise	BOOL	FALSE	extension KHR_RENDERER_DENOISE, whether the rendered image should be denoised

If both KHR_RENDERER_BACKGROUND_COLOR and KHR_RENDERER_BACKGROUND_IMAGE are supported the background parameter can accept either type.

The ambient light is a light with an invisible source which surrounds the scene and illuminates it from infinity.

5.4. World

Worlds are a container of scene data represented by instances. Worlds are created with

```
ANARIWorld anariNewWorld(ANARIDevice);
```

Objects are placed in the world through an array of instances, geometries, volumes, or lights. Similar to instances, each array of objects is optional; there is no need to create empty arrays if there are no instances (though there might be nothing to render).

Table 19. Parameters understood by the world.

Name	Type	Description
instance	ARRAY1D of INSTANCE	optional array with handles of instances
surface	ARRAY1D of SURFACE	optional array with handles of surfaces
volume	ARRAY1D of VOLUME	optional array with handles of volumes
light	ARRAY1D of LIGHT	optional array with handles of lights

Table 20. Properties queryable on a world.

Name	Type	Description
bounds	FLOAT32_BOX3	axis-aligned bounding box in world-space (excluding the lights)

5.5. Instance

Instances apply transforms to groups for placement in the World. Instances are created with

```
ANARIInstance anariNewInstance(ANARIDevice, const char *subtype);
```

All instances take a Group representing all the objects which share the instance's world-space transform. They also always take a generic `FLOAT32_MAT4` transform which serves as a fall back but may be overridden by subtype specific transform definitions.

Table 21. Parameters understood by instances.

Name	Type	Default	Description
group	`GROUP`		Group to be instanced, required
transform	`FLOAT32_MAT4`	((1, 0, 0, 0), (0, 1, 0, 0), (0, 0, 1, 0), (0, 0, 0, 1))	world-space transformation matrix for all attached objects
id	`UINT32`	-1u	extension `KHR_FRAME_CHANNEL_INSTANCE_ID`, optional user Id, for frame channel `instanceId`
color	`FLOAT32_VEC4`		uniform color attribute
attribute0	`FLOAT32_VEC4`		uniform attribute 0
attribute1	`FLOAT32_VEC4`		uniform attribute 1
attribute2	`FLOAT32_VEC4`		uniform attribute 2
attribute3	`FLOAT32_VEC4`		uniform attribute 3

The matrix `transform` represents an affine transformation which is applied to homogeneous coordinates.

The uniform attribute parameters apply to all objects contained in the instance and have a lower precedence than attribute values found in objects within the instance when both are present.

> *Note*
>
> Since the `FLOAT32_MAT4` matrix `transform` is in column-major layout the translational part of the affine transformation is the 13th to 15th float in memory. Implementations are free to always treat the last row (4th, 8th, 12th and 16th float) as being (0, 0, 0, 1).

> *Note*
>
> Since the parameters of all other instance subtypes are supersets of the basic parameters listed above, it is recommend that the `transform` parameter should always be set in addition to any subtype specific transform parameters.

Table 22. Properties queryable on an instance.

Name	Type	Description
bounds	FLOAT32_BOX3	axis-aligned bounding box in world-space (excluding the lights)

5.5.1. Transform

Extension KHR_INSTANCE_TRANSFORM

The transform instance subtype is a basic instance that implements the parameters and properties listed above.

The KHR_INSTANCE_TRANSFORM_ARRAY extension adds to the transform subtype additional types for the transform (and related) parameters by allowing arrays to do multi-instantiation. This gives applications a more efficient means to transform a single group many times by avoiding the need to create an entire object per-transform.

Table 23. Additional parameters introduced by KHR_INSTANCE_TRANSFORM_ARRAY instance.

Name	Type	Description
transform	ARRAY1D of FLOAT32_MAT4	array of matrices, instantiating group once per element
id	ARRAY1D of UINT32	extension KHR_FRAME_CHANNEL_INSTANCE_ID, optional user Id, for frame channel instanceId

The additional id array applies an instance identifier value to each element instance of the transform array. The size of the id array must be large enough to cover each element of the transform array. If the id array is not present when transform is set as an array, the single value version of id is used.

> *Note*
>
> Since setting transforms using an array of matrices does not have a sensible fallback when a device does not implement it, a unique extension KHR_INSTANCE_TRANSFORM_ARRAY is provided so this can be detected as early as possible for applications to decide whether or not the device is considered usable.

5.5.2. Motion Transform

Extension KHR_INSTANCE_MOTION_TRANSFORM

The motionTransform instance subtype represents uniformly (in time) distributed transformation keys as defined by motion.transform to achieve transformation motion blur in combination with time and extension KHR_CAMERA_SHUTTER.

Table 24. Additional parameters understood by the motion transform instance.

Name	Type	Default	Description
motion.transform	ARRAY1D of FLOAT32_MAT4		uniformly distributed world-space transformations
time	FLOAT32_BOX1	[0, 1]	time associated with first and last key in motion.transform array

The `motion.transform` parameter takes precedence over the generic `transform` parameter.

5.5.3. Motion Scale Rotation Translation

Extension `KHR_INSTANCE_MOTION_SCALE_ROTATION_TRANSLATION`

The `motionScaleRotationTranslation` instance subtype represents uniformly (in `time`) distributed transformation keys as defined by decomposed `motion.scale`, `motion.rotation` and `motion.translation` transform components (applied in this order) to achieve transformation motion blur in combination with `time` and extension `KHR_CAMERA_SHUTTER`.

Table 25. Additional parameters understood by the motion scale rotation translation instance.

Name	Type	Default	Description
motion.scale	ARRAY1D of FLOAT32_VEC3		uniformly distributed scale
motion.rotation	ARRAY1D of FLOAT32_QUAT_IJKW		uniformly distributed quaternion rotation
motion.translation	ARRAY1D of FLOAT32_VEC3		uniformly distributed translation
time	FLOAT32_BOX1	[0, 1]	time associated with first and last key in motion.* arrays

The `motion.*` parameters takes precedence over the generic `transform` parameter.

5.6. Group

Groups in ANARI represent collections of surfaces, volumes, and lights which share a common local-space coordinate system. Groups are created with

```
ANARIGroup anariNewGroup(ANARIDevice);
```

Each array on a group is optional; there is no need to create empty arrays if there are no surfaces, no volumes, or no lights instanced.

Table 26. Parameters understood by groups.

Name	Type	Description
surface	ARRAY1D of SURFACE	optional array with handles of surfaces
volume	ARRAY1D of VOLUME	optional array with handles of volumes
light	ARRAY1D of LIGHT	optional array with handles of lights

Table 27. Properties queryable on a group.

Name	Type	Description
bounds	FLOAT32_BOX3	axis-aligned bounding box (excluding the lights)

5.7. Light

Lights in ANARI are virtual objects that emit light into the world and thus illuminate objects. To create a new light object of given subtype `subtype` use

```
ANARILight anariNewLight(ANARIDevice, const char *subtype);
```

All light sources accept the following parameters:

Table 28. Parameters understood by all lights.

Name	Type	Default	Description
color	FLOAT32_VEC3	(1, 1, 1)	color of the light, in 0..1
visible	BOOL	TRUE	extension KHR_LIGHT_PRIMARY_VISIBILITY, whether the light can be directly seen (only meaningful for area lights)

The `color` parameter is a unitless factor and acts as a filter of the emitted light.

The transformation of an instance apply only to vectors like `position` or `direction` of a light, but *not* to affect sizes like `radius`.

5.7.1. Directional

Extension `KHR_LIGHT_DIRECTIONAL`

The directional light is thought to be far away (outside of the scene), thus its light arrives (mostly) as parallel rays. It is created by passing the subtype string `directional` to `anariNewLight`. In addition to the general parameters understood by all lights, the directional light supports the following special parameters:

Table 29. Additional parameters understood by the directional light.

Name	Type	Default	Description
direction	FLOAT32_VEC3	(0, 0, -1)	main emission direction of the directional light
angularDiameter	FLOAT32	0	apparent size (angle in radians) of the light
irradiance	FLOAT32	1	the amount of light arriving at a surface point, assuming the light is oriented towards to the surface, in W/m^2
radiance	FLOAT32		alternative specification of the brightness (if irradiance is not explicitly set): the amount of light emitted in a direction, in $W/sr/m^2$

If irradiance and radiance are both explicitly set, then irradiance takes precedence.

