BPX Format

https://github.com/BlockProject3D/

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Abstract

This document describes the BPX format, providing an optimized, flexible and DRM [12] free storage designed for various multimedia content types commonly used in 3D applications.

1 Introduction

When developing a 3D game engine often comes the problem of dealing with game modifications (mods). For example one might consider how easy would it be for the end player to add custom assets, change existing assets; would the end player need to agree against certain complex licences or if it is even legally allowed to modify the content of certain asset files.
Here the term asset refers to various type of file loaded by the game for a specific game world or for the entire game. These resources can be multimedia files, scripts, configurations and other formats the game engine would use.
This format provides an alternative to existing asset formats geared towards the development of highly moddable (modify the game; add new assets, remove existing assets, change existing assets) and cross platform 3D games. The benefits are:

- Open source with a permissive licence.
  Redistribute source code, allow improvements of the format by others.
- DRM [12] free.
  Avoid licensing problems and restrictions. DRM stands for Digital Rights Management and is used to control how the user is allowed to interact with certain multimedia content. In moddable game DRM usually restricts the user from modifying existing assets.
- Flexible.
  Designed for providing support for moddability. The nature of container allows support for all kind of multimedia resources used in a typical real-time 3D application.
- Optimized for 3D APIs such as OpenGL [4], DirectX [8], Vulkan [5]
  Certain types of BPX uses some assumptions on the input data in order to reduce pre-process time when loading assets in a typical real time rendering engine.
- Cross platform.
  Can store data for compatibility over multiple platforms within a single file due to its nature of containers.

2 History

The BPX format also refered to BlockProject Extended is a remake of an old format designed for the first version of the BlockProject 3D engine as an attempt to allow moddability, that means change the behaviour of a game while it's running and in this case change also any multimedia asset including scenes, shaders, models and even textures...
This has proved to be a difficult task due to licensing issues, restrictions imposed by existing frameworks and restrictions imposed by certain formats.
As a result a custom asset format has been developed for initially a very limited set of type of assets in order to solve the issue.
This format is an evolution geared towards re-usability and performance.

3 Comparison against mainstream formats

Below is a non-exhaustive table showing the differences between the idea of BPX and existing mainstream formats:

Name	Open	DRM	Flexible	Optimized	Compat.
FBX	No	No	No	Yes	Partial
Unreal	No	Yes	Yes	Yes	Partial
Unity	No	Yes	Partial	Yes	Partial
OBJ	Yes	No	No	No	Yes

- FBX: It is possible to save files as Text based FBX however no open documentations exists for the format. The binary FBX requires the use of a closed source library FBX supports Windows without issues however getting the SDK to work on different platforms might be an issue.
  FBX is designed to support 3D models.
- The source code of Unreal can be accessed if you are agree to certain licences which prohibits the redistribution of the editor source code in the game preventing the use of Unreal's format as a base to support modding. Unreal does also not provide easy installations under Linux.
  Unreal is also using a unified format for all assets of the game. It has support for modding however the modder is required to agree to licences and to download the full SDK.
- Unity although it has better support for Linux it might still be a bit tricky in certain combinations of distribution/system.
  Unity is also using a unified format for all assets of the game but the game engine does not allow load of arbitrary custom assets. The asset format used by unity is also closed and does not permit modification by the player of the game like Unreal.
- OBJ is a text based 3D model format. The format has no support for skeletal based models/animations and has poor support for materials.

4 General

The format is based on the idea of a container with a reusable main header that can be extended for the different applications.
The following assumptions are used:

- A byte is assumed to be 8 bits.
- The sizes are expressed in bits in the entire document.
- The byte order in a BPX file should be **little endian** to match most of current hardware/software architectures, and then avoid a pre-processing step when loading the file.
- A transformation is stored in terms of float to match most current rendering APIs.
- The coordinate system used for this format is assumed to be left handed with the Z axis to be pointing upward.

Description of the coordinate system:

$$Right = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} Forward = \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix} Up = \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} \tag{1}$$

The TypeExt section available in certain BPX types describes what fields to expect in the 128 bits of extension located in the BPX Main Header.
If the TypeExt field isn't used by a specific BPX type then this field should be set to 0.

5 Padding rules

All data structures exposed in this format specification are padded to comply with major C/C++ compilers: Visual C++, GCC and Clang.

6 Floating points

All floating points in this format are stored in IEEE 754 format [6].

7 Hashing function

Some types of BPX requires hashing for some strings. The string hash function to apply is defined by:

$$h_X(0) = 5381 \tag{2}$$

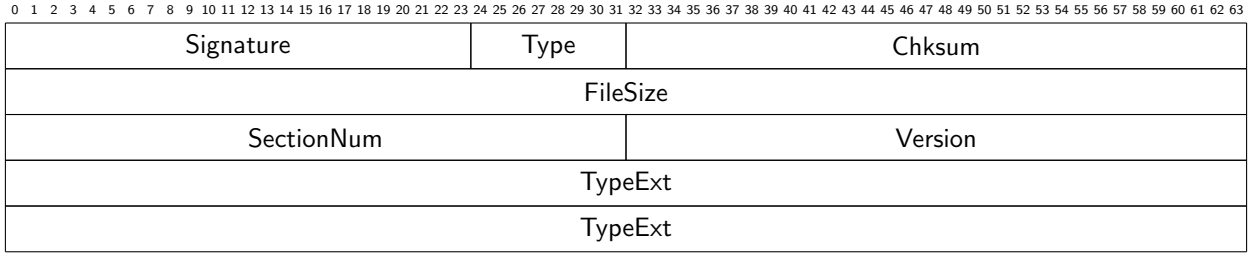
$$h_X(n+1) = \left(\left(h_X(n) \times 2^5\right) + h_X(n)\right) + X_{n+1} \tag{3}$$

where X is a row vector containing the raw bytes of the string.

