Tomb Raider Data Formats (TRosettaStone)

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Document Version 3.0 preview (last edit: 2020-06-25)

Including Tomb Raider `.PHD/.TUB`, Tomb Raider II-III `.TR2`, Tomb Raider IV `.TR4` and Tomb Raider Chronicles (V) `.TRC` information, where available.

Also includes `TOMBPC.DAT` and `SCRIPT.TR4` script information, `CDAUDIO.WAD` and `CUTSEQ.PAK`/`CUTSEQ.BIN` information.

1. Introduction

Until now the Tomb Raider community, especially programmers and resource hacking enthusiasts, referenced a document called *TRosettaStone*, which hadn't been updated since 1999, and its revised version (we can call it *TRosettaStone 2*), which was done by E. Popov in 2000 or 2001. Both of these documents served well for their time, but they were plagued by many errors and inaccuracies.

Many people noted these errors and inaccuracies, but nobody of them revised existing documentation, keeping all their knowledge just in their head. It is widely known that original document lacks some info here and there, and something is wrongly described — but it's *not mentioned anywhere* (except some lost forum posts). So when a newbie programmer comes to community, he has to come through all the same trials and errors as everyone else once came.

> "It shouldn't happen like that."

The purpose of *TRosettaStone 3* is to replace original document and serve as the comprehensive source of information for anyone willing to participate in classic-era Tomb Raider software development. We will use original TRosettaStone as a basis, heavily borrowing from E. Popov revision. Also, this document will widely borrow information from TREP user's manual, NGLE manual, and a bunch of forum threads and messages concerning internal game engine structures.

However, while original TRosettaStone and update by Popov were aimed primarily at exploring already existing game assets, such as levels, sound files, scripts, etc., this document is being created by and as a reference for programmers who are creating open-source reimplementations of original game engines. Because of this, we will sometimes explore not only game file formats, but also internal game logic, procedures and other related aspects. It will be updated synchronously with development of *OpenTomb*, one of such reimplementation projects, which has received lots of feedback from the community.

1.1. Description

This document contains detailed descriptions of the classic-era Tomb Raider data file formats. It is assumed that the reader has knowledge and experience programming in C or C++ and has at least a passing familiarity with graphics programming. This document is self-contained; all hyperlinks refer only to itself.

All information in this document was derived independently, without the aid or assistance of anyone at Core Design or Eidos. As such, the information in this document may contain errors or omissions, and many structure and variable names were deduced from the interpretation of the data (and therefore could be misleading or completely wrong). However, we re-use certain variable and function names from original Tomb Raider debug builds and mappings/symbols from the leaked Tomb Raider Chronicles PSX SDK.

All the information in this document was tested and is therefore plausible, but could also be a misinterpretation. All information herein is provided as is — you get what you pay for, and this one's free. This is a spare-time project that set out to document the Tomb Raider file formats.

1.2. Conventions

Generally, game versions are referenced by abbreviations:

- **TR1** refers to Tomb Raider and Tomb Raider: Unfinished Business
- **TR2** refers to Tomb Raider II and Tomb Raider II: The Golden Mask
- **TR3** refers to Tomb Raider III and Tomb Raider III: The Lost Artifact
- **TR4** refers to Tomb Raider: The Last Revelation
- **TR5** refers to Tomb Raider: Chronicles


Note

As level formats are concerned, **TR4** usually applies not only to original game, but to *custom levels* built by fans using *Tomb Raider Level Editor* (`winroomedit.exe`) version `.49`, used to work

> with TR4-specific level file format. This level editor version is the only one level editor officially released by Eidos / Core, along with TR5.

When we provide some version-specific info about certain structures or methods, this information will be marked with special bullet images, defining engine versions for which this info is applicable: ① is for TR1, ② is for TR2, ③ is for TR3, ④ is for TR4, and ⑤ is for TR5. Version-specific information will continue up to the next paragraph or list entry, until otherwise noted.

Also, if external programs and utilities are involved, here are abbreviations for them:

- **TRLE** refers to Tomb Raider Level Editor — an official tool by Core Design used to build levels.
- **NGLE** refers to TRLE version which was unofficially patched and now extensively used by level editing community.
- **Dxtre3d** refers to so-called *unofficial* level editor developed by Felix aka *Turbo Pascal*.
- **TE** refers to new advanced level editor called *Tomb Editor*, developed by joint efforts of TRLE community with *MontyTRC* as lead programmer.
- **TREP** refers to a binary patcher which is used to patch *TR4 engine* in its *Level Editor* version (bundled with TR5) for some advanced features and upgrades by level editing community.
- **TRNG** is another patcher with same purpose as TREP, however, incompatible with it. TRNG offers even more advanced features and upgrades to old *TR4 engine*.
- **FLEP** refers to a similar patcher as *TREP*, which is used for same *TR4 engine*, albeit previously modified by *TRNG*.

1.3. Current Unknowns

1. Clarify what's the purpose of `Normal` field in [tr5_room_vertex] structure, and if really `Attributes` field was removed.
2. Whole [tr5_room] structure needs detailed analysis with all its extra *Unknown* fields.
3. Clarify fog bulb values which affect its radius.
4. Clarify the CUTSEQ.bin packed coordinates structure format.

1.4. Copyright note

2. The Fundamentals

2.1. File Types

Tomb Raider is driven by various sets of files — level files, script files, FMVs, audio tracks and sound files. In TR4 and TR5, there is also specific file type which contains cutscene data — *cutseq pack*.

2.1.1. The Script Files

The script file structure differs from version to version.

In TR1, all script info was embedded into executable file (`TOMB.EXE`), and thus is *hardcoded*. TR2 and TR3 had unified `TOMBPC.DAT` file, which contains all the text strings describing the various elements in the game (e.g. the game engine knows about "Key 1"; it looks in `TOMBPC.DAT` to determine the name to be displayed in Lara's inventory, such as "Rusty Key" or "Taste rostige" or "Clé Rouillée"), the level and cut-scene filenames (e.g. `WALL.TR2`, `CUT3.TR2`), the order in which they are to be played, and various per-level and per-game configuration options (e.g. what weapons and objects Lara starts the level with, whether or not the "cheat" codes work, etc.).

TR4 and TR5 introduced a new script format, where the actual script defining the gameflow was separated from text strings used in game — hence, both TR4 and TR5 have two `.DAT` files — `SCRIPT.DAT` and `LANGUAGE.DAT`, where `LANGUAGE` differs depending on regional origin of the game — `US.DAT`, `FRENCH.DAT`, `JAPANESE.DAT`, and so on.

2.1.2. The Level Files

The level files, `{level-name}.PHD/TUB/TR2/TR4/TRC`, contain everything about the level, including the geographical geometry, the geometry (meshes) of all animate and inanimate objects in the level, all the textures and colour data, all animation data, index information (and, in TR1, TR4 and TR5 — also the *actual sound sample data*) for all sounds, accessibility maps — everything necessary to run the game. For whatever reason, Core has included everything in one file instead of breaking it up into logical groupings; this means that every level contains all the meshes, textures, sound information, and animation data for Lara and all of her weapons. There are a fair number of other redundancies, too.

Since TR4, the level file is divided into *several chunks*, each of them being compressed with *zlib*. Usually, each chunk of compressed data is preceded by two 32-bit unsigned integers defining the *uncompressed size* of the chunk and the

compressed size of the chunk. Therefore, the engine allocates an empty buffer equal to the *uncompressed size* of a specific chunk, and another buffer equal to the *compressed size*. The compressed data is loaded directly within it based on the *compressed size*. The compressed data is then decompressed into the result buffer and the buffer containing the compressed data is destroyed. In TR5, those chunks aren't compressed anymore.

It's good to note the origins of level file extension. While it is obvious that TR2/TR4/TRC extensions specify abbreviations of the game name. `.PHD` is actually the initials of the *Lead Programmer* for Tomb Raider 1: *Paul Howard Douglas*. Looks like this programmer contributed a lot of the code during early development stages of Tomb Raider. This is suggested because the *phd* initials also became a prefix for several helper functions in the original source code, for instance: `phd_sin`, `phd_cos` etc. Most likely, he was also responsible for developing the level file structure for Tomb Raider.

2.1.3. FMVs (Full Motion Videos)

TR1-3 shared the same proprietary Eidos codec for videos, called *Escape*. The extension for such files is `.RPL`, that's why they occasionally (and mistakingly) called Replay codec. Signature feature of RPL videos is that they are always interlaced with black stripes; most likely, this was used to conserve disk space (however, *PlayStation* videos were in `.STR` format, which is basic MPEG compression, and they had no interlacing — but suffered from blocking issues). In TR1 and TR2, framerate was limited to 15 FPS, while in TR3 it was doubled to 30 FPS.

For a long time, Escape codec was largely unexplored and barely reverse-engineered; there was only an abandoned open source *Mplayer* implementation for some Escape codec versions, but recent *ffmpeg* revisions feature fully functional decoder for Escape videos.

Since TR4, all FMVs are in *Bink Video* format, which is much more common and easy to rip, convert and explore.

2.1.4. Sound Files — Audio Tracks

These are long sound files which occasionally play either on some in-game events (e.g. approaching certain important checkpoint in game, like big hall with ladder and two wolves in "Caves" — it triggers danger music theme) or in looped manner as background ambience. Audio tracks are stored differently across TR game versions — *CD-Audio* in TR1-TR2, single merged file `CDAUDIO.WAD` in TR3, and separate audio files in TR4 and TR5.

2.1.5. Sound Files — Samples

TR2 and TR3 also featured external sound sample files, which allowed to share samples between all level files. This sound file is called `MAIN.SFX`, and usually placed in `DATA` subfolder. Hence, engine loads sound samples not from level files (as it's done in TR1, TR4 and TR5 — see above), but rather from this `MAIN.SFX` file.

2.1.6. Cut Sequence Packs

TR4 and TR5 featured special data type containing all the necessary information to play *in-game cutscenes*. While in earlier games such info was embedded into the level file itself, and generally, cutscenes themselves were separate level files (easily distinguished by their filenames, e.g. `CUT1.TR2` etc.), TR4 changed this approach, and cutscenes could be loaded and played right inside level files at runtime.

