Buffer Objects

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Outline

- Background
- Buffer Objects
- Vertex Arrays
- Examples

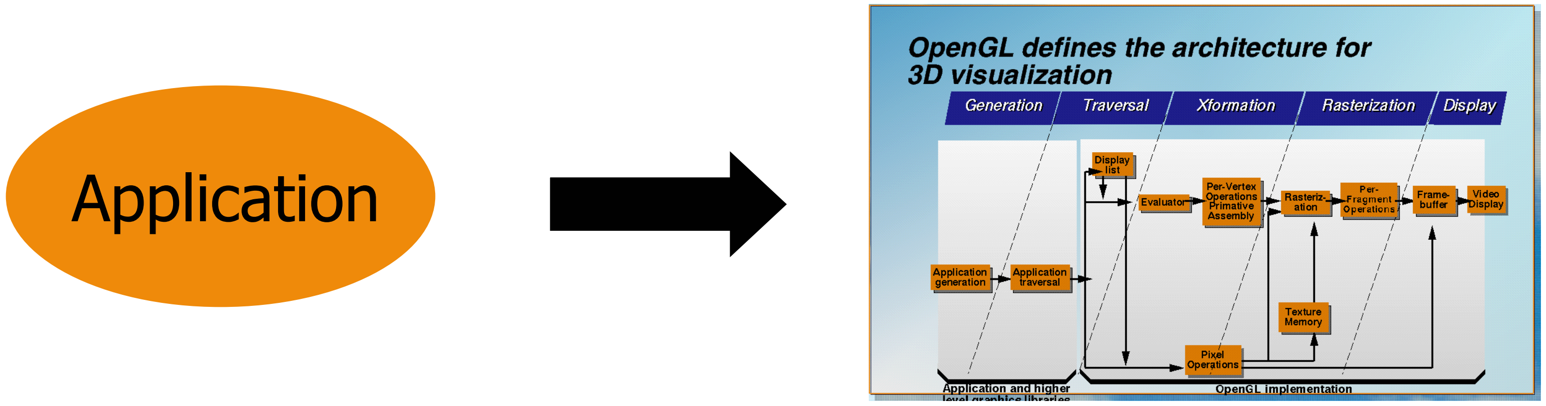
Background

- Geometry transfer is too slow
  - Begin/End is inefficient
  - Vertex array memory management is poor
- Vendor extensions are incompatible
  - `ATI_vertex_array_object`
  - `NV_vertex_array_range`
  - Others
- ATI and NVIDIA work together
  - `ARB_vertex_array_object`
- Result: `ARB_Vertex_Buffer_Object`

