



# ANARI<sup>TM</sup> 1.2.0 – Draft Specification

The Khronos<sup>®</sup> 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) (<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.

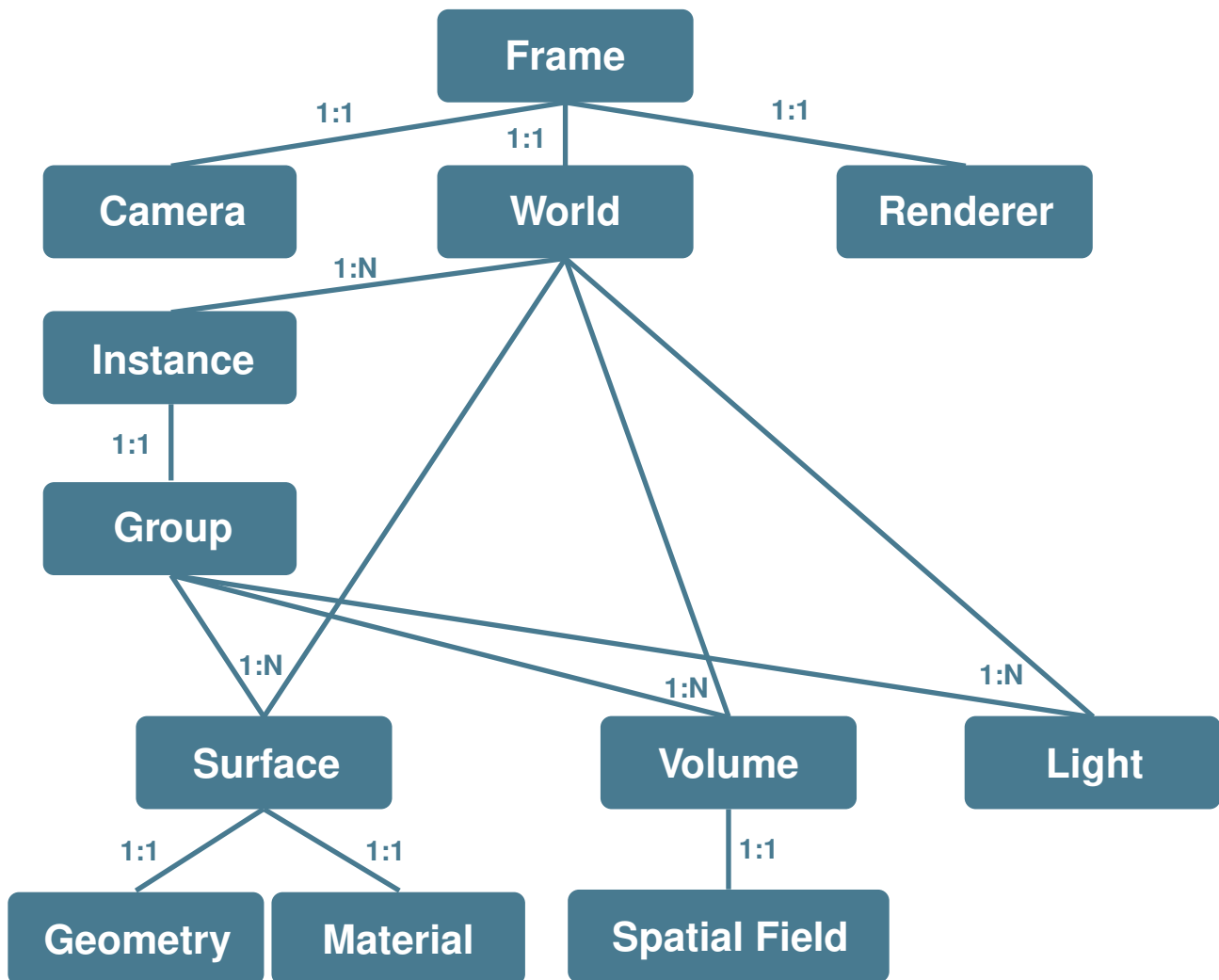
## 3.2. Scene Hierarchy (Informative)

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, ANARIObjct);  
  
void anariRetain(ANARIDevice, ANARIObjct);
```

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,  
    ANARIObjct,  
    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, ANARIObjct);
```