The data for such cutscene setup was packed into single file titled `CUTSEQ.PAK` in TR4 or `CUTSEQ.BIN` in TR5. There will be a special section describing whole cutseq file format.

2.2. Basic Data Types

For the purposes of further discussion, the following are assumed:

`int8_t`	specifies an 8-bit signed integer (range -128..127)
`uint8_t`	specifies an 8-bit unsigned integer (range 0..255)
`int16_t`	specifies a 16-bit signed integer (range -32768..32767)
`uint16_t`	specifies a 16-bit unsigned integer (range 0..65535)
`int32_t`	specifies a 32-bit signed integer (range -2147483648..2147483647)
`uint32_t`	specifies a 32-bit unsigned integer (range 0..4294967295)
`float`	specifies a 32-bit IEEE-754 floating-point number
`fixed`	specifies a 32-bit non-trivial 16.16 fixed point value — see further
`ufixed16`	specifies a 16-bit non-trivial 8.8 fixed point value — see further

All multi-byte integers (`{u}int16_t`, `{u}int32_t`) are stored in little-endian (Intel-x86, etc.) format, with the least significant byte stored first and the most significant byte stored last. When using this data in platforms with big-endian (PowerPC, etc.) number format, be sure to reverse the order of bytes.

2.2.1. Fixed Point Data Types

These very specific data types mimic floating-point behaviour, *while remaining integer*. It is done by splitting floating-point value into whole and fractional parts, and keeping each part as `int16_t` and `uint16_t` correspondingly for `fixed` type and as `uint8_t` and `uint8_t` for `ufixed16` type. Whole part is kept as it is, while fractional part is multiplied by 65536 (for `fixed`) or by 255 (for `ufixed16`), and then kept as unsigned integer. So, the formula to calculate floating-point from `fixed` is:

$$F_{real} = P_{whole} + \left(P_{frac} \div 65536 \right)$$

Formula to calculate floating-point from `ufixed16` is:

$$F_{real} = P_{whole} + \left(P_{frac} \div 255 \right)$$

...where P_{whole} is whole part of mixed float (signed for `fixed`, unsigned for `ufixed16`), and P_{frac} is fractional part (unsigned).

The reason why such complicated setup was invented is to avoid using floating-point numbers. In 90% of all cases, Tomb Raider engines use integer numbers, even for geometry calculations and animation interpolations. The root of this setup lies in multi-platform nature of the code, which was simultaneously written for PC and PlayStation. While PCs had enough computational power to deal with floats at that time, PlayStation relied only on integers.

However, some internal variables and constants (like drawing distance, fog distance constants and some light properties) are PC-specific and stored in floating point numbers. Also, last game in series, TR5, extensively used floating-point numbers for certain data types — like colours, vertices and coordinates.

2.2.2. Data Alignment

Data alignment is something one has to be careful about. When some entity gets an address that is a multiple of *n*, it is said to be *n*-byte aligned. The reason it is important here is that some systems prefer multibyte alignment for multibyte quantities, and compilers for such systems may pad the data to get the "correct" alignments, thus making the in-memory structures out of sync with their file counterparts. However, a compiler may be commanded to use a lower level of alignment, one that will not cause padding. And for TR's data structures, 2-byte alignment should be successful in nearly all cases, with exceptions noted below.

To set single-byte alignment in any recent compiler, use the following compiler directive:

```
#pragma pack(push, 1)
```

To return to the project's default alignment, use the following directive:

```
#pragma pack(pop)
```

2.3. Basic Terms

2.3.1. Coordinates

The world coordinate system is oriented with the *X* - *Z* plane horizontal and *Y* vertical, with *-Y* being "up" (e.g. decreasing *Y* values indicate increasing altitude). The world coordinate system is specified using `int32_t` values; however, the geography is limited to the $+X/+Z$ quadrant for reasons that are explained below. Mesh coordinates are relative and are specified using `int16_t`.

There are some additional coordinate values used, such as "the number of 1024-unit blocks between points A and B"; these are simply scaled versions of more conventional coordinates.

2.3.2. Colours

All colours in TR are specified either explicitly (using either the [tr_colour] structure, described below, 16-bit structures or 32-bit structures) or implicitly, by indexing one of the palettes. However, it is only applicable to TR1-3 — there is no palette in TR4 and TR5.

In TR1-3, mesh surfaces could be either *coloured* or *textured*. *Coloured* surfaces are "painted" with a single colour that is either specified explicitly or using an index into the palette.

Beginning from TR4, coloured faces feature was removed, so each face must have a texture attached to it.

2.3.3. Textures

Textured surfaces map textures (bitmapped images) from the texture tiles (textiles) to each point on the mesh surface. This is done using conventional UV mapping, which is specified in "Object Textures" below; each object texture specifies a mapping from a set of vertices to locations in the textile, and these texture vertices are associated with position vertices specified here. Each textile is a 256x256 pixels wide area.

The 16-bit textile array, which contains [tr_textile16] structures, specifies colours using 16-bit ARGB, where the highest bit (`0x8000`) is a crude alpha channel (really just simple transparency — *0 = transparent*, *1 = opaque*). The next 5 bits (`0x7C00`) specify the red channel, the next 5 bits (`0x03E0`) specify the green channel, and the last 5 bits (`0x001F`) specify the blue channel, each on a scale from 0..31.

① ② ③ If, for some reason, 16-bit textures are turned off, all colours and textures use an 8-bit palette that is stored in the level file. This palette consists of a 256-element array of [tr_colour] structures, each designating some colour; textures and other elements that need to reference a colour specify an index (0..255) into the `Palette[]` array. There is also a 16-bit palette, which is used for identifying colours of solid polygons. The 16-bit palette contains up to 256 four-byte entries; the first three bytes are a [tr_colour], while the last byte is ignored (set to 0).

④ ⑤ The 32-bit textile array, which contains [tr4_textile32] structures, specifies colours using 32-bit ARGB, where the highest byte (A) is unused. The next bytes specify (in this order) the red / green / blue channels. The 16-bit and 32-bit textile arrays depict the same graphics data, but of course the 32-bit array has a better colour resolution. It's the one used if you select a 32-bit A8R8G8B8 texture format in the setup menu from TR4 and TR5.

2.3.4. Meshes and Sprites

There are two basic types of "visible objects" in TR2 — meshes and sprites.

Meshes are collections of textured or coloured polygons that are assembled to form a three-dimensional object (such as a tree, a tiger, or Lara herself). The "rooms" themselves are also composed of meshes. Mesh objects may contain more than one mesh; though these meshes are moved relative to each other, each mesh is rigid.

Sprites are two-dimensional images that are inserted into three-dimensional space, such as the "secret" dragons, ammunition, medi-packs, etc. There are also animated sprite sequences, such as the fire at the end of "The Great Wall." Core had presumably used this method to reduce CPU utilization on the PlayStation and/or the earlier PCs. Sprites become less and less abundant; TR2 has very few scenery sprites, and TR3's pickups are models instead of sprites.

2.3.5. Entities

Each Tomb Raider game has an internal hardcoded set of *entity types*, each of them linked to specific *model* (hence, *entity type* and *model* can be considered equal). Entity is an individual object with its own specific function and purpose. Almost every "moving" or "acting" thing you see is an entity — like enemies, doors, pick-up items, and even Lara herself.

A level can contain numerous instances of the same entity type, e.g. ten crocodiles, five similar doors and switches, and so on.

Entities are referenced in one of two ways — as an offset into an array (e.g. `Entities[i]`) or internally, using an unique index . In the latter case, the related array (`Entities[]`) is searched until a matching index is found. Each entity also refers to its `entity type` by `TypeID` to select behaviour and model to draw. In this case, `Models[]` array is searched for matching `TypeID` until one found.

2.3.6. Animations

There are three basic types of animations in TR, two corresponding with textures — sprite animations and animated textures — and one corresponding directly with meshes.

Sprite Animations

Sprite animation (sprite sequences) consists simply of a series of sprites that are to be displayed one after another, e.g. grenade explosions. Sprite animations were quite common in earlier games (TR1 and TR2), while in TR3 onwards there are almost no sprite animations — only notable example is fire particle sprites and water splash effect.

Animated Textures

These are either a list of textures cycled through in endless loop, or (in TR4-5) a single texture with shifting coordinates, creating an illusion of "rolling" image.

Mesh Animations

Mesh animations are much more complex than sprite and texture animations, and done by what is essentially a skeletal-modeling scheme. These involve some arrays (Frames[] and MeshTree[]) of offsets and rotations for each element of a composite mesh. Frames are then grouped into an array (Animations[]) that describes discrete "movements", e.g. Lara taking a step or a tiger striking with its paw. The animations are "sewn together" by a state change array and an animation dispatch array, which, together with state information about the character, ensure that the animation is fluid (e.g. if Lara is running and the player releases the RUN key, she will stop; depending upon which of her feet was down at the time, either her left or right foot will strike the floor as part of the "stop" animation. The correct animation (left foot stop vs. right foot stop) is selected using these structures and the state information).

2.3.7. Lighting

There are two main types of lighting in Tomb Raider, *constant* and *vertex*. Constant lighting means that all parts of an object have the same illumination, while in vertex lighting, each polygon vertex has its own light value, and the illumination of the polygon interiors is interpolated from the vertex values.

Furthermore, lighting can be either internal or external. Internal lighting is specified in an object's data, external lighting is calculated using the room's light sources (ambient light, point light sources, spotlights (TR4-5), dynamic lights).

When available, external lighting also uses the vertex normals to calculate the incoming light at each vertex. Light intensities are described either with a single value or with a 16 bits color value (you can see it more like a "color filter"), depending mainly on the TR version.

Light intensities are described with a single value in TR1 and a pair of values in TR2 and TR3; the paired values are almost always equal, and the pairing may reflect some feature that was only imperfectly implemented, such as off/on or minimum/maximum values. In TR1 and TR2, the light values go from 0 (maximum light) to 8192 (minimum light), while in TR3, the light values go from 0 (minimum light) to 32767 (maximum light).