8 BPX Main Header

The BPX Main Header describes general information about the container and the contained data.
This section is **not compressable**.
Below is a table describing the different fields to be expected in the header:

Name	Type	Size	Notes
Signature	String	24	File signature; always "BPX"
Type	Unsigned	8	Type of BPX
Chksum	Unsigned	32	Checksum
FileSize	Unsigned	64	Size of file after compression
SectionNum	Unsigned	32	Number of sections
Version	Unsigned	32	Version of BPX format
TypeExt	Unspecified	128	Extension space for various BPX types



8.1 Signature

Three characters to describe the file when open in a text/hex editor

8.2 Type

The type of BPX. This is used to describe what type of sections to expect in the file.
Currently only the following are supported:

- 'T' for Texture
- 'M' for Model
- 'S' for Shader
- 'C' for Scene
- 'P' for Package

Here the characters between single quotes are to interpreted as their byte representation in ASCII encoding.

8.3 Version

Version of BPX, currently 2 values are supported:

- a value of 1 refers to the initial release of this document implemented in SDK 1.0 and 2.0.
- a value of 2 refers to this current revision of the format and is available in SDK 3.0.

8.4 SectionNum

Number of sections in the file.

8.5 Chksum

Checksum of BPX main header and section header table. Compute this value by adding all bytes of data in unsigned format. Consider the value of this field to be **0** in order to correctly compute the checksum.
All fields of all section headers in the section header table and of the above header must be filled before computing this checksum otherwise the purpose of this checksum would be defeated.

8.6 FileSize

The file size field corresponds to the total size of the file including the size of this header in bytes after compression. This can be used as an additional security over the integrity of the file. It can also be used to check the remaining number of bytes in a network based streaming application.
Currently, the implementation is **not required to implement this field**. In case an implementation does not implement this field, it should be set to **0**.

8.7 TypeExt

The TypeExt field provides 128 bits of extension for different kind of BPX avoiding having to store or load additional sections in order to get usefull general information about a specific file reducing load time and memory complexity.
All unused space in this field should be to **0**.

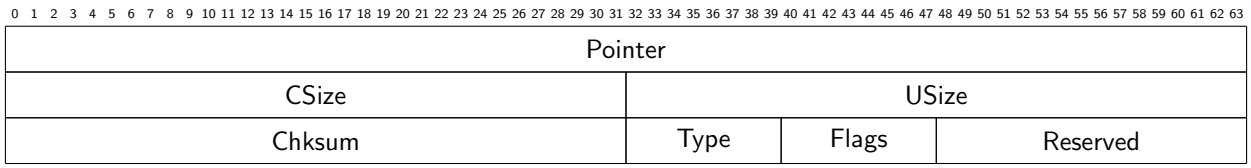
9 BPX Section Header Table

The BPX Section Header Table is an array of data structures describing important information for each section present in the file. It is located after the BPX Main Header.
The size of this array is determined by the SectionNum field in the BPX Main Header. The array is expected to be contiguous.
Certain types of BPX expects to be able to index sections in this table using positions. For that reason, the array is expected to be 1-indexed to allow for a value of 0 to represent a null or non-existent section.
This section is **not compressable**.

9.1 BPX Section Header

Below is a table describing the feilds to expect in a BPX Section Header:

Name	Type	Size	Notes
Pointer	Unsigned	64	Offset in bytes from the beginning of the file
CSize	Unsigned	32	Size in bytes of section (compressed)
USize	Unsigned	32	Size in bytes of section (uncompressed)
Chksum	Unsigned	32	Checksum
Type	Unsigned	8	Type of Section
Flags	Unsigned	8	Flags for the current section
Reserved	Unspecified	16	Blank, always 0



9.1.1 Pointer

Position in bytes in the file where the content for a given section should be found.

9.1.2 CSize

Size in bytes of the content after compression for a given section excluding Section Header.

9.1.3 USize

Size in bytes of the content before compression for a given section excluding Section Header.

9.1.4 Chksum

Checksum of uncompressed data, refer to the Check type of flags in the flags sub-section (9.1.6) to know how to interpret and generate this field. If no checksum flag is specified, the checksum is ignored.

9.1.5 Type

An integer to represent the type of section.

9.1.6 Flags

Bit mask based flags (or flags together). Currently the only supported flags are:

Name	Value	Notes
CompressedZlib	0x1	Indicates the section is compressed using the zlib [7] algorithm
CompressedXZ	0x2	Indicates the section is compressed using the XZ [10] algorithm
CheckCrc32	0x4	Indicates the section checksum is computed using Crc32 algorithm
CheckWeak	0x8	Indicates the section checksum is computed with the weak variant as used in the BPX Main Header

10 Standard Sections

Additionally any BPX type may use any of the following standard sections specification. The count and usage requirements of such a section is still defined by the type of BPX. The type byte for this section is generally 0xFF (255).