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,  
    ANARIObjct,  
    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 anariUnsetParameters(ANARIDevice, ANARIObjct);
```

Table 2. Data types.

| Name                   | Closest C99-Type                     | Description                   |
|------------------------|--------------------------------------|-------------------------------|
| <code>DATA_TYPE</code> | <code>ANARIDataType = int32_t</code> | 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            | ANARIParacter*               | array of ANARIParacter 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   |
|----------------------------|--------------------------|---|
| <code>FIXED16_VEC4</code>  | <code>int16_t[4]</code>  | four element 16 bit signed normalized fixed point vector    |
| <code>UFIXED16</code>      | <code>uint16_t</code>    | 16 bit unsigned normalized fixed point number               |
| <code>UFIXED16_VEC2</code> | <code>uint16_t[2]</code> | two element 16 bit unsigned normalized fixed point vector   |
| <code>UFIXED16_VEC3</code> | <code>uint16_t[3]</code> | three element 16 bit unsigned normalized fixed point vector |
| <code>UFIXED16_VEC4</code> | <code>uint16_t[4]</code> | four element 16 bit unsigned normalized fixed point vector  |
| <code>FIXED32</code>       | <code>int32_t</code>     | 32 bit signed normalized fixed point number                 |
| <code>FIXED32_VEC2</code>  | <code>int32_t[2]</code>  | two element 32 bit signed normalized fixed point vector     |
| <code>FIXED32_VEC3</code>  | <code>int32_t[3]</code>  | three element 32 bit signed normalized fixed point vector   |
| <code>FIXED32_VEC4</code>  | <code>int32_t[4]</code>  | four element 32 bit signed normalized fixed point vector    |
| <code>UFIXED32</code>      | <code>uint32_t</code>    | 32 bit unsigned normalized fixed point number               |
| <code>UFIXED32_VEC2</code> | <code>uint32_t[2]</code> | two element 32 bit unsigned normalized fixed point vector   |
| <code>UFIXED32_VEC3</code> | <code>uint32_t[3]</code> | three element 32 bit unsigned normalized fixed point vector |
| <code>UFIXED32_VEC4</code> | <code>uint32_t[4]</code> | four element 32 bit unsigned normalized fixed point vector  |
| <code>FIXED64</code>       | <code>int64_t</code>     | 64 bit signed normalized fixed point number                 |
| <code>FIXED64_VEC2</code>  | <code>int64_t[2]</code>  | two element 64 bit signed normalized fixed point vector     |
| <code>FIXED64_VEC3</code>  | <code>int64_t[3]</code>  | three element 64 bit signed normalized fixed point vector   |
| <code>FIXED64_VEC4</code>  | <code>int64_t[4]</code>  | four element 64 bit signed normalized fixed point vector    |
| <code>UFIXED64</code>      | <code>uint64_t</code>    | 64 bit unsigned normalized fixed point number               |
| <code>UFIXED64_VEC2</code> | <code>uint64_t[2]</code> | 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                                      |
| 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                                      |
| 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 an 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 <code>ANARIParameter</code> ) |
| channel     | STRING_LIST    | for FRAME     | list of supported channels   |
| extension   | STRING_LIST    | for RENDERERS | 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 <code>minimum..maximum</code> if present   |
| required    | BOOL                          | Yes                     | whether the parameter must be set for an object to be valid, must be <code>FALSE</code> if a <code>default</code> is present |
| softMinimum | type                          | No                      | typical minimum, must be in <code>minimum..maximum</code> if present (useful, e.g., for a slider widget)                     |
| softMaximum | type                          | No                      | typical maximum, must be in <code>minimum..maximum</code> if present (useful, e.g., for a slider widget)                     |
| elementType | DATA_TYPE_LIST                | for <code>ARRAYs</code> | array of supported element types of the <code>ANARIDevice</code> parameter, with last element <code>UNKNOWN</code>           |
| 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,
    ANARIObjct,
    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, ANARIObj, 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 | <code>UINT64_REGION1</code> | extension <code>KHR_ARRAY1D_REGION</code> , 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 ANARIParаметerValue
{
    const char *name;
    ANARIDataType type;
    const void *value;
};

ANARIDevice anariNewInitializedDevice(
    ANARILibrary,
    const char *subtype,
    ANARIParаметerValue *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 <a href="#">geometries</a> |
| 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,
    ANARIObjct 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 `ANARISStatusSeverity` 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         | <code>STATUS_CALLBACK</code> | callback used to report information to the application               |
| statusCallbackUserData | <code>VOID_POINTER</code>    | 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                 |
|-----------------------------|---------------------------|-----------------------------|
| <code>color</code>          | <code>FLOAT32_VEC4</code> | color                       |
| <code>worldPosition</code>  | <code>FLOAT32_VEC4</code> | world space position        |
| <code>worldNormal</code>    | <code>FLOAT32_VEC4</code> | world space shading normal  |
| <code>objectPosition</code> | <code>FLOAT32_VEC4</code> | object space position       |
| <code>objectNormal</code>   | <code>FLOAT32_VEC4</code> | object space shading normal |
| <code>attribute0</code>     | <code>FLOAT32_VEC4</code> | generic attribute 0         |
| <code>attribute1</code>     | <code>FLOAT32_VEC4</code> | generic attribute 1         |
| <code>attribute2</code>     | <code>FLOAT32_VEC4</code> | generic attribute 2         |
| <code>attribute3</code>     | <code>FLOAT32_VEC4</code> | generic attribute 3         |

| Identifier               | Internal Type                | Description  |
|--------------------------|------------------------------|--|
| <code>primitiveId</code> | <code>UINT32 / UINT64</code> | geometry specific primitive identifier, at most <code>device limit</code><br><code>geometryMaxIndex</code> 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 <code>anariRenderFrame</code> 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 <code>color</code> channel and specify its observable type; RGB color including alpha; possible values: <code>UFIXED8_VEC4</code> , <code>UFIXED8_RGBA_SRGB</code> , <code>FLOAT32_VEC4</code>   |
| channel.depth       | DATA_TYPE | enable mapping the <code>depth</code> channel and specify its observable type; euclidean distance to the camera ( <i>not</i> to the image plane), for multiple samples per pixel their minimum is taken; possible values: <code>FLOAT32</code>  |