Note

The main way to specify the brightness of the directional light via irradiance and its alternative specification via radiance differs in behavior when the angularDiameter is changing: With irradiance, increasing the angular diameter will result in softer shadows (when soft shadows are supported by the implementation), but the overall brightness in the scene stays roughly the same. With radiance however, increasing the angular diameter will also result in a brighter illumination in the scene. Using radiance is only meaningful if angularDiameter is larger than zero (otherwise the directional light is not emitting any light).

Using a directional light with an angular diameter is a good approximation for sunlight: the apparent size of the sun is about 0.53° or 0.00925 rad.

5.7.2. HDRI

Extension KHR_LIGHT_HDRI

The HDRI light is a textured light source surrounding the scene and illuminating it from infinity. It is created by passing the subtype string hdri to anariNewLight. In addition to the general parameters the HDRI light supports the following special parameters:

Table 30. Additional parameters understood by the HDRI light.

Name	Type	Default	Description
up	FLOAT32_VEC3	(0, 0, 1)	up direction of the light in world-space
direction	FLOAT32_VEC3	(1, 0, 0)	direction to which the center of the texture will be mapped to
radiance	ARRAY2D of FLOAT32_VEC3		environment map, typically HDR with values >1, the amount of light emitted by a point on the light source in a direction, in W/sr/m^2
layout	STRING	equirectangular	possible values: equirectangular
scale	FLOAT32	1	scale factor for radiance

5.7.3. Point

Extension KHR_LIGHT_POINT

The point light (or with radius > 0 the sphere light) is a light emitting uniformly in all directions (from the surface toward the outside). It is created by passing the subtype string point to anariNewLight. In addition to the general parameters understood by all lights, the point light supports the following special parameters:

Table 31. Additional parameters understood by the point light.

Name	Type	Default	Description
position	FLOAT32_VEC3	(0, 0, 0)	the position of the point light
radius	FLOAT32	0	the size of the point light (becoming a sphere)
intensity	FLOAT32	1	the overall amount of light emitted by the light in a direction, in W/sr
power	FLOAT32		alternative specification of the brightness (if intensity is not explicitly set): the overall amount of light energy emitted, in W
radiance	FLOAT32		alternative specification of the brightness (if neither intensity nor power is explicitly set): the amount of light emitted by a point on the light source in a direction, in W/sr/m^2

The precedence order is intensity, power, radiance: the first (in this ordering) explicitly set parameter is used.

> *Note*
>
> The main way to specify the brightness of the point light via intensity and its alternative specifications via power or radiance differs in behavior when the radius is changing: With intensity or power, increasing the radius will result in softer shadows (when soft shadows are supported by the implementation), but the overall brightness in the scene stays roughly the same. With radiance however, increasing the radius will also result in a brighter illumination in the scene. Using radiance is only meaningful if radius is larger than zero (otherwise the point light

is not emitting any light).

Since power is the integral of intensity over the sphere of directions, using the same value for `power` and `intensity` will differ by a constant factor of 4π in brightness.

5.7.4. Quad

Extension `KHR_LIGHT_QUAD`

The quad light is a planar, procedural area light source, a parallelogram, emitting uniformly either on one side into the half-space, or on both sides. It is created by passing the subtype string `quad` to `anariNewLight`. In addition to the general parameters understood by all lights, the quad light supports the following special parameters:

Table 32. Additional parameters understood by the quad light.

Name	Type	Default	Description
position	`FLOAT32_VEC3`	(0, 0, 0)	position of one vertex of the quad light
edge1	`FLOAT32_VEC3`	(1, 0, 0)	vector to one adjacent vertex
edge2	`FLOAT32_VEC3`	(0, 1, 0)	vector to the other adjacent vertex
intensity	`FLOAT32`	1	the overall amount of light emitted by the light in a direction, in W/sr
power	`FLOAT32`		alternative specification of the brightness (if `intensity` is not explicitly set): the overall amount of light energy emitted, in W
radiance	`FLOAT32`		alternative specification of the brightness (if neither `intensity` nor `power` is not explicitly set): the amount of light emitted by a point on the light source in a direction, in $W/sr/m^2$
side	`STRING`	`front`	side into which light is emitted; possible values: `front`, `back`, `both`
intensityDistribution	`ARRAY1D` / `ARRAY2D` of `FLOAT32`		luminous intensity distribution for photometric lights; can be 2D for asymmetric illumination; values are assumed to be uniformly distributed

The precedence order is `intensity`, `power`, `radiance`: the first (in this ordering) explicitly set parameter is used.

Note

The main way to specify the brightness of the quad light via `intensity` and its alternative specifications via `power` or `radiance` differs in behavior when area (determined by `edge1` and `edge2`) is changing: With `intensity` or `power`, increasing the area will result in softer shadows (when soft shadows are supported by the implementation), but the overall brightness in the scene stays roughly the same. With `radiance` however, increasing the area will also result in a brighter illumination in the scene.

Measured light sources (IES, EULUMDAT, …) are supported by providing an `intensityDistribution` array to modulate the intensity per direction. The mapping is using the C-γ coordinate system: the values of the first (or only) dimension of `intensityDistribution` are uniformly mapped to γ in [0–π]; the first intensity value to 0, the last value to π, thus at least two values need to be present. If the array has a second dimension then the intensities are not rotational symmetric around `direction`, but are accordingly mapped to the C-halfplanes in [0–2π]; the first `row` of values to 0 and 2π, the other rows such that they have uniform distance to its neighbors. The orientation of the C0-plane is aligned with `edge1`.

The front side is determined by the cross product of `edge2` × `edge1`.

Note

Some renderers will compute soft shadows from the quad light. Other implementations may just sample the center of the quad light (resulting in hard shadows), or may not compute shadows at all.

5.7.5. Ring

Extension `KHR_LIGHT_RING`

The ring light is a light emitting into a cone of directions. It is created by passing the subtype string `ring` to `anariNewLight`. In addition to the general parameters understood by all lights, the ring light supports the special parameters listed in the table. The ring light is an area light and thus has a cosine falloff.

Table 33. Additional parameters understood by the ring light.

Name	Type	Default	Description
position	FLOAT32_VEC3	(0, 0, 0)	the center of the ring light
direction	FLOAT32_VEC3	(0, 0, -1)	main emission direction, the center axis of the ring
openingAngle	FLOAT32	π	full opening angle (in radians) of the cone of directions; outside of this cone is no illumination
falloffAngle	FLOAT32	0.1	size (angle in radians) of the region between the rim (of the illumination cone) and full intensity; should be smaller than half of `openingAngle`
radius	FLOAT32	0	the (outer) size of the ring, the radius of a disk with normal `direction`
innerRadius	FLOAT32	0	in combination with `radius` turns the disk into a ring; must be smaller than `radius`
intensity	FLOAT32	1	the overall amount of light emitted by the light in a direction, in W/sr
power	FLOAT32		alternative specification of the brightness (if `intensity` is not explicitly set): the overall amount of light energy emitted, in W
radiance	FLOAT32		alternative specification of the brightness (if neither `intensity` nor `power` is explicitly set): the amount of light emitted by a point on the light source in a direction, in W/sr/m^2
intensityDistribution	ARRAY1D / ARRAY2D of FLOAT32		luminous intensity distribution for photometric lights; can be 2D for asymmetric illumination; values are assumed to be uniformly distributed
c0	FLOAT32_VEC3	(1, 0, 0)	orientation, i.e., direction of the C0-(half)plane (only needed if illumination via `intensityDistribution` is asymmetric)

The precedence order is `intensity`, `power`, `radiance`: the first (in this ordering) explicitly set parameter is used.

Note

The main way to specify the brightness of the ring light via `intensity` and its alternative specifications via `power` or `radiance` differs in behavior when area (determined by `radius` and `innerRadius`) is changing: With `intensity` or `power`, increasing the area will result in softer shadows (when soft shadows are supported by the implementation), but the overall brightness in the scene stays roughly the same. With `radiance` however, increasing the area will also result in a brighter illumination in the scene. Using `radiance` is only meaningful if `radius` is larger than zero (otherwise the point light is not emitting any light).