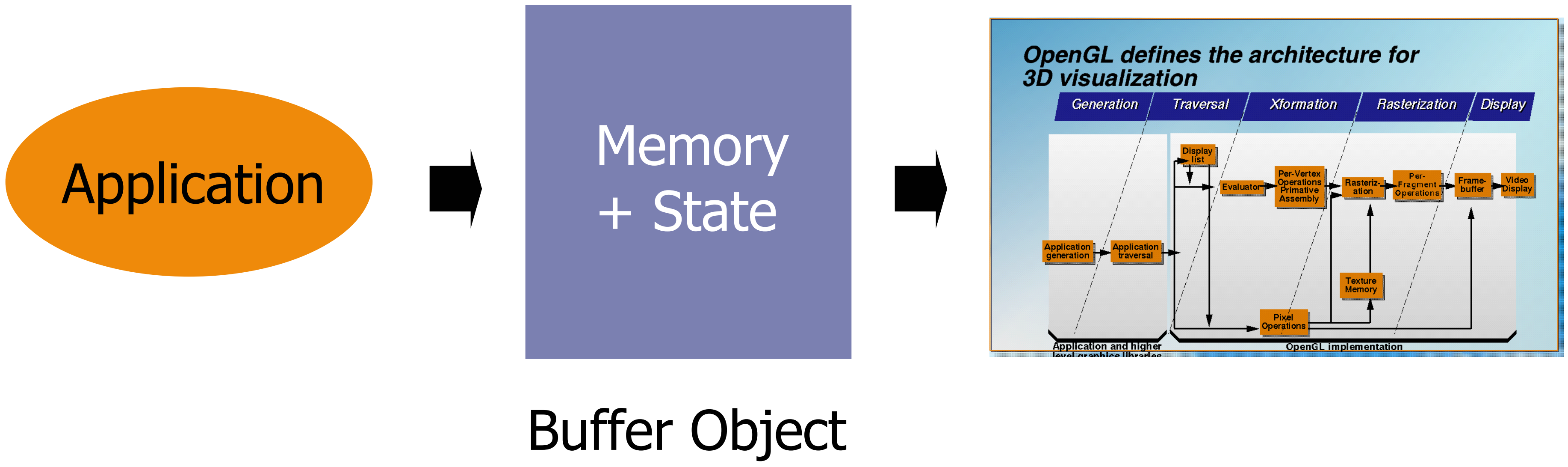
Requirements

- High Performance
  - Optimize for static and dynamic data
  - Use the “best” memory
  - Provide mapped access
- Good Application Fit
  - Support mixed static/dynamic data sets
  - Support “mix and match” of vertex data
    - e.g. multiple tex coord arrays for one position array
    - e.g. constant color
  - Minimize code changes

Architecture

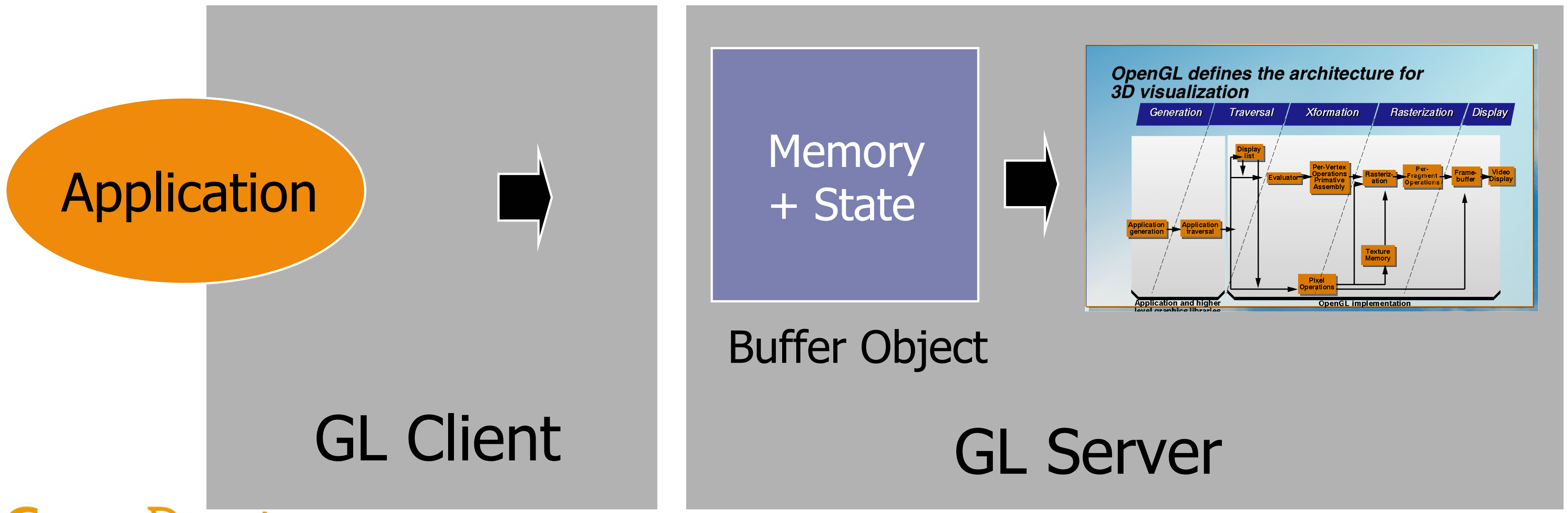


Architecture



Server-side state

- **Allows sharing between GL contexts**
- **Matches use of GPU memory**
- **Good for GLX client/server rendering**