2.3.8. Sound Samples

There are two ways for sound samples to play.

First one is basically sound emitter sitting at a static global position in level, and continuously emitting specified sound (such as waterfalls — these are in `SoundSources[]`). Second one is triggered sounds — these are sounds played when some event happens, such as at certain animation frames (footsteps and other Lara sounds), when doors open and close, and when weapons are fired.

Either way, each played sound is referred to using a three-layer indexing scheme, to provide a maximum amount of abstraction. An internal sound index references `SoundMap[]`, which points to a `SoundDetails[]` record, which in turn points to a `SampleIndices[]` entry, which in turn points to a sound sample. `SoundDetails[]`, contains such features as sound intensity, how many sound samples to choose from, among others. The sound samples themselves are in Microsoft WAVE format, and, as already mentioned, they are embedded either in the data files (TR1, TR4 and TR5) or in a separate file (`MAIN.SFX`) in TR2 and TR3.

2.4. Basic Data Structures

Much of the .TR2 file is comprised of structures based on a few fundamental data structures, described below.

2.4.1. Colour Structures

This is how most colours are specified.

```
struct tr_colour    // 3 bytes
{
    uint8_t Red;         // Red component (0 -- darkest, 255 -- brightest)
    uint8_t Green;       // Green component (0 -- darkest, 255 -- brightest)
    uint8_t Blue;        // Blue component (0 -- darkest, 255 -- brightest)
};
```

(Some compilers will pad this structure to make 4 bytes; one must either read and write 3 bytes explicitly, or else use a simple array of bytes instead of this structure.)

And as mentioned earlier, the 16-bit palette uses a similar structure:

```
struct tr_colour4   // 4 bytes
{
    uint8_t Red;
    uint8_t Green;
    uint8_t Blue;
    uint8_t Unused;
};
```

In TR5, there is new additional colour type composed of floating-point numbers. This type is primarily used in light structures.

```
struct tr5_colour   // 4 bytes
{
    float Red;
    float Green;
    float Blue;
    float Unused;    // Usually filler value = 0xCDCDCDCD
};
```

2.4.2. Vertex Structures

This is how vertices are specified, using relative coordinates. They are generally formed into lists, such that other entities (such as quads or triangles) can refer to them by simply using their index in the list.

```
struct tr_vertex    // 6 bytes
{
    int16_t x;
    int16_t y;
    int16_t z;
};
```

As with colours, TR5 introduced additional vertex type comprised of floating-point numbers:

```
struct tr5_vertex    // 12 bytes
{
    float x;
    float y;
    float z;
};
```

2.4.3. Rectangular (Quad) Face Definition

Four vertices (the values are indices into the appropriate vertex list) and a texture (an index into the object-texture list) or colour (index into 8-bit palette or 16-bit palette). If the rectangle is a coloured polygon (not textured), the .Texture element contains two indices: the low byte (`Texture & 0xFF`) is an index into the 256-colour palette, while the high byte (`Texture >> 8`) is in index into the 16-bit palette, when present. A textured rectangle will have its vertices mapped onto all 4 vertices of an object texture, in appropriate correspondence.

```
struct tr_face4     // 12 bytes
{
    uint16_t Vertices[4];
    uint16_t Texture;
};
```

`Texture` field can have the bit 15 set: when it is, the face is *double-sided* (i.e. visible from both sides).

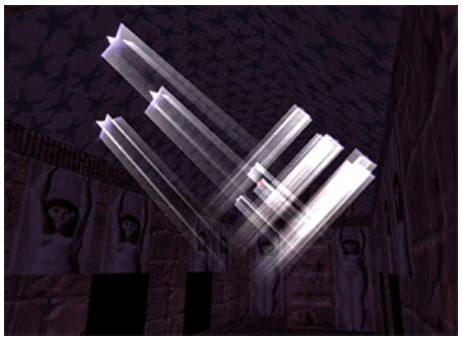
1 2 3 If the rectangle is a coloured polygon (not textured), the .Texture element contains two indices: the low byte (`Texture & 0xFF`) is an index into the 256-colour palette, while the high byte (`Texture >> 8`) is in index into the 16-bit palette, when present.

4 5 TR4 and later introduced an extended version *only used for meshes*, not for triangles and quads making rooms:

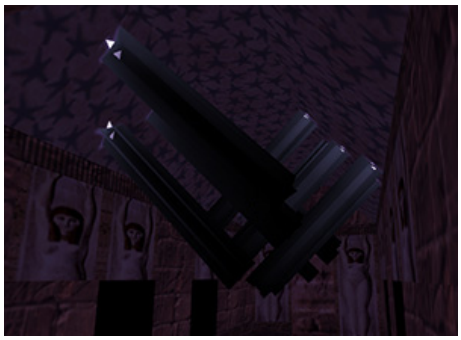
```
struct tr4_mesh_face4     // 12 bytes
{
    uint16_t Vertices[4];
    uint16_t Texture;
    uint16_t Effects;
};
```

The only difference is the extra field `Effects`. It has this layout:

- *Bit 0:* if set, face has *additive alpha blending* (same meaning that when the `Attribute` field of [tr_object_texture] is 2, but this flag overrides it).

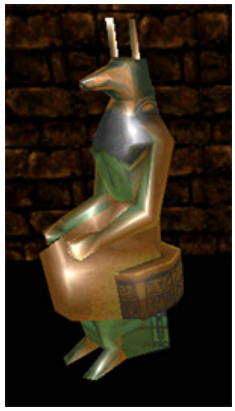


Bit 0 set, blending enabled

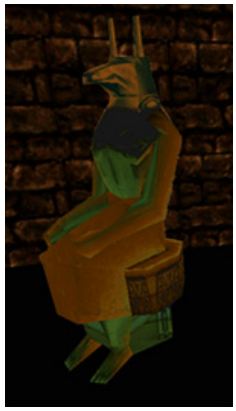


Bit 0 not set, blending disabled

- *Bit 1:* if set, face has *environment mapping* effect (so-called “shiny effect” in TRLE community). Environment map is derived from special pre-rendered texture.
- *Bits 2..7:* strength of *environment mapping* effect. The bigger the value is, the more visible the effect is.



Shiny effect at max



No shiny effect

1. Note that only externally lit meshes can use environment mapping in original engines. If you use it with internally lit meshes, you will crash the game.
2. TR4 engine doesn't support environmental map for Lara's joints. It simply wasn't implemented, so if you apply effect to Lara joints, game will crash. For TR5, a special object called *Lara's catsuit* was developed to support environmental map on transformed meshes.

2.4.4. Triangular Face Definition

These structures has the same layout than the quad face definitions, except a textured triangle will have its vertices mapped *onto the first 3 vertices of an object texture, in appropriate correspondence*. Moreover, a triangle has only 3 vertices, not 4.

```
struct tr_face3    // 8 bytes
{
    uint16_t Vertices[3];
    uint16_t Texture;
};
```

```
struct tr4_mesh_face3    // 10 bytes
{
    uint16_t Vertices[3];
    uint16_t Texture;
    uint16_t Effects;    // TR4-5 ONLY: alpha blending and environment mapping
strength
};
```

All the info about `Texture` and `Effects` fields is also similar to same info from [tr_face4] and [tr4_mesh_face4] respectively.

2.4.5. 8-bit Texture Tile

Each `uint8_t` represents a pixel whose colour is in the 8-bit palette.

```
struct tr_textile8    // 65536 bytes
{
    uint8_t Tile[256 * 256];
};
```

2.4.6. 16-bit Texture Tile

Each `uint16_t` represents a pixel whose colour is of the form ARGB, MSB-to-LSB:

1-bit transparency (`0` = transparent, `1` = opaque) (`0x8000`)
5-bit red channel (`0x7C00`)
5-bit green channel (`0x03E0`)
5-bit blue channel (`0x001F`)

```
struct tr_textile16    // 131072 bytes
{
    uint16_t Tile[256 * 256];
};
```

2.4.7. 32-bit Texture Tile

Each `uint32_t` represents a pixel whose colour is of the form ARGB, (A = most significant byte), each component being one byte.

```
struct tr4_textile32    // 262144 bytes
{
    uint32_t Tile[256 * 256];
};
```

3. Room Geometry

3.1. Overview

A *room* in TR2 is simply a rectangular three-dimensional area. A room may be "indoors" or "outdoors," may or may not be enclosed, may be accessible or inaccessible to Lara, may or may not contain doors or objects.

All rooms have "portals," called "doors" in some documentation, which are pathways to adjacent rooms. There are two kinds of portals — visibility portals and collisional portals. Visibility portals are for determining how much of a room (if any) is visible from another room, while collisional portals are for enabling an object to travel from one room to another.

The visibility portals are most likely for doing "portal rendering", which is a visibility-calculation scheme that goes as follows: the viewpoint is a member of some room, which is then listed as visible from it. This room's portals are checked for visibility from that viewpoint, and visible portals have their opposite-side rooms marked as visible. These rooms are then checked for portals that are visible from the viewpoint through the viewpoint's room's portals, and visible ones have their opposite-side rooms marked as visible. This operation is repeated, with viewing through intermediate portals, until all visible portals have been found. The result is a tree of rooms, starting from the viewpoint's room; only those rooms and their contents need to be rendered.

It is clear that both visibility and collision calculations require that objects have room memberships given for them, and indeed we shall find that most map objects have room memberships.

Rooms may overlap; as we shall see, this is involved in how horizontal collisional portals are implemented. However, different rooms may overlap without either being directly accessible from the other; there are several inadvertent examples of such "5D space" in the Tomb Raider series. The only possibly deliberate example I know of is the flying saucer in "Area 51" in TR3, whose interior is bigger than its exterior.

A room can have an "alternate room" specified for it; that means that that room can be replaced by that alternate as the game is running. This trick is used to produce such tricks as empty rooms vs. rooms full of water, scenery rearrangements (for example, the dynamited house in "Bartoli's Hideout" in TR2), and so forth. An empty room is first created, and then a full room is created at its location from a copy of it. The empty room then has that full room set as its alternate, and when that room is made to alternate, one sees a full room rather than an empty one.