Measured light sources (IES, EULUMDAT, …) are supported by providing an `intensityDistribution` array to modulate the intensity per direction. The mapping is using the C-γ coordinate system: the values of the first (or only) dimension of `intensityDistribution` are uniformly mapped to γ in [0–π]; the first intensity value to 0, the last value to π, thus at least two values need to be present. If the array has a second dimension then the intensities are not rotational symmetric around `direction`, but are accordingly mapped to the C-halfplanes in [0–2π]; the first `row` of values to 0 and 2π, the other rows such that they have uniform distance to its neighbors. The orientation of the C0-plane is specified via `c0`.

5.7.6. Spot

Extension `KHR_LIGHT_SPOT`

The spotlight is a light emitting into a cone of directions. It is created by passing the subtype string `spot` to `anariNewLight`. In addition to the general parameters understood by all lights, the spotlight supports the special parameters listed in the table.

Table 34. Additional parameters understood by the spotlight.

Name	Type	Default	Description
position	`FLOAT32_VEC3`	(0, 0, 0)	the center of the spotlight
direction	`FLOAT32_VEC3`	(0, 0, -1)	main emission direction, the axis of the spot
openingAngle	`FLOAT32`	π	full opening angle (in radians) of the spot; outside of this cone is no illumination
falloffAngle	`FLOAT32`	0.1	size (angle in radians) of the region between the rim (of the illumination cone) and full intensity of the spot; should be smaller than half of `openingAngle`
intensity	`FLOAT32`	1	the overall amount of light emitted by the light in a direction, in W/sr
power	`FLOAT32`		alternative specification of the brightness (if `intensity` is not explicitly set): the overall amount of light energy emitted, in W

The intensity distribution is constant within the core cone (`openingAngle` - 2 × `falloffAngle`) and then falls off to zero (smoothly interpolated with the smoothstep function).

If `intensity` and `power` are both explicitly set, then `intensity` takes precedence.

> *Note*
>
> The main way to specify the brightness of the spotlight via `intensity` and its alternative specification via `power` differs in behavior when the `openingAngle` is changing: Increasing the opening angle with `power` will result in roughly the same overall brightness in the scene, but already lit areas will become darker, because the same energy is spread over a larger cone of illumination. With `intensity` the behavior is the opposite.
>
> Power is the cosine-weighted integral of intensity over the cone of directions (within the opening angle). It can be approximated (ignoring the falloff) by π(1 -

$\cos^2 \frac{1}{2}$ openingAngle).

5.8. Surface

Geometries are matched with appearance information through Surfaces. These take a geometry, which defines the spatial representation, and applies either full-object or per-primitive color and material information. Surfaces are created with

```
ANARISurface anariNewSurface(ANARIDevice);
```

Table 35. Parameters understood by Surface.

Name	Type	Default	Description
geometry	GEOMETRY		Geometry object used by this surface
material	MATERIAL		Material applied to the geometry
visible	BOOL	TRUE	whether the surface is visible
id	UINT32	-1u	extension KHR_FRAME_CHANNEL_OBJECT_ID, optional user Id, for frame channel objectId

Surfaces require a valid Geometry to be set as the geometry parameter and a valid Material to be set as the material parameter.

5.9. Geometry

Geometries in ANARI are objects that describe the spatial representation of a surface. To create a new geometry object of given subtype subtype use

```
ANARIGeometry anariNewGeometry(ANARIDevice, const char *subtype);
```

All geometries support the following attribute setting parameters.

Table 36. Parameters understood by all geometries.

Name	Type	Description
color	FLOAT32_VEC4	uniform color attribute
attribute0	FLOAT32_VEC4	uniform attribute 0
attribute1	FLOAT32_VEC4	uniform attribute 1
attribute2	FLOAT32_VEC4	uniform attribute 2
attribute3	FLOAT32_VEC4	uniform attribute 3
primitive.color	ARRAY1D of Color	per-primitive color attribute
primitive.attribute0	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4	per-primitive attribute 0
primitive.attribute1	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4	per-primitive attribute 1
primitive.attribute2	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4	per-primitive attribute 2
primitive.attribute3	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4	per-primitive attribute 3

When both uniform and per-primitive attribute parameters are present, then the per-primitive parameter takes precedence. If geometries have additional per-vertex parameters specifying the same attribute, then the geometry specific `vertex.*` parameters take precedence.

> *Note*
>
> Geometries are typically limited to a maximum of 2^{32} primitives.

5.9.1. Cone

Extension `KHR_GEOMETRY_CONE`

A geometry consisting of individual cones, is created by calling `anariNewGeometry` with subtype string `cone`.

> *Note*
>
> Implementations are allowed to internally tessellate the cone, or to render them procedurally such that the cones are perfectly round.

Table 37. Additional parameters understood by the cone geometry.

Name	Type	Default	Description
vertex.position	ARRAY1D of FLOAT32_VEC3		required vertex positions
vertex.radius	ARRAY1D of FLOAT32		radius at each vertex
vertex.cap	ARRAY1D of UINT8		per-vertex end cap flags (0 means no caps, 1 means flat-capped)
vertex.color	ARRAY1D of Color		per-vertex color
vertex.attribute0	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		per-vertex attribute 0
vertex.attribute1	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		per-vertex attribute 1
vertex.attribute2	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		per-vertex attribute 2
vertex.attribute3	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		per-vertex attribute 3
primitive.index	ARRAY1D of UINT32_VEC2 / UINT64_VEC2	[(0, 1), (2, 3), …]	optional indices into the `vertex.*` arrays, each pair defines one cone
caps	STRING	`none`	default vertex caps for all cones if `vertex.cap` is not set, possible values: `none`, `first`, `second`, `both`

Parameter `vertex.position` must be set and contain at least two elements to yield a valid cone geometry.

If no `primitive.index` is given, then a "cone soup" is assumed, i.e., each two consecutive vertices form one cone (if the size of the `vertex.position` array is not a multiple of two the remainder vertex is ignored).

All `primitive.*` arrays must be at least as large as (explicitly set or implicitly derived) `primitive.index`. All `vertex.*` arrays must be large enough to be indexed by the indices in (explicitly set or implicitly derived) `primitive.index`, which must be at most device limit `geometryMaxIndex`.

5.9.2. Curve

Extension `KHR_GEOMETRY_CURVE`

A geometry consisting of multiple curves is created by calling `anariNewGeometry` with type string `curve`. The vertices of the curve(s) are connected by linear, round segments (i.e., cones or cylinders). The parameters defining this geometry are listed in the table below.

> *Note*
>
> Implementations are allowed to internally tessellate the curve, or to render them procedurally such that the curve segments are perfectly round.

Table 38. Additional parameters understood by the curve geometry.

Name	Type	Default	Description
vertex.position	`ARRAY1D` of `FLOAT32_VEC3`		required vertex positions
vertex.radius	`ARRAY1D` of `FLOAT32`		radius at each vertex
vertex.color	`ARRAY1D` of Color		per-vertex color
vertex.attribute0	`ARRAY1D` of `FLOAT32` / `FLOAT32_VEC2` / `FLOAT32_VEC3` / `FLOAT32_VEC4`		per-vertex attribute 0
vertex.attribute1	`ARRAY1D` of `FLOAT32` / `FLOAT32_VEC2` / `FLOAT32_VEC3` / `FLOAT32_VEC4`		per-vertex attribute 1
vertex.attribute2	`ARRAY1D` of `FLOAT32` / `FLOAT32_VEC2` / `FLOAT32_VEC3` / `FLOAT32_VEC4`		per-vertex attribute 2
vertex.attribute3	`ARRAY1D` of `FLOAT32` / `FLOAT32_VEC2` / `FLOAT32_VEC3` / `FLOAT32_VEC4`		per-vertex attribute 3
primitive.index	`ARRAY1D` of `UINT32` / `UINT64`	[0, 1, 2, …]	optional indices into `vertex.*` arrays, each index defines the start of one segment of a curve (the end is implicitly given with index+1)
radius	`FLOAT32`	1	default radius for all curve vertices (if `vertex.radius` is not set)

Parameter `vertex.position` must be set and contain at least two elements to yield a valid curve geometry. If no `primitive.index` is given, then a single curve is assumed, connecting all vertices.