Buffer Object

- Memory buffer
  - Array of basic machine units (bytes)
  - Data are in client format
- Small amount of state
  - Buffer size
  - Usage and access hints
  - Mapping state (Boolean and pointer)

Data format is implicit, not explicit

Basic API

```
void GenBuffersARB(n, *buffers);

void BindBufferARB(target, buffer);

void DeleteBuffersARB(n, *buffers);

boolean IsBufferARB(buffer);

void GetBufferParameterivARB(target, pname, *params);

void GetBufferPointervARB(target, pname, **params);
```

Example

```
uint buf;
int parameter;

GenBuffersARB(1, &buf);
BindBufferARB(GL_ARRAY_BUFFER_ARB, buf);
GetBufferParameterivARB(ARRAY_BUFFER_ARB,
        BUFFER_SIZE_ARB, &parameter);
printf("Buffer size is %d\n", parameter);
DeleteBuffers(1, &buf);
```

Creating a Data Store

- New buffer objects have no data store
- `BufferDataARB(target, size, *data, usage)`
  - Discards any existing data store
  - Creates a new data store
  - Optionally initializes the contents
  - Specifies the intended usage pattern
- Usage hint discussed later
- Data alignment is per client requirements
- Re-initialization is inexpensive – do it

Changing Data Store Contents

- Two approaches
  - Functional interface (set and query)
  - Mapping
- Functional
  - `BufferSubDataARB(target, offset, size, *data)`
  - `GetBufferSubDataARB(target, offset, size, *data)`
  - This is the default approach
    - Static data
    - Array data
  - Always a safe approach
    - Data are never corrupted

Mapping a Buffer Object

- Intended for data streams
- `void *MapBufferARB(target, access)`
  - `READ_ONLY_ARB, WRITE_ONLY_ARB, READ_WRITE_ARB`
  - Maps the entire data store
  - Returns a pointer to the buffer memory
  - May be slow if data are copied
  - May result in data loss
- `boolean UnmapBufferARB(target)`
  - Returns true if data are uncorrupted
  - Invalidates pointer

Mapping Rules

- Specify the correct `access` value
  - Otherwise operation is undefined
- Be prepared for data loss
  - Use functional interface if this is a burden
- Don’t render from a mapped buffer
  - The error INVALID_OPERATION results
- Map for brief periods only
  - Map it, modify it, then unmap it
- Don’t pass a map pointer to the GL