| channel.normal      | DATA_TYPE | extension <code>KHR_FRAME_CHANNEL_NORMAL</code> , enable mapping the <code>normal</code> channel and specify its observable type; average world-space normal of the first hit; possible values: <code>FIXED16_VEC3</code> , <code>FLOAT32_VEC3</code>   |
| channel.albedo      | DATA_TYPE | extension <code>KHR_FRAME_CHANNEL_ALBEDO</code> , enable mapping the <code>albedo</code> channel and specify its observable type; average material albedo (color without illumination) at the first hit; possible values: <code>UFIXED8_VEC3</code> , <code>UFIXED8_RGB_SRGB</code> , <code>FLOAT32_VEC3</code> |
| channel.primitiveId | DATA_TYPE | extension <code>KHR_FRAME_CHANNEL_PRIMITIVE_ID</code> , enable mapping the <code>primitiveId</code> channel and specify its observable type; <code>primitiveId</code> attribute of the first hit; possible values: <code>UINT32</code>  |
| channel.objectId    | DATA_TYPE | extension <code>KHR_FRAME_CHANNEL_OBJECT_ID</code> , enable mapping the <code>objectId</code> channel and specify its observable type; user defined <code>Surface</code> / <code>Volume id</code> , possible values: <code>UINT32</code>  |
| channel.instanceId  | DATA_TYPE | extension <code>KHR_FRAME_CHANNEL_INSTANCE_ID</code> , enable mapping the <code>instanceId</code> channel and specify its observable type; user defined <code>Instance id</code> , possible values: <code>UINT32</code>   |

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 <code>anar iRenderFrame</code> , in [0..1] |
| refinementProgress | FLOAT32 | No       | extension <code>KHR_FRAME_ACCUMULATION</code> , 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 anar iNewCamera(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 <code>KHR_CAMERA_DEPTH_OF_FIELD</code> , size of the aperture, controls the depth of field  |
| focusDistance           | FLOAT32      | 1                | extension <code>KHR_CAMERA_DEPTH_OF_FIELD</code> , distance at where the image is sharpest when depth of field is enabled   |
| stereoMode              | STRING       | none             | extension <code>KHR_CAMERA_STEREO</code> , possible values: <code>none</code> , <code>left</code> , <code>right</code> , <code>sideBySide</code> , <code>topBottom</code> (left eye at top half)        |
| interpupillaryDistance  | FLOAT32      | 0.0635           | extension <code>KHR_CAMERA_STEREO</code> , distance between left and right eye when stereo is enabled   |
| shutter                 | FLOAT32_BOX1 | [0.5, 0.5]       | extension <code>KHR_CAMERA_SHUTTER</code> , start and end of shutter time, clamped to [0, 1]  |
| rollingShutterDirection | STRING       | none             | extension <code>KHR_CAMERA_ROLLING_SHUTTER</code> , rolling direction of the shutter, possible values: <code>none</code> , <code>left</code> , <code>right</code> , <code>down</code> , <code>up</code> |
| rollingShutterDuration  | FLOAT32      | 0                | extension <code>KHR_CAMERA_ROLLING_SHUTTER</code> , 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  |
|---------------------------------|---|---------|--|
| <code>motion.transform</code>   | ARRAY1D of <code>FLOAT32_MAT4</code>      |         | uniformly distributed world-space transformations                                      |
| <code>motion.scale</code>       | ARRAY1D of <code>FLOAT32_VEC3</code>      |         | uniformly distributed scale, overridden by <code>motion.transform</code>               |
| <code>motion.rotation</code>    | ARRAY1D of <code>FLOAT32_QUAT_IJKW</code> |         | uniformly distributed quaternion rotation, overridden by <code>motion.transform</code> |
| <code>motion.translation</code> | ARRAY1D of <code>FLOAT32_VEC3</code>      |         | uniformly distributed translation, overridden by <code>motion.transform</code>         |
| <code>time</code>               | <code>FLOAT32_BOX1</code>                 | [0, 1]  | time associated with first and last key in <code>motion.*</code> 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  |
|---------------------|----------------------|---------|--|
| <code>fovy</code>   | <code>FLOAT32</code> | $\pi/3$ | the field of view (angle in radians) of the frame's height |
| <code>aspect</code> | <code>FLOAT32</code> | 1       | ratio of width by height of the frame (and image region)   |
| <code>near</code>   | <code>FLOAT32</code> |         | near clip plane distance                                   |
| <code>far</code>    | <code>FLOAT32</code> |         | 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  $0 < \text{near} < \text{far}$ . 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 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 | <code>STRING</code> | <code>equirectangular</code> | pixel layout, possible values: <code>equirectangular</code> |

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 | <code>FLOAT32</code> | 1       | ratio of width by height of the frame (and image region) |
| height | <code>FLOAT32</code> | 1       | height of the image plane in world units                 |
| near   | <code>FLOAT32</code> |         | near clip plane distance                                 |
| far    | <code>FLOAT32</code> |         | 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  $0 \leq \text{near} < \text{far}$ . 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 | <code>STRING_LIST</code> | 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      | <b>FLOAT32_VEC4</b>            | (0, 0, 0, 1) | extension <b>KHR_RENDERER_BACKGROUND_COLOR</b> , the background color   |
| background      | <b>ARRAY2D</b> of <b>Color</b> |              | extension <b>KHR_RENDERER_BACKGROUND_IMAGE</b> , the background image, rescaled to the size of the <b>Frame</b> by linear filtering                     |
| ambientColor    | <b>FLOAT32_VEC3</b>            | (1, 1, 1)    | extension <b>KHR_RENDERER_AMBIENT_LIGHT</b> , ambient light color   |
| ambientRadiance | <b>FLOAT32</b>                 | 0            | extension <b>KHR_RENDERER_AMBIENT_LIGHT</b> , the amount of light emitted by a point on the ambient light source in a direction, in W/sr/m <sup>2</sup> |
| denoise         | <b>BOOL</b>                    | <b>FALSE</b> | extension <b>KHR_RENDERER_DENOISE</b> , 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. Worlds are created with

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

Objects are placed in the world through an array of instances, geometries, volumes, or lights. Each array of objects is optional (though there might be nothing to render).

Table 19. *Parameters* understood by the world.

| Name     | Type                              | Description                                     |
|----------|-----------------------------------|---|
| instance | <b>ARRAY1D</b> of <b>INSTANCE</b> | optional array with handles of <b>instances</b> |
| surface  | <b>ARRAY1D</b> of <b>SURFACE</b>  | optional array with handles of <b>surfaces</b>  |