All `primitive.*` arrays must be at least as large as (explicitly set or implicitly derived) `primitive.index`. All `vertex.*` arrays must be large enough to be indexed by the indices in (explicitly set or implicitly derived) `primitive.index`, which must be at most device limit `geometryMaxIndex` minus 1.

5.9.3. Cylinder

Extension `KHR_GEOMETRY_CYLINDER`

A geometry consisting of individual cylinders, each of which can have an own radius, is created by calling `anariNewGeometry` with subtype string `cylinder`.

> *Note*
>
> Implementations are allowed to internally tessellate the cylinder, or to render them procedurally such that the cylinders are perfectly round.

Table 39. Additional parameters understood by the cylinder geometry.

Name	Type	Default	Description
vertex.position	ARRAY1D of FLOAT32_VEC3		required vertex positions
vertex.cap	ARRAY1D of UINT8		per-vertex end cap flags (0 means no caps, 1 means flat-capped)
vertex.color	ARRAY1D of Color		per-vertex color
vertex.attribute0	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		per-vertex attribute 0
vertex.attribute1	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		per-vertex attribute 1
vertex.attribute2	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		per-vertex attribute 2
vertex.attribute3	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		per-vertex attribute 3
primitive.index	ARRAY1D of UINT32_VEC2 / UINT64_VEC2	[(0, 1), (2, 3), …]	optional indices into vertex.* arrays, each pair defines one cylinder
primitive.radius	ARRAY1D of FLOAT32		per-cylinder radius
radius	FLOAT32	1	default radius for all cylinders (if primitive.radius is not set)
caps	STRING	none	default vertex caps for all cylinders if vertex.cap is not set, possible values: none, first, second, both

Parameter vertex.position must be set and contain at least two elements to yield a valid cylinder geometry.

If no primitive.index is given, then a "cylinder soup" is assumed, i.e., each two consecutive vertices form one cylinder (if the size of the vertex.position array is not a multiple of two the remainder vertex is ignored).

All primitive.* arrays must be at least as large as (explicitly set or implicitly derived) primitive.index. All vertex.* arrays must be large enough to be indexed by the indices in (explicitly set or implicitly derived) primitive.index, which must be at most device limit geometryMaxIndex.

5.9.4. Isosurface

Extension KHR_GEOMETRY_ISOSURFACE

A geometry defined implicitly as the surface(s) of constant value of a spatial field is created by calling anariNewGeometry with subtype string isosurface. A isosurface geometry recognizes the following parameters:

Table 40. Additional parameters understood by the isosurface geometry.

Name	Type	Description
isovalue	FLOAT32 / ARRAY1D of FLOAT32	isovalue(s) defining the isosurface(s)
field	SPATIAL_FIELD	Spatial Field to be isosurfaced

Both parameters, isovalue and field, must be set to yield a valid isosurface geometry. If multiple isovalues are given (as array) then multiple surfaces are created, which are the primitives of the isosurface geometry.

5.9.5. Quad

Extension KHR_GEOMETRY_QUAD

A geometry consisting of quads is created by calling anariNewGeometry with subtype string quad. A quad geometry recognizes the following parameters:

Table 41. Additional parameters understood by the quad geometry.

Name	Type	Default	Description
vertex.position	ARRAY1D of FLOAT32_VEC3		required vertex positions
vertex.normal	ARRAY1D of FIXED16_VEC3 / FLOAT32_VEC3		vertex normals
vertex.tangent	ARRAY1D of FIXED16_VEC3 / FIXED16_VEC4 / FLOAT32_VEC3 / FLOAT32_VEC4		vertex tangents
vertex.color	ARRAY1D of Color		per-vertex color
vertex.attribute0	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		per-vertex attribute 0
vertex.attribute1	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		per-vertex attribute 1
vertex.attribute2	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		per-vertex attribute 2
vertex.attribute3	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		per-vertex attribute 3
faceVarying.normal	ARRAY1D of FIXED16_VEC3 / FLOAT32_VEC3		face-varying normals
faceVarying.tangent	ARRAY1D of FIXED16_VEC3 / FIXED16_VEC4 / FLOAT32_VEC3 / FLOAT32_VEC4		face-varying tangents
faceVarying.color	ARRAY1D of Color		face-varying colors
faceVarying.attribute0	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		face-varying attribute 0
faceVarying.attribute1	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		face-varying attribute 1
faceVarying.attribute2	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		face-varying attribute 2
faceVarying.attribute3	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		face-varying attribute 3
primitive.index	ARRAY1D of UINT32_VEC4 / UINT64_VEC4	[(0, 1, 2, 4), (5, 6, 7, 8), …]	optional indices (into the vertex array(s)), each 4-tuple defines one quad

Parameter `vertex.position` must be set and contain at least four elements to yield a valid quad geometry.

The fourth component of an element of `vertex.tangent` (if present) indicates the handedness of the tangent space coordinate system and thus must be 1 or -1.

Each element of `primitive.index` defines one quad, its four components index into the `vertex.*`

arrays. If no primitive.index is given, then a "quad soup" is assumed, i.e., each four consecutive vertices form one quad (if the size of the vertex.position array is not a multiple of four the remainder one, two, or three vertices are ignored).

All primitive.* arrays must be at least as large as (explicitly set or implicitly derived) primitive.index. All vertex.* arrays must be large enough to be indexed by the indices in (explicitly set or implicitly derived) primitive.index, which must be at most device limit geometryMaxIndex.

The faceVarying.* attributes map unique values to each (implicitly or explicitly) indexed primitive vertices, where each vertex takes a unique value per-primitive that uses it. Each primitive associates vertex attributes values from the attribute array using the formula 4 * primID + {0, 1, 2, 3}.

Face-varying attributes take precedence over vertex attributes when both arrays of the same attribute are present.

Table 42. Additional parameters understood by a quad geometry with extension KHR_GEOMETRY_QUAD_MOTION_DEFORMATION.

Name	Type	Default	Description
motion.vertex.position	ARRAY1D of ARRAY1D of FLOAT32_VEC3		uniformly distributed vertex position arrays
motion.vertex.normal	ARRAY1D of ARRAY1D of FIXED16_VEC3 / FLOAT32_VEC3		uniformly distributed vertex normal arrays
motion.vertex.tangent	ARRAY1D of ARRAY1D of FIXED16_VEC3 / FIXED16_VEC4 / FLOAT32_VEC3 / FLOAT32_VEC4		uniformly distributed vertex tangents arrays
time	FLOAT32_BOX1	[0, 1]	time associated with first and last key in motion.* arrays

The motion.* arrays represents uniformly (in time) distributed vertex data keys to achieve deformation motion blur in combination with extension KHR_CAMERA_SHUTTER.

5.9.6. Sphere

Extension KHR_GEOMETRY_SPHERE

A geometry consisting of individual spheres, each of which can have an own radius, is created by calling anariNewGeometry with subtype string sphere.

> *Note*
>
> Implementations are allowed to internally tessellate the sphere, or to render them procedurally such that the spheres are perfectly round.

Table 43. Additional parameters understood by the sphere geometry.

Name	Type	Default	Description
vertex.position	ARRAY1D of FLOAT32_VEC3		required center positions of the spheres
vertex.radius	ARRAY1D of FLOAT32		per-sphere radius
vertex.color	ARRAY1D of Color		per-vertex color
vertex.attribute0	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		per-vertex attribute 0
vertex.attribute1	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		per-vertex attribute 1
vertex.attribute2	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		per-vertex attribute 2
vertex.attribute3	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		per-vertex attribute 3
primitive.index	ARRAY1D of UINT32 / UINT64	[0, 1, 2, …]	optional indices (into the vertex array(s))
radius	FLOAT32	1	default radius for all spheres (if `vertex.radius` is not set)

Parameter `vertex.position` must be set to yield a valid sphere geometry.

Each element of `primitive.index` defines one sphere, indexing into the `vertex.*` arrays. If no `primitive.index` is given, then a "sphere soup" is assumed, using all spheres at `vertex.position`.

All `primitive.*` arrays must be at least as large as (explicitly set or implicitly derived) `primitive.index`. All `vertex.*` arrays must be large enough to be indexed by the indices in (explicitly set or implicitly derived) `primitive.index`, which must be at most device limit `geometryMaxIndex`.