Summary

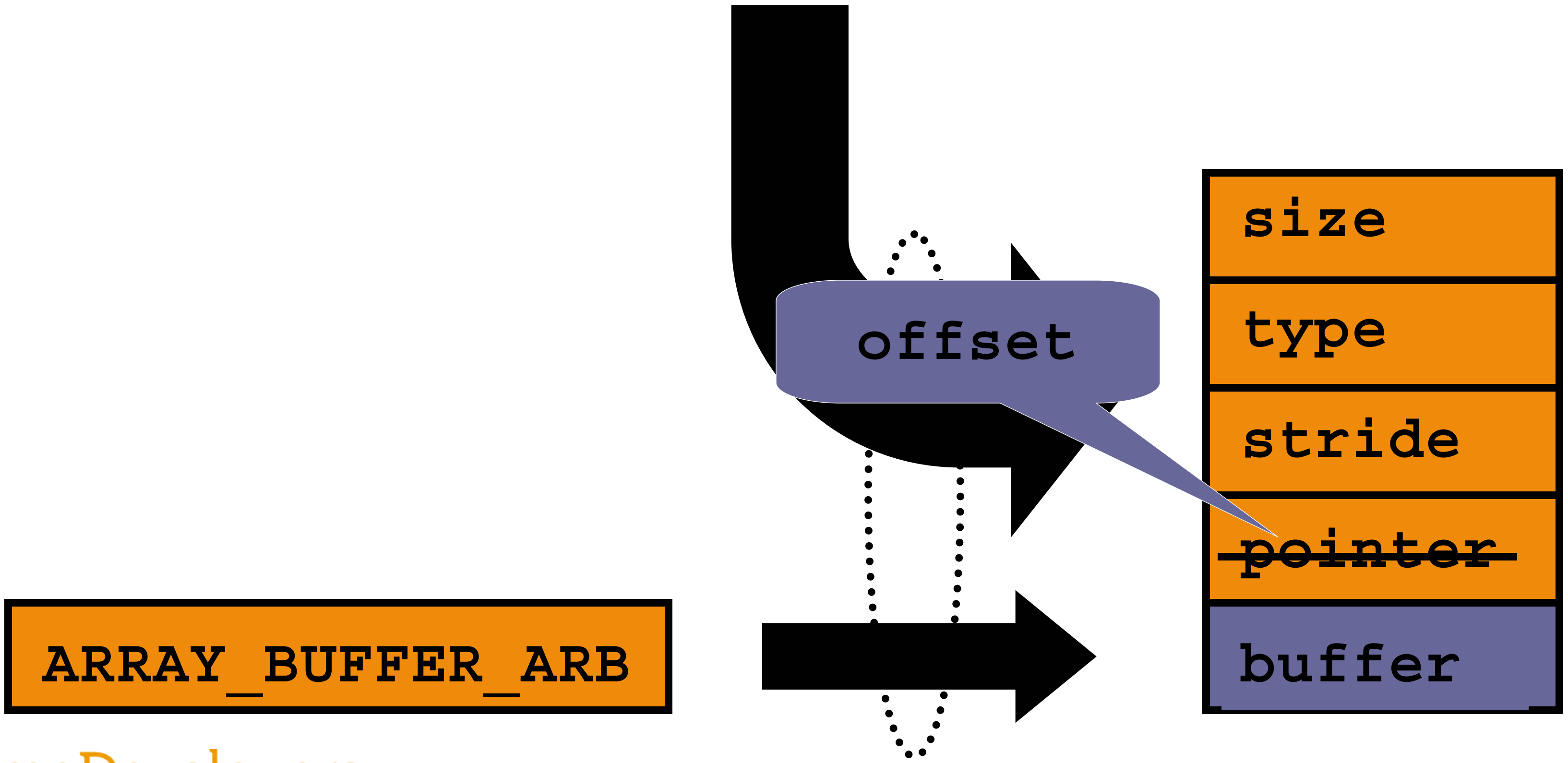
- Buffer objects
  - Unformatted, server-side memory buffers
  - Include a small amount of state
- Two ways to modify buffer contents
  - Functional interface
  - Direct mapping
- Very general mechanism
  - Could work for any GL data stream
  - Implemented for vertex arrays

Vertex Arrays

- Vertex arrays are application state
- Two-step process
  - App specifies array locations and formats
  - GL pulls vertex data from arrays
- Goals
  - Store vertex arrays in buffer objects
  - Maximize flexibility
  - Avoid misuse of the mapping pointer
  - Avoid a cluttered, incompatible API