The rooms are stored sequentially in an array, and "Room Numbers" are simply indices into this array (e.g. "Room Number 5" is simply `Rooms[5]`; the first room is `Rooms[0]`).

Rooms are divided into *sectors* (or *squares*), which are 1024x1024 unit squares that form a grid on the *X* - *Z* plane. Sectors are the defining area for floor/ceiling heights and triggers (e.g. a tiger appears and attacks when Lara steps on a given square); the various attributes of each sector are stored in the Sector Data (described in this section) and the [FloorData]. As an aside, Sectors correspond to the "squares," easily visible in all of the Tomb Raider games, that experienced players count when gauging jumps; they also account for some of the game's less-appealing graphic artifacts. Careful tiling and texture construction can make these "squares" almost invisible.

Each room has two types of surface geometry — *rendered* and *collisional*. The former are what is *seen*, while the latter control how objects *collide* and *interact* with the world. Furthermore, these two types are specified separately in the room data — each type is *completely independent of other*, i. e. collisional geometry shouldn't exactly match visible room geometry.

While this distinctive feature was never used in originals (collisional room "meshes" fully resembled visible room "meshes"), it is now extensively used by level editing community with the help of a program called *meta2tr*. This utility allows level builder to replace visible geometry generated by *TRLE* with any custom geometry, usually modelled in *Metasequoia* 3D editor (hence the name of *meta2tr* utility).

Rooms are defined with a complex structure, which is described below "inside-out," meaning that the smaller component structures are described first, followed by the larger structures that are built using the smaller structures.

3.2. Room Structures

3.2.1. Room header

X / *Z* indicate the base position of the room mesh in world coordinates (*Y* is always zero-relative)

```
struct tr_room_info    // 16 bytes
{
    int32_t x;              // X-offset of room (world coordinates)
    int32_t z;              // Z-offset of room (world coordinates)
    int32_t yBottom;
    int32_t yTop;
};
```

`yBottom` is actually largest value, but indicates *lowest* point in the room. `yTop` is actually smallest value, but indicates *highest* point in the room.

TR5 uses an extended version of this structure:

```
struct tr5_room_info    // 20 bytes
{
    int32_t x;              // X-offset of room (world coordinates)
    int32_t y;              // Y-offset of room (world coordinates) - only in TR5
    int32_t z;              // Z-offset of room (world coordinates)
    int32_t yBottom;
    int32_t yTop;
};
```

The additional `y` value is usually 0.

3.2.2. Portal Structure

These portals, sometimes called “doors”, define the view from a room into another room. This can be through a “real” door, a window, or even some open area that makes the rooms look like one big room. Note that “rooms” here are really just areas; they aren’t necessarily enclosed. The portal structure below defines *only visibility portals*, not an actual door model, texture, or action (if any). And if the portal is not properly oriented, the camera cannot “see” through it.

```
struct tr_room_portal  // 32 bytes
{
    uint16_t  AdjoiningRoom; // Which room this portal leads to
    tr_vertex Normal;
    tr_vertex Vertices[4];
};
```

`Normal` field tells which way the portal faces (the normal points *away* from the adjacent room; to be seen through, it must point *toward* the viewpoint).

`Vertices` are the corners of this portal (the right-hand rule applies with respect to the normal). If the right-hand-rule is not followed, the portal will contain visual artifacts instead of a viewport to `AdjoiningRoom`.

> The original portal testing algorithm performs a breadth-first visibility check of the bounding boxes of the screen-projected portal vertices, and also compares the vector from the camera to the first portal vertex to its normal. This works pretty fine, unless there are denormalized bounding boxes, which the original TR solves by expanding the portal bounding box to its maximum if a projected edge crosses the screen plane or its boundaries.

3.2.3. Room Sector Structure

All the geometry specified here is *collisional geometry*.

```
struct tr_room_sector // 8 bytes
{
    uint16_t FDindex;     // Index into FloorData[]
    uint16_t BoxIndex;    // Index into Boxes[] (-1 if none)
    uint8_t  RoomBelow;   // 255 is none
    int8_t   Floor;       // Absolute height of floor
    uint8_t  RoomAbove;   // 255 if none
    int8_t   Ceiling;     // Absolute height of ceiling
};
```

`Floor` and `Ceiling` are signed numbers of 256 units of height (relative to 0) — e.g. Floor `0x04` corresponds to $Y = 1024$ in world coordinates. Therefore, 256 units is a *minimum vertical stride of collisional geometry*. However, this rule could be broken by specific entities, which Lara can stand on. But *horizontal* sector dimensions, which, as mentioned earlier, are 1024 x 1024 (in world coordinates), could not. Therefore, minimal horizontal platform dimensions, on which Lara can stand and grab, are 1024 x 1024 as well.

Note | This implies that, while *X* and *Z* can be quite large, *Y* is constrained to -32768..32512.

`Floor` and `Ceiling` value of `0x81` is a magic number used to indicate impenetrable walls around the sector. `Floor` values are used by the game engine to determine what objects Lara can traverse and how. Relative steps of 1 (-256) can be walked up; steps of 2..7 (-512..-1792) can/must be jumped up; steps larger than 7 (-2048..-32768) cannot be jumped up (too tall).

`RoomAbove` and `RoomBelow` values indicate what neighboring rooms are in these directions — the number of the room below this one and the number of the room above this one. If `RoomAbove` is not *none*, then the ceiling is a *collisional portal* to that room, while if `RoomBelow` is not *none*, then the floor is a *collisional portal* to that room.

Also, `RoomBelow` value is extensively used by engine to determine actual sector data and triggers in so-called *stacked room setups*, when one room is placed above another through collisional portal. The thing is, engine uses sector data and triggers *only for the lowest sector* of the stacked room setup, so it recursively scans for a lowest room to determine which sector to use.

`FDindex` is a pointer to specific entry in [FloorData] array, which keeps all the information about sector flags, triggers and other parameters. While it is implied that one `FDindex` entry may be shared between several sectors, it is usually not the case with original Tomb Raider levels built with *TRLE*. However, *Dxtre3d* takes advantage of this feature and may optimize similar sectors to share same FDindex pointer.

`BoxIndex` is a pointer to special [Boxes] array entry, which is basically a subset of sectors with same height configuration. It is primarily used for AI pathfinding (see the Non-player character behaviour chapter for more details).

3 4 5 In these games, `BoxIndex` field is more complicated, and actually contains *two packed values*. Bits 4..14 contain the *actual box index*, and bits 0..3 contain *material index*, which is used to produce specific footstep sound, when Lara is walking or running in this sector. On PlayStation game versions, this index was also used to determine if footprint textures should be applied to this particular place. Both procedures are invoked via `FOOTPRINT_FX` flipeffect, which is described in corresponding section.

Majority of *material index* values are the same across game versions, but some of them exist only in particular game. Here is the description:

- **0** — Mud
- **1** — Snow (TR3 and TR5 only)
- **2** — Sand
- **3** — Gravel
- **4** — Ice (TR3 and TR5 only)
- **5** — Water *(unused, as water footstep is only activated in water rooms)*
- **6** — Stone *(unused, as it is default footstep sound)*
- **7** — Wood
- **8** — Metal
- **9** — Marble (TR4 only)
- **10** — Grass *(same sound effect as sand)*
- **11** — Concrete *(same sound effect as stone, hence unused)*
- **12** — Old wood *(same sound effect as wood)*
- **13** — Old metal *(same sound effect as metal)*

Mud, snow, sand, grass and maybe some other materials produce footprints in PlayStation version.

Furthermore, in TR3-5, *actual box index* may contain special value 2047, which is most likely indicates that this sector is a slope on which Lara can slide (and, therefore, possibly impassable by most NPCs).

3.2.4. Room Light Structure

Note | TR engines always used static room lights only for processing lighting on entities (such as Lara, enemies, doors, and others). This is called *external lighting*. For room meshes, they used so-called internal, or *pre-baked* lighting, which is done on level building stage: lights are calculated and applied to room faces via vertex colours. There is no way to change room lighting when the level is compiled — meaning, any changes in light positions, intensities and colour won't affect room faces.

There are four different types of room light structures. First one is used in TR1-2, second is used in TR3, third is used in TR4, and fourth is used in TR5. Here is the description of each:

TR1 Room Lighting

```
struct tr_room_light    // 18 bytes
{
```

```
     int32_t x, y, z;       // Position of light, in world coordinates
    uint16_t Intensity1;    // Light intensity
    uint32_t Fade1;         // Falloff value
};
```

`X/Y/Z` are in world coordinates. `Intensity1/Intensity2` are almost always equal. This lighting only affects *externally-lit* objects. Tomb Raider 1 has only the first of the paired `Intensity` and `Fade` values.

`Intensity1` ranges from 0 (dark) to 0x1FFF (bright). However, some rooms occasionally have some lights with intensity greater than 0x1FFF (for example, look at room #9, 2nd light in `level1.phd`). `Fade1` is the maximum distance the light shines on, and ranges from 0 to 0x7FFF.

TR2 Room Lighting

TR2 uses an extended version of TR1 light structure:

```
struct tr2_room_light   // 24 bytes
{
     int32_t x, y, z;       // Position of light, in world coordinates
    uint16_t Intensity1;    // Light intensity
    uint16_t Intensity2;    // Only in TR2
    uint32_t Fade1;         // Falloff value
    uint32_t Fade2;         // Only in TR2
};
```

`Intensity2` and `Fade2` values are seemingly not used. `Intensity1` can go very well beyond 0x1FFF, right to 0x7FFF (ultra bright light). Above 0x7FFF, it is always black, so the number is pseudo-signed (negative values are always treated as zero).