5.9.7. Triangle

Extension `KHR_GEOMETRY_TRIANGLE`

A geometry consisting of triangles is created by calling `anariNewGeometry` with subtype string `triangle`. A triangle geometry recognizes the following parameters:

Table 44. Additional parameters understood by the triangle geometry.

Name	Type	Default	Description
vertex.position	ARRAY1D of FLOAT32_VEC3		required vertex positions
vertex.normal	ARRAY1D of FIXED16_VEC3 / FLOAT32_VEC3		vertex normals
vertex.tangent	ARRAY1D of FIXED16_VEC3 / FIXED16_VEC4 / FLOAT32_VEC3 / FLOAT32_VEC4		vertex tangents
vertex.color	ARRAY1D of Color		per-vertex color
vertex.attribute0	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		per-vertex attribute 0
vertex.attribute1	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		per-vertex attribute 1
vertex.attribute2	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		per-vertex attribute 2
vertex.attribute3	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		per-vertex attribute 3
faceVarying.normal	ARRAY1D of FIXED16_VEC3 / FLOAT32_VEC3		face-varying normals
faceVarying.tangent	ARRAY1D of FIXED16_VEC3 / FIXED16_VEC4 / FLOAT32_VEC3 / FLOAT32_VEC4		face-varying tangents
faceVarying.color	ARRAY1D of Color		face-varying colors
faceVarying.attribute0	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		face-varying attribute 0
faceVarying.attribute1	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		face-varying attribute 1
faceVarying.attribute2	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		face-varying attribute 2
faceVarying.attribute3	ARRAY1D of FLOAT32 / FLOAT32_VEC2 / FLOAT32_VEC3 / FLOAT32_VEC4		face-varying attribute 3
primitive.index	ARRAY1D of UINT32_VEC3 / UINT64_VEC3	[(0, 1, 2), (4, 5, 6), …]	optional indices (into the vertex array(s)), each 3-tuple defines one triangle

Parameter `vertex.position` must be set and contain at least three elements to yield a valid triangle geometry.

The fourth component of an element of `vertex.tangent` (if present) indicates the handedness of the tangent space coordinate system and thus must be 1 or -1.

Each element of `primitive.index` defines one triangle, its three components index into the `vertex.*`

arrays. If no primitive.index is given, then a "triangle soup" is assumed, i.e., each three consecutive vertices form one triangle (if the size of the vertex.position array is not a multiple of three the remainder one or two vertices are ignored).

All primitive.* arrays must be at least as large as (explicitly set or implicitly derived) primitive.index. All vertex.* arrays must be large enough to be indexed by the indices in (explicitly set or implicitly derived) primitive.index, which must be at most device limit geometryMaxIndex.

The faceVarying.* attributes map unique values to each (implicitly or explicitly) indexed primitive vertices, where each vertex takes a unique value per-primitive that uses it. Each primitive associates vertex attributes values from the attribute array using the formula `3 * primID + {0, 1, 2}`.

Face-varying attributes take precedence over vertex attributes when both arrays of the same attribute are present.

Table 45. Additional parameters understood by a triangle geometry with extension KHR_GEOMETRY_TRIANGLE_MOTION_DEFORMATION.

Name	Type	Default	Description
motion.vertex.position	ARRAY1D of ARRAY1D of FLOAT32_VEC3		uniformly distributed vertex position arrays
motion.vertex.normal	ARRAY1D of ARRAY1D of FIXED16_VEC3 / FLOAT32_VEC3		uniformly distributed vertex normal arrays
motion.vertex.tangent	ARRAY1D of ARRAY1D of FIXED16_VEC3 / FIXED16_VEC4 / FLOAT32_VEC3 / FLOAT32_VEC4		uniformly distributed vertex tangents arrays
time	FLOAT32_BOX1	[0, 1]	time associated with first and last key in motion.* arrays

The motion.* arrays represents uniformly (in time) distributed vertex data keys to achieve deformation motion blur in combination with extension KHR_CAMERA_SHUTTER.

5.10. Sampler

ANARI sampler objects map attribute data into other object inputs such materials. To create a new sampler use

```
ANARISampler anariNewSampler(ANARIDevice, const char *subtype);
```

Table 46. Parameters understood by samplers.

Name	Type	Default	Description
outTransform	FLOAT32_MAT4	((1, 0, 0, 0), (0, 1, 0, 0), (0, 0, 1, 0), (0, 0, 0, 1))	transform applied to the sampled values
outOffset	FLOAT32_VEC4	(0, 0, 0, 0)	offset added to output transform result

The sampled value is completed to four components (if needed: unspecified components default to zero for the first three components and to one for the fourth component), multiplied by `outTransform` and added to `outOffset` to yield the final result of the sampler.

> *Note*
>
> Like all `FLOAT32_MAT4` matrices `outTransform` is in column-major memory layout and is applied to column vectors (multiplied from the left `outTransform * x outOffset`).

5.10.1. Image1D

Extension `KHR_SAMPLER_IMAGE1D`

A one dimensional image sampler is created by calling `anariNewSampler` with subtype string `image1D`. It accepts the following parameters.

Table 47. Parameters understood by the 1D image sampler.

Name	Type	Default	Description
inAttribute	STRING	`attribute0`	surface attribute used as texture coordinate, possible values: float Attributes
inTransform	FLOAT32_MAT4	((1, 0, 0, 0), (0, 1, 0, 0), (0, 0, 1, 0), (0, 0, 0, 1))	transform applied to the input transform before sampling
inOffset	FLOAT32_VEC4	(0, 0, 0, 0)	offset added to input transform result
image	ARRAY1D of Color		array backing the sampler
filter	STRING	`linear`	filter of the sampler, possible values: `nearest`, `linear`
wrapMode	STRING	`clampToEdge`	wrap mode of the sampler, possible values: `clampToEdge`, `repeat`, `mirrorRepeat`

The attribute values indicated by `inAttribute` are first multiplied by the `inTransform` and added to the `inOffset`, then its first component is used as normalized coordinate to sample `image`, taking `filter` and `wrapMode` into account. Refer to [vulkan-samplers] for the exact definitions of the sampling and filtering operation.

Applications which set unknown values for filter will result in the default being used.

> *Note*
>
> Like all FLOAT32_MAT4 matrices inTransform is in column-major memory layout and is applied to column vectors (multiplied from the left inTransform * x inOffset).

5.10.2. Image2D

Extension KHR_SAMPLER_IMAGE2D

A two dimensional image sampler is created by calling anariNewSampler with subtype string image2D. It accepts the following parameters.

Table 48. Parameters understood by the 2D image sampler.

Name	Type	Default	Description
inAttribute	STRING	attribute0	surface attribute used as texture coordinate, possible values: float Attributes
inTransform	FLOAT32_MAT4	((1, 0, 0, 0), (0, 1, 0, 0), (0, 0, 1, 0), (0, 0, 0, 1))	transform applied to the input transform before sampling
inOffset	FLOAT32_VEC4	(0, 0, 0, 0)	offset added to input transform result
image	ARRAY2D of Color / FIXED8_VEC3 / FIXED8_VEC4		array backing the sampler
filter	STRING	linear	filter of the sampler, possible values: nearest, linear
wrapMode1	STRING	clampToEdge	wrap mode of the sampler for the 1st dimension, possible values: clampToEdge, repeat, mirrorRepeat
wrapMode2	STRING	clampToEdge	wrap mode of the sampler for the 2nd dimension, possible values: clampToEdge, repeat, mirrorRepeat

The attribute values indicated by inAttribute are first multiplied by the inTransform and added to the inOffset, then its first component is used as normalized coordinate to sample image, taking filter and wrapMode into account. Refer to [vulkan-samplers] for the exact definitions of the sampling and filtering operation.

Applications which set unknown values for filter will result in the default being used.

> *Note*
>
> Like all FLOAT32_MAT4 matrices inTransform is in column-major memory layout and is applied to column vectors (multiplied from the left inTransform * x inOffset).

5.10.3. Image3D

Extension KHR_SAMPLER_IMAGE3D

A three dimensional image sampler is created by calling anariNewSampler with subtype string image3D. It accepts the following parameters.

Table 49. Parameters understood by the 3D image sampler.