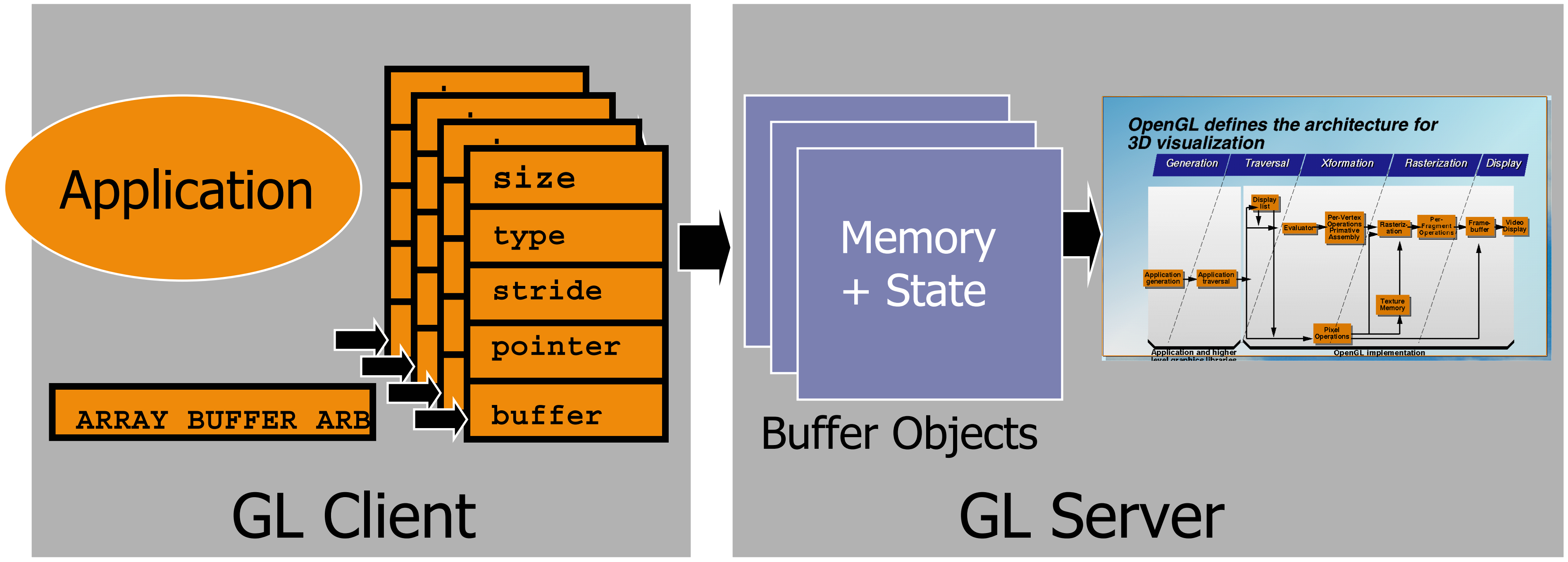
Per-Array Buffer Specification

```
VertexPointer(size, type, stride, *pointer);
```



Client and Server State

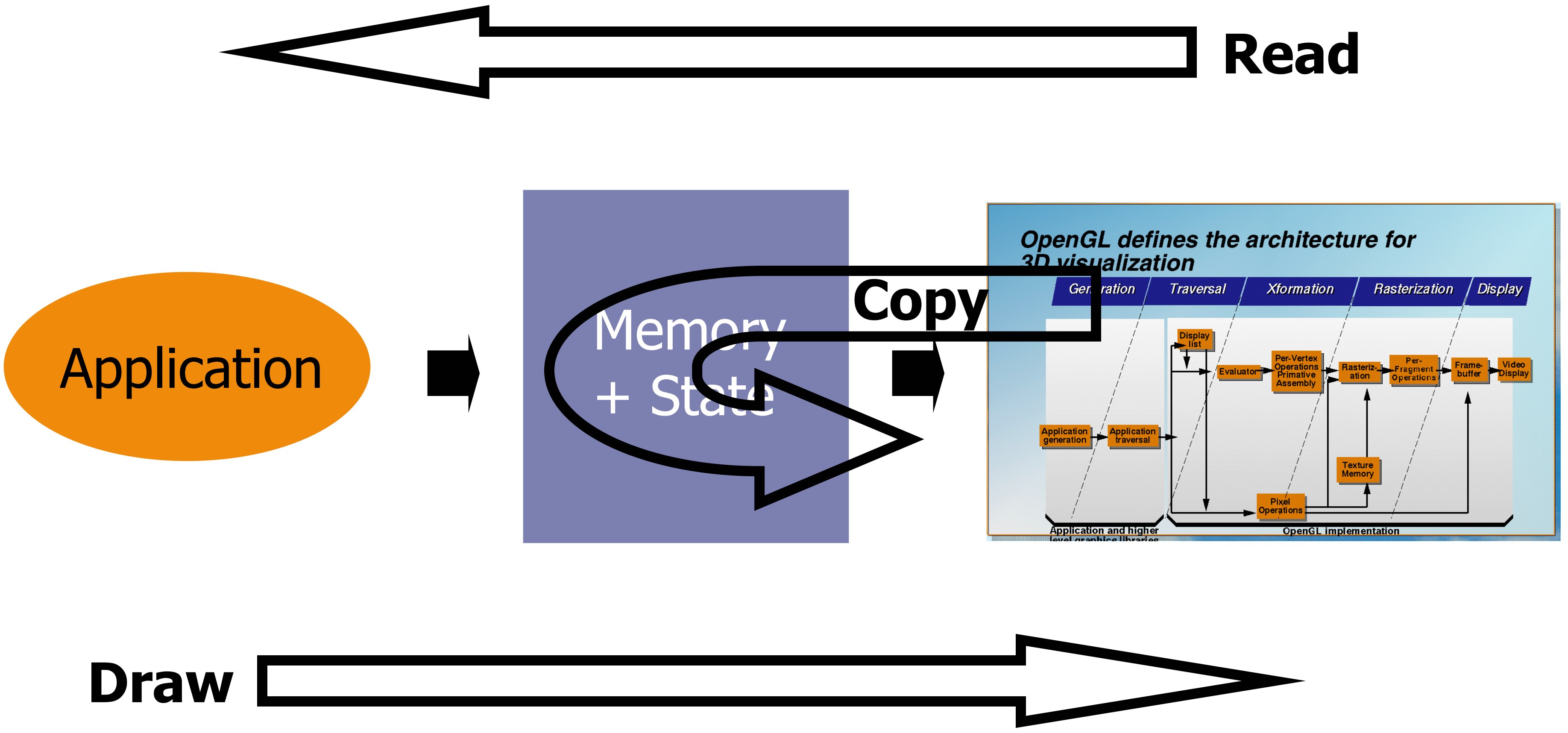
- **Buffer objects are server state**
- **Vertex arrays parameters are client state**