TR3 Room Lighting

TR3 introduced a rudimentary "light type" concept. Although only possible types are sun (type 0) and point light (type 1). It is not clear how sun affetcts room lighting, but somehow it interpolates with all other light objects in a given room. Both light types are kept using the same structure, with two last 8 bytes used as union.

```
struct tr3_room_light   // 24 bytes
{
        int32_t x, y, z;        // Position of light, in world coordinates
      tr_colour Colour;         // Colour of the light
      uint8_t LightType;      // Only 2 types - sun and point lights
      union           // 8 bytes
      {
            tr3_room_spotlight;
            tr3_room_pointlight;
      }
};
```

Depending on `LightType`, last 8 bytes are parsed differently, either as `tr3_room_spotlight` or `tr3_toom_sun` structure:

```
struct tr3_room_sun // 8 bytes
{
        int16_t nx, ny, nz; // Normal?
        int16_t Unused;
};
```

`nx`, `ny` and `nz` is most likely a normal.

```
struct tr3_room_spotlight // 8 bytes
{
        int32_t Intensity;
        int32_t Fade;   // Falloff value
};
```

`Intensity` is the power of the light and ranges mainly from 0 (low power) to 0x1FFF (high power). `Fade` is the distance max the light can shine on. Range is mainly from 0 to 0x7FFF.

TR4 Room Lighting

```
struct tr4_room_light   // 46 bytes
{
        int32_t x, y, z;        // Position of light, in world coordinates
      tr_colour Colour;         // Colour of the light

        uint8_t LightType;
        uint8_t Unknown;        // Always 0xFF?
        uint8_t Intensity;

          float In;             // Also called hotspot in TRLE manual
          float Out;            // Also called falloff in TRLE manual
          float Length;
          float CutOff;

          float dx, dy, dz;     // Direction - used only by sun and spot lights
};
```

`LightType` was extended and is now somewhat similar to D3D light type, but there are some differences.

- **0** — Sun
- **1** — Light
- **2** — Spot
- **3** — Shadow
- **4** — Fog bulb

Fog bulb is a special case of room light, which actually don't work as usual light. It serves as a point in space, where a kind of *volumetric fog* effect is generated. It works only if user has enabled corresponding option in game setup.

Fog bulbs don't use `Colour` field to define its colour. However, `Red` field of a `Colour` structure is used to define fog density. Colour itself can be only changed with special *flipeffect #28* trigger function, which takes a value from the *timer field* of the trigger to index into hardcoded RGB table of pre-defined colours. The table consists of 28 RGB values:

	0 = 0,0,0		7 = 0,64,192		14 = 111,255,223		21 = 0,30,16
	1 = 245,200,60		8 = 0,128,0		15 = 244,216,152		22 = 250,222,167
	2 = 120,196,112		9 = 150,172,157		16 = 248,192,60		23 = 218,175,117
	3 = 202,204,230		10 = 128,128,128		17 = 252,0,0		24 = 225,191,78
	4 = 128,64,0		11 = 204,163,123		18 = 198,95,87		25 = 77,140,141
	5 = 64,64,64		12 = 177,162,140		19 = 226,151,118		26 = 4,181,154
	6 = 243,232,236		13 = 0,223,191		20 = 248,235,206		27 = 255,174,0

TR5 Room Lighting

```
struct tr5_room_light   // 88 bytes
{
        float x, y, z;        // Position of light, in world coordinates
        float r, g, b;        // Colour of the light

       uint32_t Separator     // Dummy value = 0xCDCDCDCD

        float In;             // Cosine of the IN value for light / size of IN value
        float Out;            // Cosine of the OUT value for light / size of OUT value
        float RadIn;          // (IN radians) * 2
        float RadOut;         // (OUT radians) * 2
        float Range;          // Range of light

        float dx, dy, dz;     // Direction - used only by sun and spot lights
      int32_t x2, y2, z2;     // Same as position, only in integer.
      int32_t dx2, dy2, dz2;  // Same as direction, only in integer.

      uint8_t LightType;
```

```
        uint8_t Filler[3];      // Dummy values = 3 x 0xCD
};
```

x, y, z values shouldn't be used by sun type light, but sun seems to have a large x value (9 million, give or take), a zero y value, and a small z value (4..20) in the original TR5 levels.

In and Out values aren't used by *sun* type. For the *spot* type, these are the *hotspot* and *falloff angle* cosines. For the *light* and *shadow* types, these are the TR units for the *hotspot / falloff* (1024 = 1 sector).

RadIn, RadOut and Range are only used by the *spot* light type.

dx, dy and dz values are used only by the *sun* and *spot* type lights. They describe the directional vector of the light. This can be obtained by:

- if both x and y $\mathnormalLightDirectionVectorX = \cos\left(X\right) * \sin\left(Y\right)$
- $\mathnormalLightDirectionVectorY = \sin\left(X\right)$
- $\mathnormalLightDirectionVectorZ = \cos\left(X\right) * \cos\left(Y\right)$

x2, y2, z2, dx2, dy2 and dz2 values repeat previous corresponding information in long data types instead of floats.

Additionally, TR5 implements separate data structure for fog bulbs, which are kept separately from all other lights in room structure:

```
struct tr5_fog_bulb   // 36 bytes
{
        float x, y, z;        // Position of light, in world coordinates
        float r, g, b;        // Colour of the light

       uint32_t Separator     // Dummy value = 0xCDCDCDCD

        float In;             // Size of IN value
        float Out;            // Size of OUT value
};
```

3.2.5. Room Vertex Structure

This defines the vertices within a room. As mentioned above, room lighting is internal vertex lighting, except for necessarily external sources like flares, flame emitters and gunflashes. Room ambient lights and point sources are ignored.

As TR3 introduced colored lighting, room vertex structure drastically changed. It changed once again in TR5, when floating-point numbers were introduced. So we'll define vertex structure for TR1-2, TR3-4 and TR5 independently.

TR1-2 Room Vertex Structure

```
struct tr_room_vertex  // 8 bytes
{
     tr_vertex Vertex;
       int16_t Lighting;
};
```

Vertex is the coordinates of the vertex, relative to [tr_room_info] x and z values.

Lighting ranges from 0 (bright) to 0x1FFF (dark). This value is ignored by TR2, and Lighting2 is used instead with the same brightness range.

TR2 uses an extended version of the structure:

```
struct tr2_room_vertex  // 12 bytes
{
     tr_vertex Vertex;
       int16_t Lighting;
      uint16_t Attributes; // A set of flags for special rendering effects
       int16_t Lighting2;  // Almost always equal to Lighting1
};
```

Attributes field is a *set of flags*, and their meaning is:

- *Bits 0..4* are only used together in combination with the LightMode field of the [tr_room] structure. See below.
- *Bit 15:* When used in room filled with water, don't move the vertices of the room when viewed from above (normally, when viewed from above, the vertices of a room filled with water moves to *simulate* the refraction of lights in water). Note that when viewed from inside the room filled with water, the vertices of the other rooms outside still moves.

`Lighting` field is ignored by TR2, and `Lighting2` is used instead with the same brightness range — from 0 (bright) to 0x1FFF (dark).

TR3-4 Room Vertex Structure

```
struct tr3_room_vertex  // 12 bytes
{
     tr_vertex Vertex;
       int16_t Lighting;   // Value is ignored!
      uint16_t Attributes; // A set of flags for special rendering effects
      uint16_t Colour;     // 15-bit colour
};
```

`Lighting` value is ignored by the engine, as now each vertex has its own defined 15-bit colour (see below).

`Attributes` bit flags were extended. Also, old bits 0..4 aren't working properly anymore, because effect lighting was broken in TR3. Here is the list of new flags:

- *Bit 13:* Water / quicksand surface "wave" movement. Brightness is also shifting, if this flag is set (but it's not the same type as with *Bit 14*, it's much less noticeable).
- *Bit 14:* Simulates caustics by constantly shifting vertex colour brightness. Used mainly in underwater rooms, but can be used in rooms without water. In TR2, there was a similar effect, but it was assigned for all vertices in any water room.
- *Bit 15:* ④ ⑤ Broken in these game versions. Instead, same "wave" effect is produced as with *Bit 13*, but with slightly less glow.

Note The amplitude of the "wave" effect depends on `WaterScheme` value specified in room structure.

`Colour` value specifies vertex colour in 15-bit format (each colour occupies 5 bits). Therefore, each colour value's maximum is *31*. You can use this code to get each colour:

- *Red:* `((Colour & 0x7C00) >> 10)`
- *Green:* `((Colour & 0x03E0) >> 5)`
- *Blue:* `(Colour & 0x001F)`

TR5 Room Vertex Structure

In TR5, room vertex structure was almost completely changed. Coordinates were converted to floats, and normal was added:

```
struct tr5_room_vertex  // 28 bytes
{
    tr5_vertex Vertex;     // Vertex is now floating-point
    tr5_vertex Normal;
      uint32_t Colour;     // 32-bit colour
};
```

There is no more `Attributes` field in room vertex structure for TR5.

3.2.6. Room Sprite Structure

```
struct tr_room_sprite  // 4 bytes
{
    int16_t Vertex;       // Offset into vertex list
    int16_t Texture;      // Offset into sprite texture list
};
```

`Vertex` indicates an index into room vertex list (`Room.Vertices[room_sprite.Vertex]`), which acts as a point in space where to display a sprite.

`Texture` is an index into the sprite texture list.

3.2.7. Room Data Structure

This is the whole geometry of the "room," including walls, floors, ceilings, and other embedded landscape. It *does not* include objects that Lara can interact with (keyholes, moveable blocks, moveable doors, etc.), neither does it include *static meshes* (mentioned below in the next section).

The surfaces specified here are rendered surfaces.

Caution This is not a "real" C/C++ structure, in that the arrays are sized by the `NumXXX` elements that precede them. Also [tr_room_vertex] could be replaced by any other version-specific room vertex type ([tr3_room_vertex], etc.).

```
virtual struct tr_room_data    // (variable length)
{
    int16_t NumVertices;                    // Number of vertices in the following list
    tr2_room_vertex Vertices[NumVertices]; // List of vertices (relative coordinates)

    int16_t NumRectangles;                  // Number of textured rectangles
    tr_face4 Rectangles[NumRectangles];     // List of textured rectangles

    int16_t NumTriangles;                   // Number of textured triangles
    tr_face3 Triangles[NumTriangles];       // List of textured triangles

    int16_t NumSprites;                     // Number of sprites
    tr_room_sprite Sprites[NumSprites];     // List of sprites
};
```

3.2.8. Room Static Mesh Structure

Positions and IDs of static meshes (e.g. skeletons, spiderwebs, furniture, trees). This is comparable to the [tr_entity] structure, except that static meshes have no animations and are confined to a single room.