Name	Type	Default	Description
inAttribute	STRING	attribute0	surface attribute used as texture coordinate, possible values: float Attributes
inTransform	FLOAT32_MAT4	((1, 0, 0, 0), (0, 1, 0, 0), (0, 0, 1, 0), (0, 0, 0, 1))	transform applied to the input transform before sampling
inOffset	FLOAT32_VEC4	(0, 0, 0, 0)	offset added to input transform result
image	ARRAY3D of Color		array backing the sampler
filter	STRING	linear	filter of the sampler, possible values: nearest, linear
wrapMode1	STRING	clampToEdge	wrap mode of the sampler for the 1st dimension, possible values: clampToEdge, repeat, mirrorRepeat
wrapMode2	STRING	clampToEdge	wrap mode of the sampler for the 2nd dimension, possible values: clampToEdge, repeat, mirrorRepeat
wrapMode3	STRING	clampToEdge	wrap mode of the sampler for the 3rd dimension, possible values: clampToEdge, repeat, mirrorRepeat

The attribute values indicated by inAttribute are first multiplied by the inTransform and added to the inOffset, then its first component is used as normalized coordinate to sample image, taking filter and wrapMode into account. Refer to [vulkan-samplers] for the exact definitions of the sampling and filtering operation.

Applications which set unknown values for filter will result in the default being used.

> *Note*
>
> Like all FLOAT32_MAT4 matrices inTransform is in column-major memory layout and is applied to column vectors (multiplied from the left inTransform * x inOffset).

5.10.4. Primitive

Extension KHR_SAMPLER_PRIMITIVE

The primitive sampler samples an Array1D at integer coordinates based on the primitiveId surface attribute. It is created by calling anariNewSampler with subtype string primitive. The inOffset parameter value is added to primitiveId before sampling.

Table 50. Parameters understood by the primitive sampler.

Name	Type	Default	Description
array	ARRAY1D of Color		backing array of the sampler
inOffset	UINT64	0	offset into the array

> *Note*
>
> Primitive samplers serve a similar role as per primitive attributes on geometries but are attached to the material instead.

5.10.5. Transform

Extension `KHR_SAMPLER_TRANSFORM`

The transform sampler simply uses the input attribute as the "sampled" value. It is created by calling `anariNewSampler` with subtype string `transform`.

Table 51. Parameters understood by the transform sampler.

Name	Type	Default	Description
inAttribute	STRING	attribute0	surface attribute used as input

> *Note*
>
> The transform sampler does not actually sample any array or image but merely applies a transformation to an attribute for purposes such as swizzling or scaling the components.

5.11. Material

Materials describe how light interacts with surfaces to give objects their appearance. Materials are created with

```
ANARIMaterial anariNewMaterial(ANARIDevice, const char *subtype);
```

Most material parameters can be set to a constant, `ANARISampler` or string value. Unless otherwise noted, the string selects the surface attribute that will be used to source the parameter during rendering.

5.11.1. Matte

Extension `KHR_MATERIAL_MATTE`

The `matte` material reflects light uniformly into the hemisphere, i.e., it exhibits Lambertian reflectance and thus its apparent brightness is independent of the viewing direction. The matte material supports (partial) cut-out transparency depending on `alphaMode`.

Table 52. Parameters of the matte material.

Name	Type	Default	Description
color	FLOAT32_VEC3 / SAMPLER / STRING	(0.8, 0.8, 0.8)	diffuse color
opacity	FLOAT32 / SAMPLER / STRING	1.0	opacity
alphaMode	STRING	opaque	control cut-out transparency, possible values: opaque, blend, mask
alphaCutoff	FLOAT32	0.5	threshold when alphaMode is mask

If color is of type ANARI_SAMPLER or ANARI_STRING, the fourth component of the value fetched from a sampler or attribute is multiplied with the opacity value. The final opacity is determined by alphaMode:

- opaque: fully opaque (opacity treated as 1)
- blend: partial opacity
- mask: fully opaque (opacity treated as 1) if the computed opacity value is greater than or equal to alphaCutoff, otherwise fully transparent (opacity treated 0)

5.11.2. Physically Based

Extension KHR_MATERIAL_PHYSICALLY_BASED

The physicallyBased material offers a wealth of extensions while being user friendly. It aims to be compatible to glTF's pbrMetallicRoughness material and ratified Khronos material extensions, thus refer to [gltf-brdf] for the exact definitions of the BRDF and also non-normative implementation hints, as well as to glTF extensions KHR_materials_specular, KHR_materials_clearcoat, KHR_materials_emissive_strength, KHR_materials_ior, KHR_materials_transmission, KHR_materials_volume, KHR_materials_sheen, and KHR_materials_iridescence.

Table 53. Parameters of the physicallyBased material.

Name	Type	Default	Description
baseColor	FLOAT32_VEC3 / SAMPLER / STRING	(1.0, 1.0, 1.0)	base color
opacity	FLOAT32 / SAMPLER / STRING	1.0	opacity
metallic	FLOAT32 / SAMPLER / STRING	1.0	metalness
roughness	FLOAT32 / SAMPLER / STRING	1.0	roughness
normal	SAMPLER		normal map for the base layer
emissive	FLOAT32_VEC3 / SAMPLER / STRING	(0.0, 0.0, 0.0)	emissive
occlusion	SAMPLER		occlusion map
alphaMode	STRING	opaque	control cut-out transparency, possible values: opaque, blend, mask

Name	Type	Default	Description
alphaCutoff	FLOAT32	0.5	threshold when alphaMode is mask
specular	FLOAT32 / SAMPLER / STRING	0.0	strength of the specular reflection
specularColor	FLOAT32_VEC3 / SAMPLER / STRING	(1.0, 1.0, 1.0)	color of the specular reflection at normal incidence
clearcoat	FLOAT32 / SAMPLER / STRING	0.0	strength of the clearcoat layer
clearcoatRoughness	FLOAT32 / SAMPLER / STRING	0.0	roughness of the clearcoat layer
clearcoatNormal	SAMPLER		normal map for the clearcoat layer
transmission	FLOAT32 / SAMPLER / STRING	0.0	strength of the transmission
ior	FLOAT32	1.5	index of refraction
thickness	FLOAT32 / SAMPLER / STRING	0.0	thickness of the volume beneath the surface (with 0 the material is thin-walled)
attenuationDistance	FLOAT32	∞	average distance that light travels in the medium before interacting with a particle
attenuationColor	FLOAT32_VEC3	(1.0, 1.0, 1.0)	color that white light turns into due to absorption when reaching the attenuation distance
sheenColor	FLOAT32_VEC3 / SAMPLER / STRING	(0.0, 0.0, 0.0)	sheen color
sheenRoughness	FLOAT32 / SAMPLER / STRING	0.0	sheen roughness
iridescence	FLOAT32 / SAMPLER / STRING	0.0	strength of the thin-film layer
iridescenceIor	FLOAT32	1.3	index of refraction of the thin-film layer
iridescenceThickness	FLOAT32 / SAMPLER / STRING	0.0	thickness of the thin-film layer

If `baseColor` is of type `ANARI_SAMPLER` or `ANARI_STRING` and `alphaMode` is not `opaque`, the fourth component of the value fetched from a sampler or attribute is multiplied with the `opacity` value. The final opacity is determined by `alphaMode`:

- `opaque`: fully opaque (opacity treated as 1)
- `blend`: partial opacity
- `mask`: fully opaque (opacity treated as 1) if the computed opacity value is greater than or equal to

alphaCutoff, otherwise fully transparent (opacity treated 0)

The values sampled from samplers normal and clearcoatNormal represent tangent space normals (the first two components are expected to be in range [-1, 1] and the third component is expected to be in range [0, 1]).

> *Note*
>
> To use the glTF metallicRoughnessTexture create two samplers with the same image array and a "swizzle" outTransform for roughness.
>
> The normal maps normal and clearcoatNormal typically use an Image2D sampler with image array element type UFIXED8_VEC3 with a transformation from range [0, 1] to range [-1, 1] via outTransform and outOffset, computing 2 * texel - 1 per channel. The glTF scale parameter of normal maps should be factored into the outTransform and outOffset of the corresponding sampler. Putting it all together, set outTransform to ((2 * scale, 0, 0, 0), (0, 2 * scale, 0, 0), (0, 0, 2, 0), (0, 0, 0, 1)) and outOffset to (-scale, -scale, -1, 0).
>
> Similarly, glTF parameters emissiveStrength and emissiveFactor should be factored into emissive (or outTransform if emissive is an ANARI_SAMPLER).
>
> Also, the glTF parameters iridescenceThicknessMinimum and iridescenceThicknessMaximum should be mapped to outTransform and outOffset of the iridescenceThickness sampler.