| volume   | <b>ARRAY1D</b> of <b>VOLUME</b>   | optional array with handles of <b>volumes</b>   |
| light    | <b>ARRAY1D</b> of <b>LIGHT</b>    | optional array with handles of <b>lights</b>    |

Table 20. *Properties* queryable on a world.

| Name   | Type                | Description   |
|--------|---------------------|---|
| bounds | <b>FLOAT32_BOX3</b> | 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      | <a href="#">GROUP</a>        |   | <a href="#">Group</a> to be instanced, required  |
| transform  | <a href="#">FLOAT32_MAT4</a> | ((1, 0, 0, 0),<br>(0, 1, 0, 0),<br>(0, 0, 1, 0),<br>(0, 0, 0, 1)) | world-space transformation matrix for all attached objects   |
| id         | <a href="#">UINT32</a>       | -1u   | <a href="#">extension</a> <a href="#">KHR_FRAME_CHANNEL_INSTANCE_ID</a> , optional user Id, for frame <a href="#">channel</a> <a href="#">instanceId</a> |
| color      | <a href="#">FLOAT32_VEC4</a> |   | uniform color attribute  |
| attribute0 | <a href="#">FLOAT32_VEC4</a> |   | uniform attribute 0  |
| attribute1 | <a href="#">FLOAT32_VEC4</a> |   | uniform attribute 1  |
| attribute2 | <a href="#">FLOAT32_VEC4</a> |   | uniform attribute 2  |
| attribute3 | <a href="#">FLOAT32_VEC4</a> |   | 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 | <b>FLOAT32_BOX3</b> | 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 | <b>ARRAY1D</b> of <b>FLOAT32_MAT4</b> | array of matrices, instantiating <b>group</b> once per element   |
| id        | <b>ARRAY1D</b> of <b>UINT32</b>       | <b>extension</b> <b>KHR_FRAME_CHANNEL_INSTANCE_ID</b> , optional user Id, for frame <b>channel</b> <b>instanceId</b> |

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<br>FLOAT32_MAT4 |         | uniformly distributed world-space transformations                                 |
| time             | FLOAT32_BOX1               | [0, 1]  | time associated with first and last key in<br><code>motion.transform</code> 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<br>FLOAT32_VEC3      |         | uniformly distributed scale  |
| motion.rotation    | ARRAY1D of<br>FLOAT32_QUAT_IJKW |         | uniformly distributed quaternion rotation                                  |
| motion.translation | ARRAY1D of<br>FLOAT32_VEC3      |         | uniformly distributed translation  |
| time               | FLOAT32_BOX1                    | [0, 1]  | time associated with first and last key in<br><code>motion.*</code> 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 <code>KHR_LIGHT_PRIMARY_VISIBILITY</code> , 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 <sup>2</sup>                                  |
| radiance        | FLOAT32      |            | alternative specification of the brightness (if <i>irradiance</i> is not explicitly set): the amount of light emitted in a direction, in W/sr/m <sup>2</sup> |

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<br>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 <sup>2</sup> |
| layout    | STRING                     | equiangular | possible values: equiangular   |
| 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 <i>intensity</i> is not explicitly set): the overall amount of light energy emitted, in W   |
| radiance  | FLOAT32      |           | alternative specification of the brightness (if neither <i>intensity</i> nor <i>power</i> is explicitly set): the amount of light emitted by a point on the light source in a direction, in W/sr/m <sup>2</sup> |

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  $4\pi$  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              | <b>FLOAT32_VEC3</b>                 | (0, 0, 0)    | position of one vertex of the quad light  |
| edge1                 | <b>FLOAT32_VEC3</b>                 | (1, 0, 0)    | vector to one adjacent vertex   |
| edge2                 | <b>FLOAT32_VEC3</b>                 | (0, 1, 0)    | vector to the other adjacent vertex   |
| intensity             | <b>FLOAT32</b>                      | 1            | the overall amount of light emitted by the light in a direction, in W/sr  |
| power                 | <b>FLOAT32</b>                      |              | alternative specification of the brightness (if <b>intensity</b> is not explicitly set): the overall amount of light energy emitted, in W   |
| radiance              | <b>FLOAT32</b>                      |              | alternative specification of the brightness (if neither <b>intensity</b> nor <b>power</b> is not explicitly set): the amount of light emitted by a point on the light source in a direction, in W/sr/m <sup>2</sup> |
| side                  | <b>STRING</b>                       | <b>front</b> | side into which light is emitted; possible values: <b>front</b> , <b>back</b> , <b>both</b>   |
| intensityDistribution | <b>ARRAY1D / ARRAY2D of FLOAT32</b> |              | 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- $\gamma$  coordinate system: the values of the first (or only) dimension of `intensityDistribution` are uniformly mapped to  $\gamma$  in  $[0-\pi]$ ; the first intensity value to 0, the last value to  $\pi$ , 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  $[0-2\pi]$ ; the first row of values to 0 and  $2\pi$ , 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`  $\times$  `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                            | $\pi$      | 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 <i>openingAngle</i>   |
| radius                | FLOAT32                            | 0          | the (outer) size of the ring, the radius of a disk with normal <i>direction</i>   |
| innerRadius           | FLOAT32                            | 0          | in combination with <i>radius</i> turns the disk into a ring; must be smaller than <i>radius</i>  |
| 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 <i>intensity</i> is not explicitly set): the overall amount of light energy emitted, in W   |
| radiance              | FLOAT32                            |            | alternative specification of the brightness (if neither <i>intensity</i> nor <i>power</i> is explicitly set): the amount of light emitted by a point on the light source in a direction, in W/sr/m <sup>2</sup> |
| intensityDistribution | ARRAY1D /<br>ARRAY2D of<br>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 <i>intensityDistribution</i> 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- $\gamma$  coordinate system: the values of the first (or only) dimension of `intensityDistribution` are uniformly mapped to  $\gamma$  in  $[0-\pi]$ ; the first intensity value to 0, the last value to  $\pi$ , 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  $[0-2\pi]$ ; the first row of values to 0 and  $2\pi$ , 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     | <code>FLOAT32_VEC3</code> | (0, 0, 0)  | the center of the spotlight   |
| direction    | <code>FLOAT32_VEC3</code> | (0, 0, -1) | main emission direction, the axis of the spot   |