TR1 Room Static Mesh Structure

```
struct tr_room_staticmesh  // 18 bytes
{
    uint32_t x, y, z;     // Absolute position in world coordinates
    uint16_t Rotation;
    uint16_t Intensity1;
    uint16_t MeshID;      // Which StaticMesh item to draw
};
```

`Intensity1` ranges from 0 (bright) to 0x1FFF (dark).

In `Rotation` field, high two bits (`0xC000`) indicate steps of 90 degrees (e.g. (Rotation >> 14) * 90). However, when parsing this value, no extra bitshifting is needed, as you can simply interpret it using this formula:

```
float Real_Rotation = (float)Rotation / 16384.0f * -90;
```

TR2 Room Static Mesh Structure

TR2 again uses an extended version:

```
struct tr2_room_staticmesh  // 20 bytes
{
    uint32_t x, y, z;     // Absolute position in world coordinates
    uint16_t Rotation;
    uint16_t Intensity1;
    uint16_t Intensity2; // Absent in TR1
    uint16_t MeshID;      // Which StaticMesh item to draw
};
```

`Intensity2` is seemingly not used, as changing this value does nothing.

TR3-5 Room Static Mesh Structure

```
virtual struct tr3_room_staticmesh  // 20 bytes
{
    uint32_t x, y, z;     // Absolute position in world coordinates
    uint16_t Rotation;
    uint16_t Colour;      // 15-bit colour
    uint16_t Unused;      // Not used!
    uint16_t MeshID;      // Which StaticMesh item to draw
};
```

`Colour` value specifies vertex colour in 15-bit format (each colour occupies 5 bits): 0x0[red]RRRRR[green]GGGGG[blue]BBBBB. Therefore, each colour value's maximum is *31*. You can use this code to get

each colour:

- *Red:* `((Colour & 0x7C00) >> 10)`
- *Green:* `((Colour & 0x03E0) >> 5)`
- *Blue:* `(Colour & 0x001F)`

3.3. TR5 Room Structure Changes

In TR5 the room format was drastically changed. The room itself is made up of *sections*. These sections encompass a 3x3 sector grid (actually 3069x3069 pixels). Historically, these sections are referred as *layers*, however, more proper name for them is *volumes*. Layers are organized in a quadtree-like structure, and their purpose was presumably optimizing rendering by some kind of space partitioning and culling invisible volumes.

Another thing to note is that some *rooms* in TR5 do not actually contain visible mesh data. If concerned, we will refer to these rooms as *null rooms*.

3.3.1. TR5 Room Layer Structure

```
struct tr5_room_layer   // 56 bytes
{
    uint32_t NumLayerVertices;   // Number of vertices in this layer (4 bytes)
    uint16_t UnknownL1;
    uint16_t NumLayerRectangles; // Number of rectangles in this layer (2 bytes)
    uint16_t NumLayerTriangles;  // Number of triangles in this layer (2 bytes)
    uint16_t UnknownL2;

    uint16_t Filler;             // Always 0
    uint16_t Filler2;            // Always 0

    // The following 6 floats define the bounding box for the layer

    float    LayerBoundingBoxX1;
    float    LayerBoundingBoxY1;
    float    LayerBoundingBoxZ1;
    float    LayerBoundingBoxX2;
    float    LayerBoundingBoxY2;
    float    LayerBoundingBoxZ2;

    uint32_t Filler3;      // Always 0 (4 bytes)
    uint32_t UnknownL6;    // Unknown
    uint32_t UnknownL7;    // Unknown
    uint32_t UnknownL8;    // Always the same throughout the level.
}
```

`UnknownL2` appears to be the number of double sided textures in this layer, however is sometimes 1 off (2 bytes).

3.4. The Whole Room Structure

Here's where all the room data come together.

Room structure differs drastically across different game versions (especially in TR5). For this reason, we will define each version of Room structure independently, to avoid confusion. Also, version-specific fields will be described in each version's section in a "backwards-compatible" manner, while common fields with version-specific variations, such as `Flags`, will be described afterwards in separate section.

These are not "real" C/C++ structures, in that the arrays are sized by the `NumXXX` elements that precede them.

3.4.1. TR1 Room Structure

As it's stored in the file, the [tr_room_info] structure comes first, followed by a `uint32_t NumDataWords`, which specifies the number of 16-bit words to follow. Those data words must be parsed in order to interpret and construct the variable-length arrays of vertices, meshes, doors, and sectors. Such setup is also applicable to all variations of room structures, *except* [tr5_room], which will be described independently.

```
virtual struct tr_room  // (variable length)
{
    tr_room_info info;            // Where the room exists, in world coordinates

    uint32_t NumDataWords;        // Number of data words (uint16_t's)
    uint16_t Data[NumDataWords]; // The raw data from which the rest of this is
derived

    tr_room_data RoomData;        // The room mesh
```

```
    uint16_t NumPortals;                // Number of visibility portals to other
rooms
    tr_room_portal Portals[NumPortals];  // List of visibility portals

    uint16_t NumZsectors;                                   // ``Width'' of sector list
    uint16_t NumXsectors;                                   // ``Height'' of sector
list
    tr_room_sector SectorList[NumXsectors * NumZsectors];  // List of sectors in this
room

    int16_t AmbientIntensity;

    uint16_t NumLights;                // Number of lights in this room
    tr_room_light Lights[NumLights];    // List of lights

    uint16_t NumStaticMeshes;                              // Number of static meshes
    tr2_room_staticmesh StaticMeshes[NumStaticMeshes];    // List of static meshes

    int16_t AlternateRoom;
    int16_t Flags;
};
```

`AmbientIntensity` is a brightness value which affects only *externally-lit* objects. It ranges from 0 (bright) to 0x1FFF (dark).

`AlternateRoom` (or, as it is called in TRLE terms, *flipped room*) is the number of the room that this room can *flip* with. In the terms of the gameplay, *flipped* room is a state change of the same room — for example, empty or flooded with water, filled with sand or debris. Alternate room usually has the same boundaries as original room, but altered geometry and/or texturing. Detailed description of *alternate rooms* will be provided in a separate section.

3.4.2. TR2 Room Structure

```
virtual struct tr2_room  // (variable length)
{
    tr_room_info info;            // Where the room exists, in world coordinates

    uint32_t NumDataWords;        // Number of data words (uint16_t's)
    uint16_t Data[NumDataWords]; // The raw data from which the rest of this is
derived

    tr_room_data RoomData;        // The room mesh

    uint16_t NumPortals;                // Number of visibility portals to other
rooms
    tr_room_portal Portals[NumPortals];  // List of visibility portals

    uint16_t NumZsectors;                                   // ``Width'' of sector list
    uint16_t NumXsectors;                                   // ``Height'' of sector
list
    tr_room_sector SectorList[NumXsectors * NumZsectors];  // List of sectors in this
room

    int16_t AmbientIntensity;
    int16_t AmbientIntensity2;  // Usually the same as AmbientIntensity
    int16_t LightMode;

    uint16_t NumLights;                // Number of point lights in this room
    tr_room_light Lights[NumLights];    // List of point lights

    uint16_t NumStaticMeshes;                              // Number of static meshes
    tr_room_staticmesh StaticMeshes[NumStaticMeshes];    // List of static meshes

    int16_t AlternateRoom;
    int16_t Flags;
};
```

`AmbientIntensity2` value is usually equal to `AmbientIntensity` value. Seems it's not used.

`LightMode` specifies lighting mode special effect, which is applied to all room vertices in conjunction with 5 lowest bits of `Attributes` field belonging to [tr_room_vertex] structure. Here we will refer these 5 bits value to as `effect_value`:

- **0** — Normal lighting mode, no special effects.
- **1** — Produces flickering effect, with `effect_value` acting the same way — as intensity multiplier.

- **2** — If `effect_value` is in 1-15 range, then vertex lighting is cyclically fading to more bright value. The lower the value is, the deeper the fade to full vertex lighting is. If `effect_value` is in 17-30 range (*not* 31!), then vertex lighting is cyclically fading to more dark value. The higher the value is, the deeper the fade to black is. If `effect_value` is 16 or 0, no effect is produced. So practically, `effect_value` serves as a multiplier to overall effect brightness.
- **3** — If `sunset` gameflow script opcode is set, rooms with this light type will gradually dim all lights for 20 minutes. This happens in Bartoli's Hideout. Sunset state isn't saved in savegames and will be reset on reload.

3.4.3. TR3 Room Structure

```
virtual struct tr3_room  // (variable length)
{
    tr_room_info info;            // Where the room exists, in world coordinates

    uint32_t NumDataWords;        // Number of data words (uint16_t's)
    uint16_t Data[NumDataWords]; // The raw data from which the rest of this is
derived

    tr_room_data RoomData;        // The room mesh

    uint16_t NumPortals;                  // Number of visibility portals to other
rooms
    tr_room_portal Portals[NumPortals];  // List of visibility portals

    uint16_t NumZsectors;                                    // ``Width'' of sector list
    uint16_t NumXsectors;                                    // ``Height'' of sector
list
    tr_room_sector SectorList[NumXsectors * NumZsectors];  // List of sectors in this
room

    int16_t AmbientIntensity;   // Affects externally-lit objects
    int16_t LightMode;       // Broken in this game version

    uint16_t NumLights;                  // Number of point lights in this room
    tr3_room_light Lights[NumLights];    // List of point lights

    uint16_t NumStaticMeshes;                               // Number of static meshes
    tr_room_staticmesh StaticMeshes[NumStaticMeshes];    // List of static meshes

    int16_t AlternateRoom;
    int16_t Flags;

    uint8_t WaterScheme;
    uint8_t ReverbInfo;

    uint8_t Filler;  // Unused.
};
```

`LightMode` types are broken and produce aburpt "bumpy ceiling" effect. It happens because internally same data field was reused for vertex waving effects (seen in quicksand and water rooms)

3.4.4. TR4 Room Structure

```
virtual struct tr4_room  // (variable length)
{
    tr_room_info info;            // Where the room exists, in world coordinates

    uint32_t NumDataWords;        // Number of data words (uint16_t's)
    uint16_t Data[NumDataWords]; // The raw data from which the rest of this is
derived

    tr_room_data RoomData;        // The room mesh

    uint16_t NumPortals;                  // Number of visibility portals to other
rooms
    tr_room_portal Portals[NumPortals];  // List of visibility portals

    uint16_t NumZsectors;                                    // ``Width'' of sector list
    uint16_t NumXsectors;                                    // ``Height'' of sector
list
    tr_room_sector SectorList[NumXsectors * NumZsectors]; // List of sectors in this
room
```

```
    uint32_t RoomColour;        // In ARGB format!

    uint16_t NumLights;                 // Number of point lights in this room
    tr4_room_light Lights[NumLights];   // List of point lights

    uint16_t NumStaticMeshes;                           // Number of static meshes
    tr_room_staticmesh StaticMeshes[NumStaticMeshes];   // List of static meshes

    int16_t AlternateRoom;
    int16_t Flags;

    uint8_t WaterScheme;
    uint8_t ReverbInfo;

    uint8_t AlternateGroup;  // Replaces Filler from TR3
};
```

`RoomColour` replaces `AmbientIntensity` and `AmbientIntensity2` values from [tr2_room] structure. Note it's *not in [tr_colour4] format*, because colour order is reversed. It should be treated as ARGB, where A is unused.