> *Note*
>
> Implementations should apply the occlusion attenuation only for otherwise unoccluded ambient lighting. The glTF parameter strength should be factored into the diagonal of outTransform (as scale) and 1 - strength added to outOffset of its sampler.

5.12. Volume

Volumes in ANARI represent volumetric objects (complementing surfaces), encapsulating spatial data as well as appearance information. To create a new volume object of given subtype subtype use

```
ANARIVolume anariNewVolume(ANARIDevice, const char *subtype);
```

Table 54. Parameters understood by volumes.

Name	Type	Default	Description
visible	BOOL	TRUE	whether the volume is visible
id	UINT32	-1u	extension KHR_FRAME_CHANNEL_OBJECT_ID, optional user Id, for frame channel objectId

5.12.1. TransferFunction1D

Extension KHR_VOLUME_TRANSFER_FUNCTION1D

The 1D transfer function volume is created by passing the subtype string transferFunction1D to anariNewVolume. It supports the following parameters:

Table 55. Parameters understood by the transferFunction1D volume.

Name	Type	Default	Description
value	SPATIAL_FIELD		Spatial field used for the scalar values of the volume
valueRange	FLOAT32_BOX1 / FLOAT64_BOX1	[0, 1]	sampled values of value are clamped to this range
color	FLOAT32_VEC4 / FLOAT32_VEC3 / ARRAY1D of Color	(1.0, 1.0, 1.0, 1.0)	color to which the sampled values are mapped to
opacity	FLOAT32 / ARRAY1D of FLOAT32	1.0	opacity to which the sampled values are mapped to
unitDistance	FLOAT32	1.0	distance after which a 'opacity' fraction of light traveling through the volume is absorbed

> *Note*
>
> The color and opacity parameters together represent a transfer function, which is used to visually emphasize the structure or certain features in the value data.

The parameters color and opacity represent a look-up table to map the sampled values of the spatial field value (after clamping to valueRange) to a color and a opacity: The first array element representing the lowest value in valueRange and the last element representing the the last element in valueRange and elements are linearly interpolated in between. A color array can have a different size than a opacity array.

The fourth component of the resulting color is multiplied with the resulting opacity to form the final opacity.

The 1D transfer function volume represents (monochromatic) absorbing and (colored) light emitting particles whose local density is defined at each point of the spatial field by the final opacity and unitDistance: the fraction of light which is absorbed while traveling a unitDistance length through the volume will be 'opacity'.

> *Note*
>
> An opacity of 1.0 results in an infinitely high density of particles, a solid surface. Implementations may limit opacity to a value slightly smaller than one.

> *Note*
>
> A possible implementation of a rendering algorithm for this volume type is given

in Example Algorithm for Rendering a TransferFunction1D Volume (Informative).

5.13. Spatial Field

ANARI spatial field objects define collections of data values spread throughout a local coordinate system in order to be sampled in space. Spatial fields are created with

```
ANARISpatialField anariNewSpatialField(ANARIDevice, const char *subtype);
```

5.13.1. Structured Regular

Extension `KHR_SPATIAL_FIELD_STRUCTURED_REGULAR`

Structured regular spatial fields are created by passing the subtype string `structuredRegular` to `anariNewSpatialField`. The parameters understood by structured regular spatial fields are summarized in the table below.

Table 56. Configuration parameters for structured regular spatial fields.

Name	Type	Default	Description
data	`ARRAY3D` of `UFIXED8` / `FIXED16` / `UFIXED16` / `FLOAT32` / `FLOAT64`		the actual field values for the 3D grid, i.e., the scalars are vertex-centered; the size of the spatial field is inferred from `data`
origin	`FLOAT32_VEC3`	(0, 0, 0)	origin of the grid in object-space
spacing	`FLOAT32_VEC3`	(1, 1, 1)	size of the grid cells in object-space
filter	`STRING`	`linear`	filter used for reconstructing the field, possible values: `nearest`, `linear`, `cubic` (extension `KHR_SPATIAL_FIELD_STRUCTURED_REGULAR_FILTER_CUBIC`)

The spatial field grid can be moved with `origin` and scaled with `spacing`, in local object coordinates. The spatial field data is interpreted to be vertex-centered, which means at least two data values need to be specified in each dimension to avoid a degenerated spatial field. Its local bounds are [`origin`, `origin` + (`data`.size - 1) × `spacing`].

Applications which set unknown values for `filter` will result in the default being used.

Note

Structured regular fields only need to store the values of the samples, because their addresses in memory can be easily computed from a 3D position. A common type of structured spatial fields are regular grids.

5.13.2. NanoVDB

Extension `KHR_SPATIAL_FIELD_NANOVDB`

NanoVDB spatial fields are created by passing the subtype string `nanovdb` to `anariNewSpatialField`.

The parameters understood by NanoVDB spatial fields are summarized in the table below.

Table 57. Configuration parameters for NanoVDB spatial fields.

Name	Type	Default	Description
data	ARRAY1D of UINT8		NanoVDB grid, as a binary blob
filter	STRING	linear	filter used for reconstructing the field, possible values: nearest, linear, cubic

The data parameter content is expected to be a single NanoVDB grid, as read from a NanoVDB file or constructed by the NanoVDB API. The spatial field extent is implicitly defined in the grid header.

The device must support NanoVDB grids with major version 32.

Applications which set unknown values for filter will result in the default being used.

5.13.3. Unstructured

Extension KHR_SPATIAL_FIELD_UNSTRUCTURED

Unstructured spatial fields are created by passing the subtype string unstructured to anariNewSpatialField. The parameters understood by unstructured spatial fields are summarized in the table below.

Table 58. Configuration parameters for unstructured spatial fields.

Name	Type	Description
vertex.position	ARRAY1D of FLOAT32_VEC3	array of vertex positions
vertex.data	ARRAY1D of UFIXED8 / FIXED16 / UFIXED16 / FLOAT32 / FLOAT64	array of values at vertices
index	ARRAY1D of UINT32	array of indices into the vertex.* arrays that form cells
cell.data	ARRAY1D of UFIXED8 / FIXED16 / UFIXED16 / FLOAT32 / FLOAT64	alternative specification of the values (if vertex.data is not explicitly set): array of values in cells
cell.type	ARRAY1D of UINT8	array of cell types, where 10 encodes tetrahedral, 12 hexahedral, 13 wedge, and 14 pyramidal cells
cell.index	ARRAY1D of UINT32	array of indices into the index array, specifying the first (index of the) vertex of each cell

Sampled cell values can be specified either per-vertex (via vertex.data) or per-cell (via cell.data). If both arrays are explicitly set, vertex.data takes precedence.

Each cell is formed by a consecutive group of indices from index into the vertices, the first index of the group indicated by cell.index.

The index order for a tetrahedron (cell type 10) is bottom triangle counterclockwise, then the top vertex.

For hexahedral cells (type 12), each hexahedron is formed by a group of eight indices into the vertices and data values. Vertex ordering is four bottom vertices counterclockwise, then top four counterclockwise.

For wedge cells (type 13), each wedge is formed by a group of six indices into the vertices and data values. Vertex ordering is three bottom vertices counterclockwise, then top three counterclockwise.

For pyramid cells (type 14), each cell is formed by a group of five indices into the vertices and data values. Vertex ordering is four bottom vertices counterclockwise, then the top vertex.

> *Note*
>
> The unstructured spatial field is modeled after and thus compatible to `vtkUnstructuredGrid`: `cell.type` values are the same as VTK cell types, and the the index order of the cells is the same as their VTK counterparts (`VTK_TETRA`, `VTK_HEXAHEDRON`, `VTK_WEDGE`, and `VTK_PYRAMID`). The arrays `cell.index` corresponds to the Offsets array and `index` to the Connectivity array of (current, not legacy) `vtkCellArray`.