10.1 String section

A BPX may contain string section(s). As string section is a standardized way to store c-like strings in a BPX.

10.1.1 Encoding

The character encoding of strings in this section must be UTF-8.

10.1.2 Structure

The section is just a contiguous block of null-byte terminated UTF-8 encoded strings.
Reading a string is done by taking it's offset in the corresponding string section and start reading characters until a null byte is found.
Writing a string is done by taking the UTF-8 encoded bytes of this string and writing the bytes followed by a null byte at the end of the section.

10.2 Structured Data Section

The BPX Structured Data format, also called BPXSD, borrows various concepts from JSON. Any Structured Data section begins by an Object (see 10.2.4). The type byte for this section is generally 0xFE (254).
NOTE: This format is not exclusive to BPX: it may be used in other applications like network protocols.

10.2.1 Type codes

Each property property is encoded with a Type byte also called type code. Below is a table listing all type codes:

Type Code	Type Name
0	NULL
1	Boolean
2	Uint8
3	Uint16
4	Uint32
5	Uint64
6	Int8
7	Int16
8	Int32
9	Int64
10	Float
11	Double
12	String
13	Array
14	Object

10.2.2 Native types

Below is a table showing encoding of native types. Native types are considerered fixed-size value types.

Type Name	Value size (bits)	Notes
NULL	0	A null value
Boolean	8	A boolean value false (0), true (1)
Uint8	8	8 bit unsigned integer
Uint16	16	16 bit unsigned integer
Uint32	32	32 bit unsigned integer
Uint64	64	64 bit unsigned integer
Int8	8	8 bit signed integer
Int16	16	16 bit signed integer
Int32	32	32 bit signed integer
Int64	64	64 bit signed integer
Float	32	32 bit floating point number
Double	64	64 bit floating point number

For simplicity booleans are encoded as 8 bit bytes.

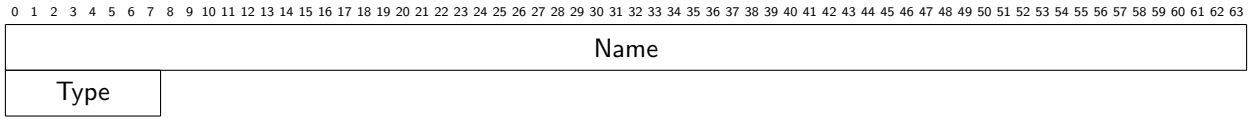
10.2.3 Strings

Strings are encoded as a UTF-8 null-terminated contiguous block of bytes.

10.2.4 Objects

An object is encoded as a contiguous list of properties each defined by a key-value pair. The first byte to read of an object gives the number of properties in this object. The encoding of a property is as follows:

Name	Type	Size	Notes
Name	Unsigned	64	Hash of property name
Type	Unsigned	8	Type of the property value
Value	Unsigned	Depends on Type	Value of the property



10.2.5 Debugging

As stated in the previous sub-section, the BPXSD Object stores hashes of the property names which means the original name is lost. To mitigate this issue, a BPXSD Object may contain a property, accessed by $Hash(\text{"}\_\_debug\_\_\text{"})$, which stores debugging symbols. This property always points to an array of strings. In order to display property name the implementation is responsible for finding in this debug symbol array the property name string such as $Hash(V_i) = P$ where V is the array of debug symbols (i representing the index in that array) and P the property hash that the implementation whishes to know the original name for.

10.2.6 Arrays

An array is encoded as a contiguous list of values. The first byte to read of an array gives the number of values in this array.

Name	Type	Size	Notes
Type	Unsigned	8	Type of the value
Value	Unsigned	Depends on Type	Value

11 BPX Type: Texture ('T')

11.1 Overview

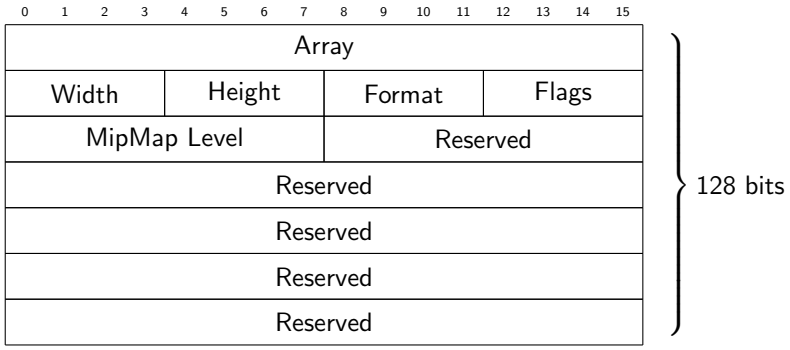
The Texture BPX is using 'T' as the type byte of BPX Main Header. This type provides optimized and efficient texture storage for 3D rendering APIs.
Below is a table describing the different sections to be expected in a BPXT:

Name	Type	Required	Single Time
PixelArray	1	Yes	Yes

11.2 TypeExt

Contains information about the texture encoding.