`AlternateGroup` was introduced in TR4 to solve long-existing engine limitation, which flipped *all alternate rooms at once* (see *flipmap* trigger action description in Trigger actions section). Since TR4, engine only flips rooms which have similar index in room's `AlternateGroup` field and trigger operand.

3.4.5. TR5 Room Structure

As it was mentioned before, TR5 room structure was almost completely changed, when compared to previous versions. For example, TR5 completely throws out a concept of [tr_room_data] structure, shuffles numerous values and structures in almost chaotic manner, and introduces a bunch of completely new parameters (mostly to deal with *layers*). Also, there is vast amount of *fillers* and *separators*, which contain no specific data.

The one possible reason for such ridiculous structure change is an attempt to *crypt file format*, so it won't be accessed by unofficial level editing tools, which received major development by that time. Another possible reason is whole TR5 development process was rushed, as the team developed *Tomb Raider: Angel of Darkness* at the very same time.

```
virtual struct tr5_room // (variable length)
{
    char XELA[4];           // So-called "XELA landmark"

    uint32_t RoomDataSize;

    uint32_t Seperator;     // 0xCDCDCDCD (4 bytes)

    uint32_t EndSDOffset;
    uint32_t StartSDOffset;

    uint32_t Separator;     // Either 0 or 0xCDCDCDCD

    uint32_t EndPortalOffset;

    tr_room_info info;

    uint16_t NumZSectors;
    uint16_t NumXSectors;

    uint32_t RoomColour;   // In ARGB format!

    uint16_t NumLights;
    uint16_t NumStaticMeshes;

    uint8_t  ReverbInfo;
    uint8_t  AlternateGroup;
    uint16_t WaterScheme;

    uint32_t Filler[2];    // Both always 0x00007FFF
    uint32_t Separator[2]; // Both always 0xCDCDCDCD
    uint32_t Filler;       // Always 0xFFFFFFFF

    uint16_t AlternateRoom;
    uint16_t Flags;

    uint32_t Unknown1;
```

```
    uint32_t Unknown2;      // Always 0
    uint32_t Unknown3;      // Always 0

    uint32_t Separator;     // 0xCDCDCDCD

    uint16_t Unknown4;
    uint16_t Unknown5;

    float RoomX;
    float RoomY;
    float RoomZ;

    uint32_t Separator[4]; // Always 0xCDCDCDCD
    uint32_t Separator;    // 0 for normal rooms and 0xCDCDCDCD for null rooms
    uint32_t Separator;    // Always 0xCDCDCDCD

    uint32_t NumRoomTriangles;
    uint32_t NumRoomRectangles;

    tr5_room_light* RoomLights; // points to tr5_room_data.Lights
    tr5_fog_bulb* FogBulbs;     // points to tr5_room_data.FogBulbs

    uint32_t NumLights2;    // Always same as NumLights

    uint32_t NumFogBulbs;       // If set, there is an unknown data after Lights

    int32_t RoomYTop;
    int32_t RoomYBottom;

    uint32_t NumLayers;

    tr5_room_layer* LayerOffset;    // points to tr5_room_data.Layers
    tr5_room_vertex* VerticesOffset; // points to tr5_room_data.Vertices
    uint32_t PolyOffset;
    uint32_t PolyOffset2;   // Same as PolyOffset

    uint32_t NumVertices;

    uint32_t Separator[4];  // Always 0xCDCDCDCD
}

// Immediately after previous block

virtual struct tr5_room_data
{
    tr5_room_light Lights[NumLights];    // Data for the lights (88 bytes *
NumRoomLights)
    tr5_fog_bulb FogBulbs[NumFogBulbs];  // Data for the fog bulbs (36 bytes *
NumFogBulbs)
    tr_room_sector SectorList[NumXSectors * NumZSectors]; // List of sectors in this
room

    uint16_t NumPortals;                 // Number of visibility portals to other
rooms
    tr_room_portal Portals[NumPortals];  // List of visibility portals

    uint16_t Separator;  // Always 0xCDCD

    tr3_room_staticmesh StaticMeshes[NumStaticMeshes];   // List of static meshes

    tr5_room_layer Layers[NumLayers]; // Data for the room layers (volumes) (56 bytes
* NumLayers)
    uint8_t Faces[(NumRoomRectangles * sizeof(tr_face4) + NumRoomTriangles *
(tr_face3)];
    tr5_room_vertex Vertices[NumVertices];
}
```

`XELA` landmark seemingly serves as a header for room structure. It is clear that *XELA* is a reversed *ALEX*, which is most likely the name of TR5 programmer, *Alex Davis*. It probably indicates that Alex Davis is responsible for changes in room structures.

`RoomDataSize` is a handy value determining the size of the following data. You can use this value to quickly *parse thru* to the next room.

`EndSDOffset`: usually this number `+216` will give you the offset from the start of the room data to the end of the `SectorData` section. However, it is known that this uint32_t could be equal to `0xFFFFFFFF`, so to calculate the end of

`SectorData`, it is better to use the following value `StartSDOffset + 216 + ((NumXSectors * NumZSectors)*8)`, if you need to obtain this information.

`StartSDOffset`: This number `+216` will give you the offset from the start of the room to the start of the `SectorData` section.

`EndPortalOffset`: this number `+216` will give you the offset from the start of the room to the end of the portal data.

`RoomX`, `RoomY` and `RoomZ` values are positions of room in world coordinates. **NOTE:** If room is *null room*, then each of these values will be `0xCDCDCDCD`.

`NumRoomTriangles` and `NumRoomRectangles` are respectively the numbers of triangular and rectangular faces in a given room. **NOTE:** If room is *null room*, each of these values will be `0xCDCDCDCD`.

`LightDataSize` is the size of the light data in bytes (*not* in [tr5_room_light] units).

`RoomYTop` and `RoomYBottom` are equal to `yTop` and `yBottom` values in [tr_room_info] structure. If room is a *null room*, both of these values are `0xCDCDCDCD`.

`NumLayers` is a number of layers (volumes) in this room.

`LayerOffset`: this number `+216` will give you an offset from the start of the room data to the start of the layer data.

`VerticesOffset`: this number `+216` will give you an offset from the start of the room data to the start of the verex data.

`PolyOffset`: this number `+216` will give you an offset from the start of the room data to the start of the rectangle/triangle data.

`NumVertices` is the size of vertex data block in bytes. Therefore, it *must* be a multiple of [tr5_room_vertex] size, else it means the block size is wrong.

`Faces` is a sequential data array for the room polygons (both [tr_face4] and [tr_face3]),


Note

`Faces` array is strictly linked with `NumLayers` value. The data is sequentially structured for each layer — at first it lists first layer's rectangles then triangles, followed by the second layer's rectangles and triangles, and so on, until all layers are done.

3.4.6. Common Fields of a Room Structure

`Flags` is an array of various flag bits, which meaning is as follows:

- **Bit 0** — Room is filled with water.
- **Bit 3** — ② ③ ④ ⑤ Set if the *skybox* can be seen from this room. Used to speed things up: if no rendered room has this bit set, then the sky can never been seen, so it is not rendered. Else, if at least one visible room has this bit set, then the sky must be drawn because it is (could be) visible.
- **Bit 5** — ② ③ ④ ⑤ Lara's ponytail gets blown by the wind. Beginning with TR3, some particle types are also be blown, if they end up in such room (particle type is specified by certain particle flag).
- **Bit 6** — ③ ④ ⑤ Unknown. A lot of rooms have this bit set but it seems it does nothing...
- **Bit 7** — ③ ④ ⑤ Different meaning in TR3 and TR4/5. In TR3, it means that room is filled with quicksand, while in TR4/5 it presumably blocks *global lens flare* from appearing in that room (in TRLE, checkbox which sets this flag is named *NL*).
- **Bit 8** — ③ ④ ⑤ Creates *caustics effect* similar to that used in water rooms. TRLE sets this bit when the M option is used (in the same time, the degree of fading intensity typed by the user is put in the `water_scheme` byte).
- **Bit 9** — ③ ④ ⑤ The room has some *water reflectivity*. TRLE sets this bit when the R (*reflectivity*) option is used (in the same time, the amount of reflectivity typed by the user + 5 is put in the `water_scheme` byte). When the flag is set for normal room and there is water room below it, game engine creates "reflection effect" above the water surface — effectively it means that all the vertices at the bottom of the room receive caustics effect described well above.
- **Bit 10** — unused. Was re-used in NGLE as a flag specifying *room with snow*.
- **Bit 11** — ④ ⑤ Not found in any original TR levels, but when the *D* flag is set in the TRLE, this bit is set. Was re-used in NGLE as a flag specifying *room with rain*.
- **Bit 12** — ④ ⑤ Not found in any original TR levels, but when the *P* flag is set in the TRLE, this bit is set. Was also re-used in NGLE as a flag specifying *cold room* (a room which produce damage on Lara).