| openingAngle | <code>FLOAT32</code>      | $\pi$      | full opening angle (in radians) of the spot; outside of this cone is no illumination  |
| falloffAngle | <code>FLOAT32</code>      | 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 <code>openingAngle</code> |
| intensity    | <code>FLOAT32</code>      | 1          | the overall amount of light emitted by the light in a direction, in W/sr  |
| power        | <code>FLOAT32</code>      |            | alternative specification of the brightness (if <code>intensity</code> is not explicitly set): the overall amount of light energy emitted, in W                           |

The intensity distribution is constant within the core cone (`openingAngle` -  $2 \times$  `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  $\pi(1 -$

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

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

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 <b>FLOAT32_VEC3</b>  |                | required vertex positions   |
| vertex.radius     | ARRAY1D of <b>FLOAT32</b>   |                | radius at each vertex   |
| vertex.color      | ARRAY1D of <b>Color</b>   |                | per-vertex color  |
| vertex.attribute0 | ARRAY1D of <b>FLOAT32</b> / <b>FLOAT32_VEC2</b> / <b>FLOAT32_VEC3</b> / <b>FLOAT32_VEC4</b> |                | per-vertex attribute 0  |
| vertex.attribute1 | ARRAY1D of <b>FLOAT32</b> / <b>FLOAT32_VEC2</b> / <b>FLOAT32_VEC3</b> / <b>FLOAT32_VEC4</b> |                | per-vertex attribute 1  |
| vertex.attribute2 | ARRAY1D of <b>FLOAT32</b> / <b>FLOAT32_VEC2</b> / <b>FLOAT32_VEC3</b> / <b>FLOAT32_VEC4</b> |                | per-vertex attribute 2  |
| vertex.attribute3 | ARRAY1D of <b>FLOAT32</b> / <b>FLOAT32_VEC2</b> / <b>FLOAT32_VEC3</b> / <b>FLOAT32_VEC4</b> |                | per-vertex attribute 3  |
| primitive.index   | ARRAY1D of <b>UINT32</b> / <b>UINT64</b>  | [0, 1, 2, ...] | optional indices into <b>vertex.*</b> arrays, each index defines the start of one segment of a curve (the end is implicitly given with index+1) |
| radius            | <b>FLOAT32</b>  | 1              | default radius for all curve vertices (if <b>vertex.radius</b> 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 <i>vertex.*</i> arrays, each pair defines one cylinder   |
| primitive.radius  | ARRAY1D of FLOAT32  |                       | per-cylinder radius  |
| radius            | FLOAT32   | 1                     | default radius for all cylinders (if <i>primitive.radius</i> is not set)   |
| caps              | STRING  | none                  | default vertex caps for all cylinders if <i>vertex.cap</i> is not set, possible values: <i>none</i> , <i>first</i> , <i>second</i> , <i>both</i> |

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                | <i>Spatial Field</i> 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 <code>FLOAT32_VEC3</code>   |                                   | required vertex positions  |
| vertex.normal          | ARRAY1D of <code>FIXED16_VEC3</code> / <code>FLOAT32_VEC3</code>   |                                   | vertex normals   |
| vertex.tangent         | ARRAY1D of <code>FIXED16_VEC3</code> / <code>FIXED16_VEC4</code> / <code>FLOAT32_VEC3</code> / <code>FLOAT32_VEC4</code> |                                   | vertex tangents  |
| vertex.color           | ARRAY1D of <code>Color</code>  |                                   | per-vertex color   |
| vertex.attribute0      | ARRAY1D of <code>FLOAT32</code> / <code>FLOAT32_VEC2</code> / <code>FLOAT32_VEC3</code> / <code>FLOAT32_VEC4</code>      |                                   | per-vertex attribute 0   |
| vertex.attribute1      | ARRAY1D of <code>FLOAT32</code> / <code>FLOAT32_VEC2</code> / <code>FLOAT32_VEC3</code> / <code>FLOAT32_VEC4</code>      |                                   | per-vertex attribute 1   |
| vertex.attribute2      | ARRAY1D of <code>FLOAT32</code> / <code>FLOAT32_VEC2</code> / <code>FLOAT32_VEC3</code> / <code>FLOAT32_VEC4</code>      |                                   | per-vertex attribute 2   |
| vertex.attribute3      | ARRAY1D of <code>FLOAT32</code> / <code>FLOAT32_VEC2</code> / <code>FLOAT32_VEC3</code> / <code>FLOAT32_VEC4</code>      |                                   | per-vertex attribute 3   |
| faceVarying.normal     | ARRAY1D of <code>FIXED16_VEC3</code> / <code>FLOAT32_VEC3</code>   |                                   | face-varying normals   |
| faceVarying.tangent    | ARRAY1D of <code>FIXED16_VEC3</code> / <code>FIXED16_VEC4</code> / <code>FLOAT32_VEC3</code> / <code>FLOAT32_VEC4</code> |                                   | face-varying tangents  |
| faceVarying.color      | ARRAY1D of <code>Color</code>  |                                   | face-varying colors  |
| faceVarying.attribute0 | ARRAY1D of <code>FLOAT32</code> / <code>FLOAT32_VEC2</code> / <code>FLOAT32_VEC3</code> / <code>FLOAT32_VEC4</code>      |                                   | face-varying attribute 0   |
| faceVarying.attribute1 | ARRAY1D of <code>FLOAT32</code> / <code>FLOAT32_VEC2</code> / <code>FLOAT32_VEC3</code> / <code>FLOAT32_VEC4</code>      |                                   | face-varying attribute 1   |
| faceVarying.attribute2 | ARRAY1D of <code>FLOAT32</code> / <code>FLOAT32_VEC2</code> / <code>FLOAT32_VEC3</code> / <code>FLOAT32_VEC4</code>      |                                   | face-varying attribute 2   |
| faceVarying.attribute3 | ARRAY1D of <code>FLOAT32</code> / <code>FLOAT32_VEC2</code> / <code>FLOAT32_VEC3</code> / <code>FLOAT32_VEC4</code>      |                                   | face-varying attribute 3   |
| primitive.index        | ARRAY1D of <code>UINT32_VEC4</code> / <code>UINT64_VEC4</code>   | [(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  $4 * \text{primID} + \{0, 1, 2, 3\}$ .

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   |
|-------------------------------------|---|---------|---|
| <code>motion.vertex.position</code> | ARRAY1D of ARRAY1D of <code>FLOAT32_VEC3</code>   |         | uniformly distributed vertex position arrays                            |
| <code>motion.vertex.normal</code>   | ARRAY1D of ARRAY1D of <code>FIXED16_VEC3</code> / <code>FLOAT32_VEC3</code>   |         | uniformly distributed vertex normal arrays                              |
| <code>motion.vertex.tangent</code>  | ARRAY1D of ARRAY1D of <code>FIXED16_VEC3</code> / <code>FIXED16_VEC4</code> / <code>FLOAT32_VEC3</code> / <code>FLOAT32_VEC4</code> |         | uniformly distributed vertex tangents arrays                            |
| <code>time</code>                   | <code>FLOAT32_BOX1</code>   | [0, 1]  | time associated with first and last key in <code>motion.*</code> 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 <code>FLOAT32_VEC3</code>  |                | required center positions of the spheres                                  |
| vertex.radius     | ARRAY1D of <code>FLOAT32</code>   |                | per-sphere radius   |
| vertex.color      | ARRAY1D of <code>Color</code>   |                | per-vertex color  |