Name	Type	Size	Notes
Array	Unsigned	16	Size of texture array
Width	Unsigned	4	Texture width
Height	Unsigned	4	Texture height
Format	Unsigned	4	Texture format
Flags	Unsigned	4	Flags
MipMap Level	Unsigned	8	Number of mip maps
Reserved	Unspecified	72	Blank, always 0



11.2.1 Width

The expected width of all pixel arrays in power of two form (2^{k+1}px where k is the stored number).

11.2.2 Height

The expected height of all pixel arrays in power of two form (2^{k+1}px where k is the stored number).

11.3 Analysis on texture size storage

Certain redering APIs requires that the textures are aligned to a specific implementation defined number of pixels per row. This number also called stride is usualy 8 or a power of two greater than 8.
By assuming any BPX encoded texture is encoded with power of twos instead of their actual resolution in pixels, we can eliminate the need, in the cases where the implementation uses power of two strides, to run a padding

alignment before presenting the texture to this implementation. Also this allows to reduce the field size for storing texture size: instead of using 32 bits or 64 bits we can store a texture size in 8 bits and keep relatively large texture sizes, **optimizing both storage space and application load speed**. Indeed the maximum texture size in each direction allowed by BPX would be $2^{15+1} = 2^{16} = 65536$. Most rendering API implementation do not support such large texture sizes.
From there one might say that we should then use less than 8 bits. However using less than 8 bits for storing the entire size vector would conflict with hardware indexing as most hardware only indexes 8 bits bytes.

11.3.1 Format

Available formats:

Name	Value	Notes
RGB	0x1	Standard 8 bits 3 channel RGB format
RGBA	0x2	8 bits 4 channel RGB with transparency level
GreyScale	0x3	Single 8 bits channel representing grey scale level
Float	0x4	Single channel 32 bits float texture

11.3.2 Flags

Bit mask based flags (or flags together). Currently the only supported flags are:

Name	Value	Notes
Array	0x1	Indicates the texture should be interpreted as a texture array
Compressed	0x2	Indicates the texture should be GPU compressed on load
CubeMap	0x4	Indicates the texture should be interpreted as a CubeMap

11.3.3 MipMap Level

Number of mip maps [2] to auto generate when loading this texture.

11.3.4 Array

Number of textures for creating a texture array. If this value is 0 consider this is not a texture array.
Ignore this value if neither of Array or CubeMap flags are set.

11.4 PixelArray

Texture data array encoded as described by texture format.
If the *Array* value in the header is greater than 0 then a series of *Array* count texture data arrays are saved one after the other encoded with respect to the texture format described by the header.
In case the CubeMap flag is set the *Array* field in the header should be 6 and this section should contain 6 texture data arrays.

12 BPX Type: Model ('M')

12.1 Overview

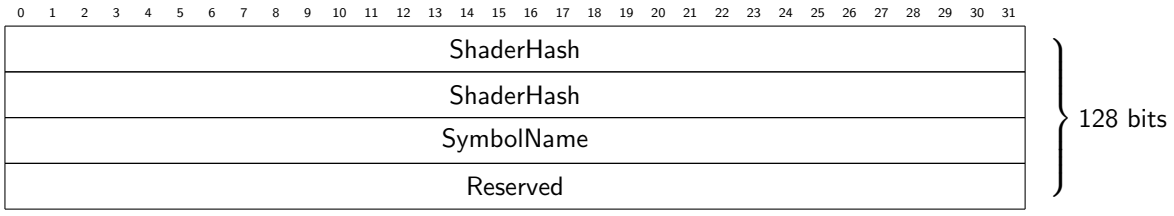
The Model BPX is using 'M' as the type byte of BPX Main Header. This type provides optimized and efficient mesh storage for 3D rendering APIs.
Below is a table describing the different sections to be expected in a BPXM:

Name	Type	Required	Single Time
VertexArray	2	Yes	No
IndexArray	3	No	No
BoneArray	4	No	Yes
FrameArray	5	No	Yes
AnimationArray	6	No	Yes
Strings	255	No	Yes

12.2 TypeExt

Contains general information about the 3D model file.

Name	Type	Size	Notes
ShaderHash	Unsigned	64	Hash of shader package virtual path
Symbol-Name	Unsigned	32	Name of vertex format symbol in the shader package
Reserved	Unsigned	32	Blank, always 0



12.2.1 ShaderHash

Hash of shader package asset virtual path containing to the vertex format of this model.

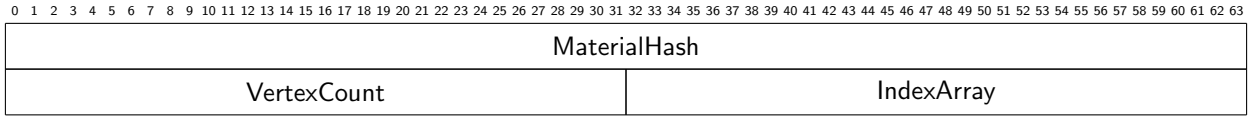
12.2.2 SymbolName

The symbol name of the vertex format to locate in the shader package identified by the ShaderHash field.