5.14. Extension Objects

Extensions may need to introduce custom object types. To create such an object use

```
ANARIObject anariNewObject(ANARIDevice, const char *type, const char *subtype);
```

Consult the extension documentation for supported `type` and `subtype` values.

Appendix A: Function Index (Informative)

- anariCommitParameters
- ANARIDeleterCallback
- anariDiscardFrame
- ANARIFrameCompletionCallback
- anariFrameReady
- anariGetDeviceExtensions
- anariGetDeviceSubtypes
- anariGetObjectInfo
- anariGetObjectSubtypes
- anariGetParameterInfo
- anariGetProperty
- anariLoadLibrary
- anariMapArray
- anariMapFrame
- anariMapParameterArray1D
- anariMapParameterArray2D
- anariMapParameterArray3D
- anariNewArray1D
- anariNewArray2D
- anariNewArray3D
- anariNewCamera
- anariNewDevice
- anariNewFrame
- anariNewGeometry
- anariNewGroup
- anariNewInstance
- anariNewLight
- anariNewMaterial
- anariNewObject
- anariNewRenderer
- anariNewSampler
- anariNewSpatialField
- anariNewSurface

- `anariNewVolume`
- `anariNewWorld`
- `anariRelease`
- `anariRenderFrame`
- `anariRetain`
- `anariSetParameter`
- `ANARIStatusCallback`
- `anariUnloadLibrary`
- `anariUnmapArray`
- `anariUnmapFrame`
- `anariUnmapParameterArray`
- `anariUnsetAllParameters`
- `anariUnsetParameter`

Appendix B: Extension Index (Informative)

- `KHR_ARRAY1D_REGION`: Permit runtime changeable valid array region
- `KHR_CAMERA_DEPTH_OF_FIELD`: depth of field is supported
- `KHR_CAMERA_MOTION_TRANSFORMATION`: camera transformation motion blur is supported
- `KHR_CAMERA_OMNIDIRECTIONAL`: `omnidirectional` camera subtype is supported
- `KHR_CAMERA_ORTHOGRAPHIC`: `orthographic` camera subtype is supported
- `KHR_CAMERA_PERSPECTIVE`: `perspective` camera subtype is supported
- `KHR_CAMERA_ROLLING_SHUTTER`: camera rolling shutter is supported
- `KHR_CAMERA_SHUTTER`: camera global shutter and motion blur in combination with other extensions is supported
- `KHR_CAMERA_STEREO`: 3D stereo rendering is supported
- `KHR_DATA_PARALLEL_MPI`: Data-parallel rendering using MPI is supported
- `KHR_DEVICE_SYNCHRONIZATION`: Relax API function synchronization requirement
- `KHR_FRAME_ACCUMULATION`: Frames are progressively rendered
- `KHR_FRAME_CHANNEL_NORMAL`: `channel.normal` is supported on ANARIFrame
- `KHR_FRAME_CHANNEL_ALBEDO`: `channel.albedo` is supported on ANARIFrame
- `KHR_FRAME_CHANNEL_PRIMITIVE_ID`: `channel.primitiveId` is supported on ANARIFrame
- `KHR_FRAME_CHANNEL_OBJECT_ID`: `channel.objectId` is supported on ANARIFrame
- `KHR_FRAME_CHANNEL_INSTANCE_ID`: `channel.instanceId` is supported on ANARIFrame
- `KHR_FRAME_COMPLETION_CALLBACK`: Frame completion callback function parameters on ANARIFrame are supported
- `KHR_GEOMETRY_CONE`: `cone` geometry subtype is supported
- `KHR_GEOMETRY_CURVE`: `curve` geometry subtype is supported
- `KHR_GEOMETRY_CYLINDER`: `cylinder` geometry subtype is supported
- `KHR_GEOMETRY_ISOSURFACE`: `isosurface` geometry subtype is supported
- `KHR_GEOMETRY_QUAD`: `quad` geometry subtype is supported
- `KHR_GEOMETRY_QUAD_MOTION_DEFORMATION`: `quad` geometry subtype supports deformation motion blur
- `KHR_GEOMETRY_SPHERE`: `sphere` geometry subtype is supported
- `KHR_GEOMETRY_TRIANGLE`: `triangle` geometry subtype is supported
- `KHR_GEOMETRY_TRIANGLE_MOTION_DEFORMATION`: `triangle` geometry subtype supports deformation motion blur
- `KHR_INSTANCE_TRANSFORM`: basic `transform` instance subtype is supported
- `KHR_INSTANCE_TRANSFORM_ARRAY`: the basic `transform` instance subtype supports matrix arrays
- `KHR_INSTANCE_MOTION_TRANSFORM`: `motionTransform` instance subtype and instance transformation

motion blur is supported

- KHR_INSTANCE_MOTION_SCALE_ROTATION_TRANSLATION: motionScaleRotationTranslation instance subtype and instance transformation motion blur is supported
- KHR_LIGHT_DIRECTIONAL: directional light subtype is supported
- KHR_LIGHT_HDRI: hdri light subtype is supported
- KHR_LIGHT_POINT: point light subtype is supported
- KHR_LIGHT_PRIMARY_VISIBILITY: whether primary visibility of area lights can be controlled
- KHR_LIGHT_QUAD: quad light subtype is supported
- KHR_LIGHT_RING: ring light subtype is supported
- KHR_LIGHT_SPOT: spot light subtype is supported
- KHR_MATERIAL_MATTE: matte material subtype is supported
- KHR_MATERIAL_PHYSICALLY_BASED: physicallyBased material subtype is supported
- KHR_RENDERER_AMBIENT_LIGHT: the renderer supports ambient lighting
- KHR_RENDERER_BACKGROUND_COLOR: the renderer supports a background color
- KHR_RENDERER_BACKGROUND_IMAGE: the renderer supports a background image
- KHR_RENDERER_DENOISE: the renderer supports denoising
- KHR_SAMPLER_IMAGE1D: image1D sampler subtype is supported
- KHR_SAMPLER_IMAGE2D: image2D sampler subtype is supported
- KHR_SAMPLER_IMAGE3D: image3D sampler subtype is supported
- KHR_SAMPLER_PRIMITIVE: primitive sampler subtype is supported
- KHR_SAMPLER_TRANSFORM: transform sampler subtype is supported
- KHR_SPATIAL_FIELD_NANOVDB: nanovdb spatial field subtype is supported
- KHR_SPATIAL_FIELD_STRUCTURED_REGULAR: structuredRegular spatial field subtype is supported
- KHR_SPATIAL_FIELD_STRUCTURED_REGULAR_FILTER_CUBIC: structuredRegular spatial field supports cubic filtering for parameter filter
- KHR_SPATIAL_FIELD_UNSTRUCTURED: unstructured spatial field subtype is supported
- KHR_VOLUME_TRANSFER_FUNCTION1D: transferFunction1D volume subtype is supported

Appendix C: Example Algorithm for Rendering a TransferFunction1D Volume (Informative)

The following is a possible ray-marching implementation of the `transferFunction1D` volume. Implementations are not required to implement this but are encouraged to use it as a reference when adapting other algorithms to produce visually similar results.

```
Color = 0
Transmittance = 1

while x in Volume
   StepValue = value(x)
   StepColor = color(StepValue).rgb
   StepOpacity = color(StepValue).a * opacity(StepValue)
   StepTransmittance = pow(1 - StepOpacity, Step / unitDistance)

   Color += Transmittance * (1 - StepTransmittance) * StepColor
   Transmittance *= StepTransmittance

   x += Direction * Step
```

Any transformations the volume is subject to are assumed to be taken into account during sampling of `value(x)`.

The current sample location `x` is in world space. The `Direction` vector is the view/ray direction and is assumed to be normalized. The variables `value`, `opacity`, `color` and `unitDistance` are parameters of the `transferFunction1D` volume object.

Appendix D: Credits (Informative)

ANARI 1.1 is the result of contributions from many people and companies participating in the Khronos ANARI Working Group, as well as input from the ANARI Advisory Panel.

Members of the Working Group, including the company that they represented at the time of their most recent contribution, are listed in the following section. Some specific contributions made by individuals are listed together with their name.

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Other Credits

The ANARI Advisory Panel members provided important real-world usage information and advice that helped guide design decisions.

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