| vertex.attribute0 | ARRAY1D of <code>FLOAT32</code> / <code>FLOAT32_VEC2</code> / <code>FLOAT32_VEC3</code> / <code>FLOAT32_VEC4</code> |                | per-vertex attribute 0  |
| vertex.attribute1 | ARRAY1D of <code>FLOAT32</code> / <code>FLOAT32_VEC2</code> / <code>FLOAT32_VEC3</code> / <code>FLOAT32_VEC4</code> |                | per-vertex attribute 1  |
| vertex.attribute2 | ARRAY1D of <code>FLOAT32</code> / <code>FLOAT32_VEC2</code> / <code>FLOAT32_VEC3</code> / <code>FLOAT32_VEC4</code> |                | per-vertex attribute 2  |
| vertex.attribute3 | ARRAY1D of <code>FLOAT32</code> / <code>FLOAT32_VEC2</code> / <code>FLOAT32_VEC3</code> / <code>FLOAT32_VEC4</code> |                | per-vertex attribute 3  |
| primitive.index   | ARRAY1D of <code>UINT32</code> / <code>UINT64</code>  | [0, 1, 2, ...] | optional indices (into the vertex array(s))                               |
| radius            | <code>FLOAT32</code>  | 1              | default radius for all spheres (if <code>vertex.radius</code> 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 /<br>FLOAT32_VEC3                                  |                                   | vertex normals   |
| vertex.tangent         | ARRAY1D of FIXED16_VEC3 /<br>FIXED16_VEC4 / FLOAT32_VEC3 /<br>FLOAT32_VEC4 |                                   | vertex tangents  |
| vertex.color           | ARRAY1D of Color   |                                   | per-vertex color   |
| vertex.attribute0      | ARRAY1D of FLOAT32 / FLOAT32_VEC2<br>/ FLOAT32_VEC3 / FLOAT32_VEC4         |                                   | per-vertex attribute 0   |
| vertex.attribute1      | ARRAY1D of FLOAT32 / FLOAT32_VEC2<br>/ FLOAT32_VEC3 / FLOAT32_VEC4         |                                   | per-vertex attribute 1   |
| vertex.attribute2      | ARRAY1D of FLOAT32 / FLOAT32_VEC2<br>/ FLOAT32_VEC3 / FLOAT32_VEC4         |                                   | per-vertex attribute 2   |
| vertex.attribute3      | ARRAY1D of FLOAT32 / FLOAT32_VEC2<br>/ FLOAT32_VEC3 / FLOAT32_VEC4         |                                   | per-vertex attribute 3   |
| faceVarying.normal     | ARRAY1D of FIXED16_VEC3 /<br>FLOAT32_VEC3                                  |                                   | face-varying normals   |
| faceVarying.tangent    | ARRAY1D of FIXED16_VEC3 /<br>FIXED16_VEC4 / FLOAT32_VEC3 /<br>FLOAT32_VEC4 |                                   | face-varying tangents  |
| faceVarying.color      | ARRAY1D of Color   |                                   | face-varying colors  |
| faceVarying.attribute0 | ARRAY1D of FLOAT32 / FLOAT32_VEC2<br>/ FLOAT32_VEC3 / FLOAT32_VEC4         |                                   | face-varying attribute 0   |
| faceVarying.attribute1 | ARRAY1D of FLOAT32 / FLOAT32_VEC2<br>/ FLOAT32_VEC3 / FLOAT32_VEC4         |                                   | face-varying attribute 1   |
| faceVarying.attribute2 | ARRAY1D of FLOAT32 / FLOAT32_VEC2<br>/ FLOAT32_VEC3 / FLOAT32_VEC4         |                                   | face-varying attribute 2   |
| faceVarying.attribute3 | ARRAY1D of FLOAT32 / FLOAT32_VEC2<br>/ FLOAT32_VEC3 / FLOAT32_VEC4         |                                   | face-varying attribute 3   |
| primitive.index        | ARRAY1D of UINT32_VEC3 /<br>UINT64_VEC3                                    | [(0, 1, 2),<br>(4, 5, 6),<br>...] | optional indices (into the<br>vertex array(s)), each 3-tuple<br>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  $3 * \text{primID} + \{0, 1, 2\}$ .

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   |
|-------------------------------------|---|---------|---|
| <code>motion.vertex.position</code> | ARRAY1D of ARRAY1D of <code>FLOAT32_VEC3</code>   |         | uniformly distributed vertex position arrays                            |
| <code>motion.vertex.normal</code>   | ARRAY1D of ARRAY1D of <code>FIXED16_VEC3</code> / <code>FLOAT32_VEC3</code>   |         | uniformly distributed vertex normal arrays                              |
| <code>motion.vertex.tangent</code>  | ARRAY1D of ARRAY1D of <code>FIXED16_VEC3</code> / <code>FIXED16_VEC4</code> / <code>FLOAT32_VEC3</code> / <code>FLOAT32_VEC4</code> |         | uniformly distributed vertex tangents arrays                            |
| <code>time</code>                   | <code>FLOAT32_BOX1</code>   | [0, 1]  | time associated with first and last key in <code>motion.*</code> 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 | <b>FLOAT32_MAT4</b> | ((1, 0, 0, 0),<br>(0, 1, 0, 0),<br>(0, 0, 1, 0),<br>(0, 0, 0, 1)) | transform applied to the sampled values |
| outOffset    | <b>FLOAT32_VEC4</b> | (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.

The **KHR\_SAMPLER\_IMAGExD\_CLAMP\_TO\_BORDER** extension adds the **clampToBorder** mode to **wrapMode**.

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

| Name        | Type                           | Default   | Description  |
|-------------|--------------------------------|---|--|
| inAttribute | <b>STRING</b>                  | <b>attribute0</b>   | surface attribute used as texture coordinate, possible values: float <b>Attributes</b>   |
| inTransform | <b>FLOAT32_MAT4</b>            | ((1, 0, 0, 0),<br>(0, 1, 0, 0),<br>(0, 0, 1, 0),<br>(0, 0, 0, 1)) | transform applied to the input transform before sampling   |
| inOffset    | <b>FLOAT32_VEC4</b>            | (0, 0, 0, 0)  | offset added to input transform result   |
| image       | <b>ARRAY1D</b> of <b>Color</b> |   | array backing the sampler  |
| filter      | <b>STRING</b>                  | <b>linear</b>   | filter of the sampler, possible values: <b>nearest</b> , <b>linear</b>   |
| wrapMode    | <b>STRING</b>                  | <b>clampToEdge</b>  | wrap mode of the sampler, possible values: <b>clampToEdge</b> , <b>repeat</b> , <b>mirrorRepeat</b> , <b>clampToBorder</b> (extension <b>KHR_SAMPLER_IMAGExD_CLAMP_TO_BORDER</b> ) |
| borderColor | <b>FLOAT32_VEC4</b>            | (0, 0, 0, 0)  | extension <b>KHR_SAMPLER_IMAGExD_CLAMP_TO_BORDER</b> , border color used when <b>wrapMode</b> is <b>clampToBorder</b>  |

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  $\text{inTransform} * x$  `inOffset`).

### 5.10.2. Image2D

Extension `KHR_SAMPLER_IMAGE2D`

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

The `KHR_SAMPLER_IMAGExD_CLAMP_TO_BORDER` extension adds the `clampToBorder` mode to `wrapMode1` and `wrapMode2`.

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 <a href="#">Attributes</a>   |
| inTransform | FLOAT32_MAT4  | ((1, 0, 0, 0),<br>(0, 1, 0, 0),<br>(0, 0, 1, 0),<br>(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<br><a href="#">Color</a> /<br>FIXED8_VEC3 /<br>FIXED8_VEC4 |   | array backing the sampler   |
| filter      | STRING  | linear  | filter of the sampler, possible values: <a href="#">nearest</a> , <a href="#">linear</a>  |
| wrapMode1   | STRING  | clampToEdge   | wrap mode of the sampler for the 1st dimension, possible values: <a href="#">clampToEdge</a> , <a href="#">repeat</a> , <a href="#">mirrorRepeat</a> , <a href="#">clampToBorder</a> (extension <a href="#">KHR_SAMPLER_IMAGExD_CLAMP_TO_BORDER</a> ) |