12.3 VertexArray

This section contains a header followed by an array of vertex data structure. The size of each vertex structure should be equal to the field VertexSize in the VertexFormat section.
The header data structure is described in the following table:

Name	Type	Size	Notes
MaterialHash	Unsigned	64	Hash of material
VertexCount	Unsigned	32	Total number of vertices
IndexArray	Unsigned	32	Index array section index
Reserved	Unsigned	32	Blank, always 0



12.3.1 MaterialHash

Hash of material asset virtual path to apply by default to this vertex array.

12.3.2 VertexCount

The amount of vertex structures to read after this header.
We remind that all modern hardware support triangles as primitives, so the vertex count should be a multiple of 3

12.3.3 IndexArray

This field is an index in the section header table to an IndexArray that should be used alongside this VertexArray. A value of 0 means that no IndexArray is associated to that VertexArray.

12.3.4 Total array size

The total size in bytes of the vertex array to use as pre-allocation buffer size when loading this model can be calculated as follows:

$$SA = S \times V \tag{4}$$

where SA is the total size of the vertex array, S the size of a single vertex structure as given in the VertexFormat asset and V the number of vertices in the array given by the VertexCount field.
To avoid storing an additional 64 bits field in the header of the VertexArray section this size SA is left to be calculated by the implementing application.

12.4 IndexArray

The index array section allows to ommit certain vertices and figure out these vertices at runtime. Instead of writing all vertices for a given model requiring more space to store them, we only store unique vertices, and duplicates are just resolved by matching a vertex index from this section to an actual vertex structure, **this allows to save storage space and RAM**.
This section contains a header describing the amount of indices to be found in the array, and an array of 32 bits unsigned integer each representing the index of a vertex in a given vertex array.
Below is a table describing the data structure to expect as header for an IndexArray section:

Name	Type	Size	Notes
IndexCount	Unsigned	32	Total number of indices

12.4.1 IndexCount

The number of indices expected to be read from the array below this header.

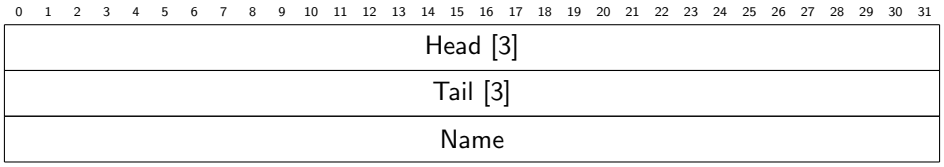
12.5 BoneArray

This section contains a header followed by an array of data structures representing each bone in a skeletal mesh. Below is a description of the header to find before bone data in this section:

Name	Type	Size	Notes
BoneCount	Unsigned	16	Total number of bones

Each bone in the array following the header is represented by the following data structure:

Name	Type	Size	Notes
Head	3D float vector	96	Initial position of bone head
Tail	3D float vector	96	Initial position of bone tail
Name	Unsigned	32	Pointer in the Strings section



12.5.1 BoneCount

Number of bones to expect in the bone array following the header. This number should belong to the interval $[1, 1024]$.

12.6 Analysis on theoretical bone limit

We can give an estimation that human skeleton can be up to 400 bones. Of course most models do not include as many bones to reduce GPU/CPU load.

- OpenGL, Vulkan and Metal maximum UBO/function constants storage size available to a shader is usualy 64Kb or 65536 bytes
- On the official MSDN page [9] for DirectX the maximum constant buffer size available to a shader is $4096constants \times 4 \times 32bits = 4096constants \times 16bytes = 65536bytes$

UBO, function constants and constant buffer refers to means of variable synchronisation between CPU accessible memory and GPU accessible memory. Vulkan is a special case as it actually supports faster memory called Push Constants, however these constants usually maxes at 256-512 bytes which is impracticable for storing bone transforms. Push constants are typically used to exchange important transformation matrices such as model, view or projection. The size of a transformation matrix in 3D space using homogeneous coordinate system [3] is $32bits(float) \times 4 \times 4(4 \times 4matrix) = 16 \times 32bits = 512bits = 64bytes$.
So assuming the lowest size for storing bones in VRAM for GPU processing is 65536 we can theoretically store up to 1024 matrices assuming each bone matrix represents 3D space transformations in homogeneous coordinate system ($\frac{65536}{64} = 1024$).
Which means in order to **keep compatibility** with as many platforms/rendering apis as possible also taking into account byte indexing, we should store the bone count as a 16 bits integer.

12.6.1 Head

Initial head position for that specific bone.

12.6.2 Tail

Initial tail position for that specific bone.

12.6.3 Name

Bone name as a pointer to a null terminated string in the strings section.