Usage Terms

- Stream
  - Specify once
  - Render once
- Static
  - Specify once
  - Render repeatedly
- Dynamic
  - Everything else
  - Specify/modify repeatedly
  - Render repeatedly

Usage Terms


Read
Application
Memory + State
Copy
OpenGL defines the architecture for 3D visualization
Generation
Traversal
Xformation
Rasterization
Display
Display list
Evaluator
Per-Vertex Operations Primative Assembly
Rasterization
Per-Fragment Operations
Frame-buffer
Video Display
Application generation
Application traversal
Texture Memory
Pixel Operations
Application and higher level graphics libraries
OpenGL implementation
Draw

Usages

Vertex Array Usage

	Draw	Read	Copy
Stream	STREAM_DRAW	STREAM_READ	STREAM_COPY
Static	STATIC_DRAW	STATIC_READ	STATIC_COPY
Dynamic	DYNAMIC_DRAW	DYNAMIC_READ	DYNAMIC_COPY

Example

```
#define BUFFER_OFFSET(i) ((char *)NULL + (i))

data = malloc(320);
...                                         // Fill system memory buffer
BindBufferARB(ARRAY_BUFFER_ARB, 1);
BufferDataARB(ARRAY_BUFFER_ARB, 320, data, STATIC_DRAW_ARB);
free(data);
while (...) {
    BindBufferARB(ARRAY_BUFFER_ARB, 1);     // must precede pointer cmds
    VertexPointer(4, FLOAT, 0, BUFFER_OFFSET(0));
    ColorPointer(4, UNSIGNED_BYTE, 0, BUFFER_OFFSET(256));
    EnableClientState(VERTEX_ARRAY);
    EnableClientState(COLOR_ARRAY);
    DrawArrays(TRIANGLE_STRIP, 0, 16);
    ...                                     // Other rendering commands
}
```

Notes

- Index arrays are supported
  - `ELEMENT_ARRAY_BUFFER_ARB`
- Other extensions are supported
  - `EXT_vertex_shader`
  - `ARB_vertex_program`
  - `...`
- Display lists are not supported
- intptr and sizeofptr types are introduced
- GLX protocol is not yet defined

Tips

- Keep static and dynamic data in separate buffer objects
- Keep vertex and index data separate
- Bind to the "correct" target
- Reinitialize data buffers
- Use mapping carefully
  - stream data
  - volatile memory
- More extensions coming soon (PBO)