| wrapMode2   | STRING  | clampToEdge   | wrap mode of the sampler for the 2nd dimension, possible values: <a href="#">clampToEdge</a> , <a href="#">repeat</a> , <a href="#">mirrorRepeat</a> , <a href="#">clampToBorder</a> (extension <a href="#">KHR_SAMPLER_IMAGExD_CLAMP_TO_BORDER</a> ) |
| borderColor | FLOAT32_VEC4  | (0, 0, 0, 0)  | extension <a href="#">KHR_SAMPLER_IMAGExD_CLAMP_TO_BORDER</a> , border color used when wrapMode is <a href="#">clampToBorder</a>  |

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  $\text{inTransform} * x$  [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.

The [KHR\\_SAMPLER\\_IMAGExD\\_CLAMP\\_TO\\_BORDER](#) extension adds the [clampToBorder](#) mode to [wrapMode1](#),

`wrapMode2` and `wrapMode3`.

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

| Name                     | Type                             | Default   | Description  |
|--------------------------|----------------------------------|---|--|
| <code>inAttribute</code> | STRING                           | <code>attribute0</code>   | surface attribute used as texture coordinate, possible values: float <a href="#">Attributes</a>  |
| <code>inTransform</code> | FLOAT32_MAT4                     | ((1, 0, 0, 0),<br>(0, 1, 0, 0),<br>(0, 0, 1, 0),<br>(0, 0, 0, 1)) | transform applied to the input transform before sampling   |
| <code>inOffset</code>    | FLOAT32_VEC4                     | (0, 0, 0, 0)  | offset added to input transform result   |
| <code>image</code>       | ARRAY3D of <a href="#">Color</a> |   | array backing the sampler  |
| <code>filter</code>      | STRING                           | <code>linear</code>   | filter of the sampler, possible values: <code>nearest</code> , <code>linear</code>   |
| <code>wrapMode1</code>   | STRING                           | <code>clampToEdge</code>  | wrap mode of the sampler for the 1st dimension, possible values: <code>clampToEdge</code> , <code>repeat</code> , <code>mirrorRepeat</code> , <code>clampToBorder</code> (extension <code>KHR_SAMPLER_IMAGExD_CLAMP_TO_BORDER</code> ) |
| <code>wrapMode2</code>   | STRING                           | <code>clampToEdge</code>  | wrap mode of the sampler for the 2nd dimension, possible values: <code>clampToEdge</code> , <code>repeat</code> , <code>mirrorRepeat</code> , <code>clampToBorder</code> (extension <code>KHR_SAMPLER_IMAGExD_CLAMP_TO_BORDER</code> ) |
| <code>wrapMode3</code>   | STRING                           | <code>clampToEdge</code>  | wrap mode of the sampler for the 3rd dimension, possible values: <code>clampToEdge</code> , <code>repeat</code> , <code>mirrorRepeat</code> , <code>clampToBorder</code> (extension <code>KHR_SAMPLER_IMAGExD_CLAMP_TO_BORDER</code> ) |
| <code>borderColor</code> | FLOAT32_VEC4                     | (0, 0, 0, 0)  | extension <code>KHR_SAMPLER_IMAGExD_CLAMP_TO_BORDER</code> , border color used when <code>wrapMode</code> is <code>clampToBorder</code>  |

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    | <code>ARRAY1D</code> of <code>Color</code> |         | backing array of the sampler |
| inOffset | <code>UINT64</code>                        | 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 | <code>STRING</code> | <code>attribute0</code> | 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       | <b>FLOAT32_VEC3</b> / <b>SAMPLER</b> / <b>STRING</b> | (0.8, 0.8, 0.8) | diffuse color   |
| opacity     | <b>FLOAT32</b> / <b>SAMPLER</b> / <b>STRING</b>      | 1.0             | opacity   |
| alphaMode   | <b>STRING</b>  | <b>opaque</b>   | control cut-out transparency, possible values: <b>opaque</b> , <b>blend</b> , <b>mask</b> |
| alphaCutoff | <b>FLOAT32</b>                                       | 0.5             | threshold when <b>alphaMode</b> is <b>mask</b>  |

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 | <b>FLOAT32_VEC3</b> / <b>SAMPLER</b> / <b>STRING</b> | (1.0, 1.0, 1.0) | base color                    |
| opacity   | <b>FLOAT32</b> / <b>SAMPLER</b> / <b>STRING</b>      | 1.0             | opacity                       |
| metallic  | <b>FLOAT32</b> / <b>SAMPLER</b> / <b>STRING</b>      | 1.0             | metalness                     |
| roughness | <b>FLOAT32</b> / <b>SAMPLER</b> / <b>STRING</b>      | 1.0             | roughness                     |
| normal    | <b>SAMPLER</b>                                       |                 | normal map for the base layer |
| emissive  | <b>FLOAT32_VEC3</b> / <b>SAMPLER</b> / <b>STRING</b> | (0.0, 0.0, 0.0) | emissive                      |
| occlusion | <b>SAMPLER</b>                                       |                 | occlusion map                 |



| Name                 | Type                            | Default         | Description  |
|----------------------|---------------------------------|-----------------|--|
| alphaMode            | STRING                          | opaque          | control cut-out transparency, possible values: <b>opaque</b> , <b>blend</b> , <b>mask</b>  |
| alphaCutoff          | FLOAT32                         | 0.5             | threshold when <b>alphaMode</b> is <b>mask</b>   |
| 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                         | $\infty$        | 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 <code>value</code> 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 <code>opacity</code> 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    | <code>ARRAY3D</code> of <code>UFIXED8</code> / <code>FIXED16</code> / <code>UFIXED16</code> / <code>FLOAT32</code> / <code>FLOAT64</code> |                     | the actual field values for the 3D grid, i.e., the scalars are vertex-centered; the size of the spatial field is inferred from <code>data</code>   |
| origin  | <code>FLOAT32_VEC3</code>   | (0, 0, 0)           | origin of the grid in object-space   |
| spacing | <code>FLOAT32_VEC3</code>   | (1, 1, 1)           | size of the grid cells in object-space   |
| filter  | <code>STRING</code>   | <code>linear</code> | filter used for reconstructing the field, possible values: <code>nearest</code> , <code>linear</code> , <code>cubic</code> (extension <code>KHR_SPATIAL_FIELD_STRUCTURED_REGULAR_FILTER_CUBIC</code> ) |

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 <code>UINT8</code> |                     | NanoVDB grid, as a binary blob   |
| filter | <code>STRING</code>           | <code>linear</code> | filter used for reconstructing the field, possible values: <code>nearest</code> , <code>linear</code> , <code>cubic</code> |

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 <code>vertex.*</code> arrays that form cells  |
| cell.data       | ARRAY1D of UFIXED8 / FIXED16 / UFIXED16 / FLOAT32 / FLOAT64 | alternative specification of the values (if <code>vertex.data</code> 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 <code>index</code> 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