12.7 FrameArray

This section contains a header followed by an array of data structures each representing the new transform for a combination of a bone and frame.
The array should be organized as the following diagram describes:

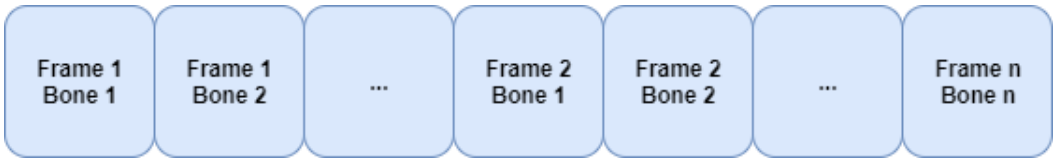


Figure 1: Diagram for organizing frame array

A single animation in a 3D model is usualy a set of actions. For example consider the following set of actions on a 3D human based model:

- move left leg
- move right leg
- move left arm
- move right arm

This set of actions could be grouped together in one animation named walking or running.
We call total animation time, the total time needed to express all animations for a single 3D model.

12.7.1 Design decision

The majority of mainstream formats represents animated models using key frames, that is storing only determinant changes in the model and interpolating intermediate frames at runtime (either when loading the file or while rendering). In BPX type M each frame is stored in the file to allow for any interpolation method, that is the interpolation if there's any is defined by the exporter of that model. The engine runtime does not have to provide any interpolation function for BPX type M.
This change grants the **flexibility** of using any interpolation functions even user defined.

12.7.2 Analysis on theoretical required storage size

We assume the total size required to store the full FrameArray is given by the following formula:

$$F \times B \times B_s \tag{5}$$

where F is the total amount of frames, B the number of bone updates per frame and B_s is the size of a single bone update structure.
We previously indicated that a bone update is determined by a transformation matrix in homogeneous coordinate space [3], that means it is exactly $512bits$ or $64bytes$.
Of course in a real application, it is very unlikely to have every frame in the timeline requiring update on every bone.

Worst case scenario
We assume the total animation time won't exceed 4 minutes.
We showed earlier that the theoretical maximum bone limit is 1024.
For the frame rate we choose 60, that means each second 60 frames in this FrameArray have to be rendered.
The total amount of frames to store is $60 \times 4 \times 60 = 14400 frames$.
The total size required to save a model assuming each frame requires dependency over exactly all bones is $14400 \times 1024 \times 512 = 7549747200 bits = 943718400 bytes$. That is approximately $944 Mb$.

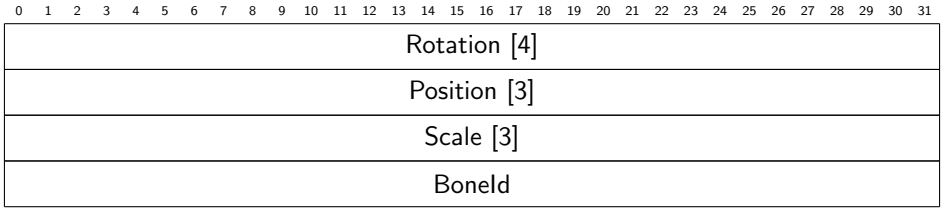
Average case scenario
Of course having 1024 bones in one model is unlikely to happen. This is why we want to have an average estimation on the size required to store the FrameArray section.
On average, the amount of bones per animated model won't exceed 50 bones.
On average, each frame will update at most 10 bones.
On average, the frame rate of a 3D model animation will be $30 FPS$.
On average, the total animation time won't exceed 2 minutes.
The total amount of frames to store is $30 \times 2 \times 60 = 3600 frames$.
The total size required to save the FrameArray of a model assuming each frame requires dependency over exactly all bones is $3600 \times 10 \times 512 = 18432000 bits = 2304000 bytes$. That is approximately $2 Mb$.

In conclusion the FrameArray section **should be compressed** to reduce the storage space consumed by a single model asset on disk. When loading the model in RAM one might consider adding some compression or supporting a lower limit than 1024 bones.

12.7.3 Bone transform

Each bone transformation in the FrameArray section is represented by the following structure:

Name	Type	Size	Notes
Rotation	4D float vector	128	Target bone rotation as a quaternion
Position	3D float vector	96	Target bone position
Scale	3D float vector	96	Target bone scale
BoneId	Unsigned	32	Index of affected bone



12.8 Strings

The strings section contains a list of null-terminated strings to be referenced by start offset from other sections (see 10.1).

13 BPX Type: Shader Package ('S')

13.1 Overview

The Shader Package BPX is using 'S' as the type byte of BPX Main Header. This type provides optimized and cross API/platform storage for rendering code intended to be executed on the GPU [11].
Below is a table describing the different sections to be expected in a BPXS:

Name	Type	Required	Single Time
Shader	1	Yes	No
SymbolTable	2	Yes	Yes
ExtendedData	3	No	Yes
Strings	255	Yes	Yes

At least one symbol table section is required to be saved in the file.

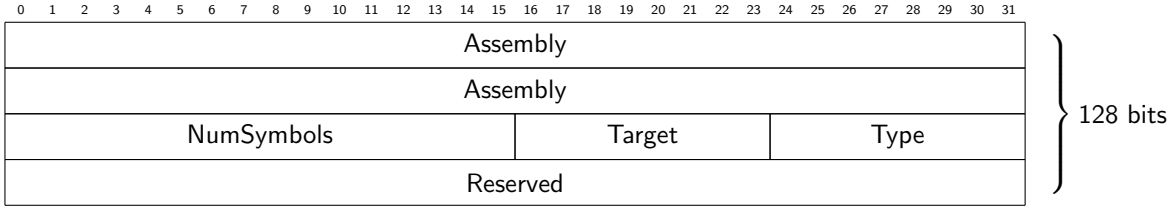
13.1.1 Design decisions

Due to software/hardware restrictions for some rendering platforms, each rendering platform will require a different BPX Shader Package. For example a Mac is required to build MSL shaders and Windows is required in order to build HLSL shaders.
Use a GL target for best compatibility across all 3 major platforms. For highest performance and compatibility, use a VK target.
The Shader Package exists in two variants: "A" and "P".
The "A" variant or Assembly is used to store common symbols used by a group of shaders. At least one Assembly must be common to all shaders in a given game. This Shader Assembly is known as the main assembly which is guarenteed to contain common symbols such as the material constant buffer, the model matrix constant, etc.
The "P" variant or Program is used to store an entire pipeline including it's compiled shaders for a target rendering platform.

13.2 TypeExt

Contains information about the shader package.

Name	Type	Size	Notes
Assembly	Unsigned	64	Hash of shader assembly
NumSymbols	Unsigned	16	Number of symbols
Target	Unsigned	8	Target renering platform
Type	Unsigned	8	Type of Shader Package
Reserved	Unspecified	32	Blank, always 0



13.2.1 Assembly

The hash of the shader assembly name that this shader package is linked against. In the case this shader package is a shader assembly or that it isn't (yet) linked against a shader assembly, **a value of 0 should be written**.

13.2.2 NumSymbols

Number of symbols in the symbol table.

13.2.3 Target

The target rendering platform represents which rendering API this package supports:

Name	Value	Notes
DX11	0x1	Built for DirectX 11 [8]
DX12	0x2	Built for DirectX 12 [8]
GL33	0x2	Built for OpenGL 3.3+ [4]
GL40	0x3	Built for OpenGL 4.0+ [4]
VK10	0x4	Built for Vulkan 1.0+ [5]
MT	0x5	Built for Metal API [1]
Any	0xFF	Works on any rendering platform (designed to be used by a Shader Assembly)

13.2.4 Type

The type of package is either "A" for a Shader Assembly or "P" for a Shader Program / Pipeline.

13.3 Shader

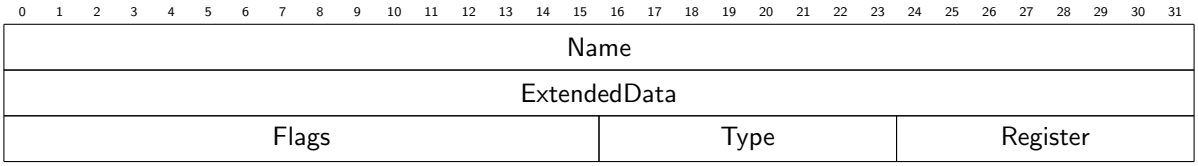
Contains shader data for a single stage. The first byte in this section corresponds to the stage the shader is for. The below table describes all possible values of the stage byte:

Name	Value
Vertex	0
Hull	1
Domain	2
Geometry	3
Pixel	4

13.4 SymbolTable

The symbol table section stores information about what symbols are used in this shader program.
This section stores an array of symbol structures. A symbol structure is defined by:

Name	Type	Size	Notes
Name	Unsigned	32	Name of symbol
ExtendedData	Unspecified	32	Data extension
Flags	Unsigned	16	Flags
Type	Unsigned	8	Type of symbol
Register	Unsigned	8	Register number



13.4.1 Name

The name of the symbol as an offset in the string section.

13.4.2 ExtendedData

An offset in the ExtendedData section to load a BPXSD object storing additional information about the symbol.
The BPXSD object structure is implementation defined.
The value of this field is undefined if the flag ExtendedData is not set.

13.4.3 Flags

Describes what this symbol is used for. These flags are bit mask that can be or'ed together. Below is a table to list the different available flags:

Name	Value	Notes
VertexStage	0x1	Indicates the symbol applies to the vertex stage
HullStage	0x2	Indicates the symbol applies to the hull stage
DomainStage	0x4	Indicates the symbol applies to the domain stage
GeometryStage	0x8	Indicates the symbol applies to the geometry stage
PixelStage	0x10	Indicates the symbol applies to the pixel stage
Assembly	0x20	Indicates the symbol is part of a Shader Assembly
External	0x40	Indicates the symbol is not defined by this package
Internal	0x80	Indicates the symbol is defined by this package
ExtendedData	0x100	Indicates the symbol has extended data
Register	0x200	Indicates the symbol consumes a register/slot number in the pipeline

13.4.4 Type

The type of symbol. Currently there are only 6 types of symbols:

Name	Value	Notes
Texture	0	A texture symbol
Sampler	1	A sampler symbol
ConstantBuffer	2	A constant buffer symbol
Constant	3	A high-performance constant
VertexFormat	4	A vertex format. **Only one vertex format is allowed per shader program**
Pipeline	5	A pipeline definition. **Only one pipeline is allowed per shader program**

13.4.5 Register

The register or slot number this symbol should be bound to.
The value of this field is undefined if the flag Register is not set.

13.5 ExtendedData

Contains all BPXSD extension objects for all symbols that needs additional information.
Refer to 10.2 for more information about BPXSD encoding/decoding.