```
ANRIOObject 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`
- `anariNewInitializedDevice`
- `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_IMAGE_CLAMPxD_TO_BORDER`:
  - `image1D` sampler `wrapMode` supports `clampToBorder`
  - `image2D` sampler `wrapMode1` and `wrapMode2` support `clampToBorder`
  - `image3D` sampler `wrapMode1`, `wrapMode2` and `wrapMode3` support `clampToBorder`
- `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: Changes in Version 1.2 (Informative)

## New Extensions

- `KHR_SAMPLER_IMAGExD_CLAMP_TO_BORDER`:
  - `image1D` sampler `wrapMode` supports `clampToBorder`
  - `image2D` sampler `wrapMode1` and `wrapMode2` support `clampToBorder`
  - `image3D` sampler `wrapMode1`, `wrapMode2` and `wrapMode3` support `clampToBorder`

## Changes to Core Functionality and Extensions

- Added `clampToBorder` to `wrapMode1`, `wrapMode2`, `wrapMode3` to `image1d`, `image2d` and `image3d` samplers.

# Appendix E: Changes in Version 1.1 (Informative)

## New Extensions

- `KHR_DATA_PARALLEL_MPI`: data-parallel rendering using MPI
- `KHR_GEOMETRY_ISOSURFACE`: `isosurface` geometry subtype
- `KHR_INSTANCE_TRANSFORM_ARRAY`: the basic `transform` instance subtype supports matrix arrays
- `KHR_LIGHT_PRIMARY_VISIBILITY`: whether primary visibility of area lights can be controlled
- `KHR_RENDERER_DENOISE`: the renderer supports denoising
- `KHR_SPATIAL_FIELD_NANOVDB`: `nanovdb` spatial field subtype
- `KHR_SPATIAL_FIELD_STRUCTURED_REGULAR_FILTER_CUBIC`: `structuredRegular` spatial field supports `cubic` filtering for parameter `filter`
- `KHR_SPATIAL_FIELD_UNSTRUCTURED`: `unstructured` spatial field subtype

## Changes to Core Functionality and Extensions

- New API function `anariNewInitializedDevice` to pass parameters which cannot be changed later; those parameters are indicated by the new `parameter info initializer`
- Added uniform attributes with parameters `color`, and `attribute0` to `attribute3` to `geometry` and `instance`
- Added face-varying normals, tangents, and attributes with parameters `faceVarying.normal`, `faceVarying.tangent`, `faceVarying.color`, and `faceVarying.attribute0` to `faceVarying.attribute3` to `triangle` and `quad` geometries
- Unified `outTransform` and `outOffset` parameters across all `samplers`, in particular for the `primitive` sampler
- Added `visible` parameter to `surface` and `volume`
- New `device` properties `anariVersion.major` and `anariVersion.minor` for targeted specification version
- New `parameter info` `softMinimum` and `softMaximum` as hints for GUI widgets
- Changed `ANARI_BOOL` to be 8 bit wide
- No implicit generation of user Ids anymore for extensions `KHR_FRAME_CHANNEL_OBJECT_ID` and `KHR_FRAME_CHANNEL_INSTANCE_ID`; if the `id` parameter is not explicitly set at `surface`, `volume`, or `instance`, then always the default -1u will be used

# Appendix F: 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.

## Working Group Contributors to ANARI

### ANARI 1.1

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## Other Credits

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