13.6 Strings

The strings section contains a list of null-terminated strings to be referenced by start offset from other sections (see 10.1).

14 BPX Type: Package ('P')

14.1 Overview

The Package BPX is using 'P' as the type byte of BPX Main Header. This type provides object packages using the BPX format.
Below is a table describing the different sections to be expected in a BPXP:

Name	Type	Required	Single Time
Data	1	Yes	No
ObjectTable	2	Yes	Yes
Metadata	254	No	Yes
Strings	255	Yes	Yes

NOTE: The order of Data sections MUST be contiguous. An object is allowed to be divided in multiple sections, however an object header MUST NOT be divided.

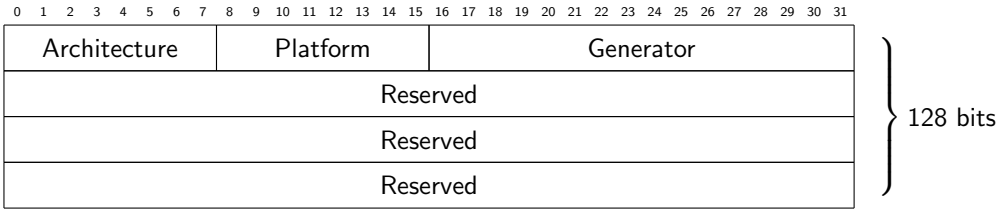
Revision 2 (SDK $\geq$ 3.0)

- A Data section is not allowed to store object headers anymore, the ObjectTable section is here to store all object headers.
- An additional required ObjectTable section MUST only be generated in a BPX rev 2 or later.
- All data of a given object must be stored in a contiguous set of Data sections.

14.2 TypeExt

Contains general information about the Package.

Name	Type	Size	Notes
Architecture	Unsigned	8	Target architecture
Platform	Unsigned	8	Target platform
Generator	Unsigned	16	Generator ID
Reserved	Unsigned	96	Blank, always 0



14.2.1 Architecture

8 bits of architecture stored as an enumeration. The current allowed values are:

Name	Value
x86_64	0
aarch64	1
x86	2
armv7hl	3
any	4

14.2.2 Platform

8 bits of platform stored as an enumeration. The current allowed values are:

Name	Value
Linux	0
MacOS	1
Windows	2
Android	3
Any	4

14.2.3 Generator

16 bits of generator identification stored as 2 ASCII characters. The current known values are:

ASCII string	Notes
"PK"	Generated by FPKG
"BP"	Generated by BlockProject 3D Engine
"BD"	Generated by BPX debug tools

The generator identification is only useful to know the expected structure of the optional Metadata section.

14.3 Data

The Data section is used to store one or more objects. Each object begins by an object header which is defined as:

Name	Type	Size	Notes
Size	Unsigned	64	File size
Path	Unsigned	32	Pointer in the Strings section

14.3.1 Size

The total size of the object to read. When extracting an object which size is greater than the remaining bytes in the section just continue reading from next section as if the next section was simply a continuation of the current one.

14.3.2 Path

The path as a pointer to a null terminated string in the strings section. Used to identify relative extraction location and/or the virtual path of the asset in a rendering application.

Revision 2 (SDK $\geq$ 3.0)

No object header is to be written inside a Data section anymore. However a Data section can still be used to store multiple objects.

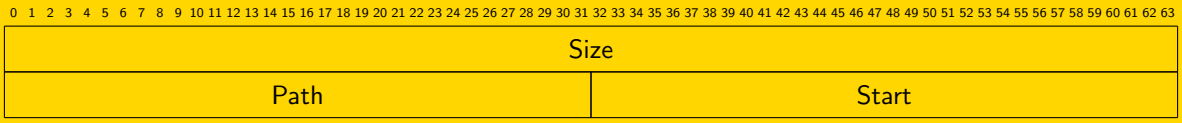
14.4 ObjectTable

The ObjectTable section stores an array of object headers where each object header points to an actual Data section where the start of the object is expected.
The number of headers in the object table is given by the relation:

$$N = \frac{S}{20}$$

where N is the number of headers and S is the size in bytes of the section before compression.
An object header is represented by the following structure:

Name	Type	Size	Notes
Size	Unsigned	64	Object size
Name	Unsigned	32	Pointer in the Strings section
Start	Unsigned	32	Index of the starting data section
Offset	Unsigned	32	Pointer relative to the start of the data section



14.4.1 Size

The total size of the object to read. When extracting an object which size is greater than the remaining bytes in the section just continue reading from next section as if the next section was simply a continuation of the current one.
It is expected to store as many objects as possible in one section in order to enable efficient data compression in case many small objects are packed.

14.4.2 Name

The name as a pointer to a null terminated string in the strings section. Used to identify relative extraction location and/or the virtual path of the asset in a rendering application.

14.4.3 Start

The index of the section to start reading the content of the object. In order to not over-read, refer to the size of the object as given in the object header.

14.5 Strings

The strings section contains a list of null-terminated strings to be referenced by start offset from other sections (see 10.1).

14.6 Metadata

The metadata section contains generator specific information about the package. It is encoded as a Structured Data Section (see 10.2).

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