③ ④ ⑤ `WaterScheme` is used for different purposes. If room is a water room, then it specifies underwater caustics patterns. If it is set for normal room *placed above the water room*, then it controls *wave strength* effect applied to the faces adjoining water room. Maximum value in both cases is 15.

③ ④ ⑤ `ReverbInfo` defines *room reverberation type*. It affects sound postprocessing, if listener position belongs to that room. This feature was present *only in PlayStation versions* of the game, but not on PC. Nevertheless, the info is preserved in PC level files. Here are the types of reverberation:

- **0** — Outside. No (or barely heard) reverberation.
- **1** — Small room. Little reverberation.
- **2** — Medium room.

- **3** — Large room.
- **4** — Pipe. Highest reverberation level. Almost never used.

4. FloorData

4.1. Overview

The *FloorData* is the key part of the level structure, which defines almost everything related to "physical" world — geometry, interaction and response of a level. While *room geometry* (see above) may be considered as a "face" of the level, *FloorData* is its "heart" and "brain".

Distinctive feature of the FloorData is its *serialized nature*. While in room geometry you can easily jump through structures using data sizes and pointers to get the needed part, *FloorData* require sequential parsing, one unit by one.

4.2. The Concept

The *FloorData* defines special sector attributes such as individual floor and ceiling *corner heights* (slopes), *collisional* portals to other rooms, *climbability* of walls, and, most important of all, *the various types of triggering*. Each room sector (see [tr_room_sector] structure) points to the FloorData using `FDIndex` variable. It is referenced as an array of *16-bit unsigned integers* (`uint16`s).

Therefore, the *current [tr_room_sector] offset* (not yet the FloorData pointer itself!) is calculated using this formula:

$$S_{Offset} = \left(\left(\left(X_{current} - X_{room} \right) / 1024 \right) \times n_{Zsectors} \right) + \left(\left(Z_{current} - Z_{room} \right) / 1024 \right)$$

...where $X_{current}$ and $Z_{current}$ are current player positions, X_{room} and Z_{room} are corresponding tr_room_info.x and tr_room_info.z fields, and $n_{Zsectors}$ is tr_room.NumZsectors value.

Then, the *current FloorData pointer* is derived from calculated [tr_room_sector] structure's `FDIndex` field. In other words, `FDindex` is an offset into the `FloorData[]` array.

As mentioned above, The FloorData consists of solely `uint16_t` entries without general structure — the way engine treats specific entry depends on the sequence order and type of previously parsed entries. While it's a bit difficult to understand it at first, you should get used to it. Main thing to remember is the FloorData should be read sequentially.

4.3. Understanding The Setup

First order of FloorData entries has a common "bitwise" structure, which we will call `FDSetup`. The structure could be divided into three fields:

`Function`	bits 0..4 (`0x001F`)
`SubFunction`	bits 8..14 (`0x7F00`)
`EndData`	bit 15 (`0x8000`)

`Function` defines the type of action that must be done with current FloorData entry, and `SubFunction` is usually used in that action's conditions and case switches (if there are any). If there are no any special conditions for a given `Function`, then `SubFunction` *is not used*.


Tip

It may seem that bits 5..7 are unused in `FDSetup` structure, but actually they belong to `Function` value, but *only in TR1 and TR2*. When parsing `FDSetup` for TR3+, you should use only the lower 5 bits (0..4) to find the `Function` value, because some of TR3 *triangulation functions* use the upper 3 bits of the lower byte for other purpose. However, this will also work correctly in TR1 and TR2, since maximum possible function value is way below 5-bit limitation.

If `EndData` is set, there should be no more *similar* FloorData entries (after the current one) in the `FloorData[]` array — so further parsing must be stopped. Otherwise, the following `uint16_t` should be interpreted after the current one in the same manner.


Note

Even if `EndData` is set, it doesn't specifically mean that there are no more `uint16_t` following the current one at all. As we will see, some FloorData functions and subfunctions require to parse additional entries with their own rules. In programming terms, `EndData` just indicates that parsing loop must be broken — however, there may be following code which reads additional entries.

Note

While `FloorData` index 0 means the sector does not use floordata, there is still a "dummy" entry for index 0. This dummy entry doesn't contain any useful information.

Note

Several of the functions indicate adjustments to the sector's *corner heights*. The corners will be denoted as `00`, `01`, `10`, and `11`, where the first digit is the corner's X coordinate and the second digit is the corner's Z coordinate, with both given as multiples of 1024.

Note

Collisional floordata functions should always come first in sequence, with floor collision function strictly being first and ceiling collision function strictly being second. The reason is hardcoded floordata collision parser which always expects these two functions to be first in sequence.

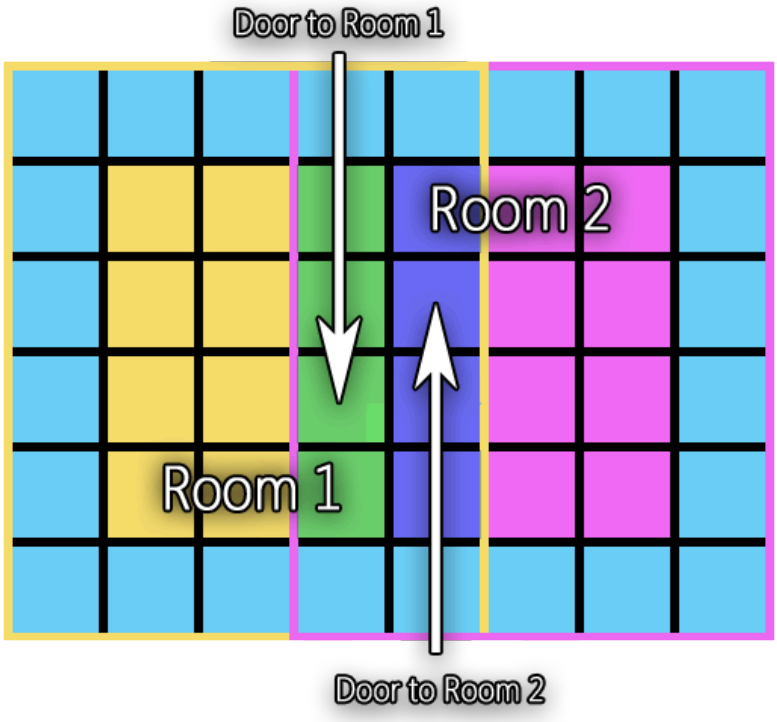
4.4. FloorData Functions

4.4.1. Function `0x01` — Portal Sector

SubFunction is not used

The *next* `FloorData` entry is the number of the room that this sector is a collisional portal to. An entity that arrives in a sector with this function present will gets its room membership changed to provided room number, without any change in position.

To understand what exactly happens when room membership is changed, you must understand how collisional portals work in Tomb Raider's 4D space. When two rooms are connected with portal, it means that they also *overlap* within a distance of two sectors (because these sectors contain portal in each of the connected rooms). This way, when room is changed, it remains unnoticed by the player, cause portal sectors are interconnected:



Collisional portal layout. Blue sectors are walls around each room. Green sector is Room 2's collisional portal to Room 1, and dark blue sector is Room 1's collisional portal to Room 2

4.4.2. Function `0x02` — Floor Slant

SubFunction is not used

The next `FloorData` entry contains two `uint8_t` *slant values* for the *floor* of this sector. Slant values are specified in increments of 256 units (so-called *clicks* in TRLE terms). The high byte is the *Z slope*, while the low byte is the *X slope*. If the X slope is greater than zero, then its value is added to the floor heights of corners `00` and `01`. If it is less than zero, then its value is subtracted from the floor heights of corners `10` and `11`. If the Z slope is greater than zero, then its value is added to the floor heights of corners `00` and `10`. If it is less than zero, then its value is subtracted from the floor heights of corners `01` and `11`.

Note

This function is never combined with *triangulation* functions present in TR3 onwards (see further).

4.4.3. Function `0x03` — Ceiling Slant

SubFunction is not used

The next `FloorData` entry contains two `uint8_t` *slant values* for the *ceiling* of this sector. Slant values are specified in increments of 256 units. The high byte is the *Z slope*, while the low byte is the *X slope*. If the X slope is greater than zero, then its value is subtracted from the ceiling heights of corners `10` and `11`. If it is less than zero, then its value is added to the ceiling heights of corners `00` and `01`. If the Z slope is greater than zero, then its value is subtracted from the ceiling heights of corners `00` and `10`. If it is less than zero, then its value is added to the ceiling heights of corners `01` and `11`.

This function is never combined with *triangulation* functions present in TR3 onwards (see further).

4.4.4. Function `0x04` — Trigger

The `uint16_t` immediately following current entry is called `TriggerSetup`, and contains general trigger properties stored in a "bitwise" manner:

`Timer`	bits 0..7 (`0x00FF`)
`OneShot`	bit 8 (`0x0100`)
`Mask`	bits 9..13 (`0x3E00`)

`Timer` is a value generally used for making *timed triggers* of certain entities — for example, the door which opens only for a few seconds and then closes, or a fire which extinguishes and then burns again. In such case, engine *copies timer value in corresponding field of each triggered entity*. Then each entity's timer begins to count time back, and when it reaches zero, entity deactivates.

However, it's not the only purpose of `Timer` field. As trigger may not specifically activate entities but do some other actions, `Timer` field may be re-used as a general-purpose numerical field to specify particular trigger behaviour. We will mention it separately for such trigger actions.

Since TR4, `Timer` field became *signed*, i.e. it may contain *negative values*. Effectively, it means that entities activated with such trigger won't be immediately activated and then deactivated after given amount of time, but *wait for a given time before being activated*. Most prominent example is timed spike pit in the beginning of "Burial Chambers".

`Mask`: The five bits at `0x3E00` are the so-called *Trigger Mask*. The purpose of trigger mask is to create puzzle set-ups which require a combination of activated triggers to achieve certain result. A good example of trigger mask use is the multiple-switch room of "Palace Midas" in TR1.

Each entity in Tomb Raider has a similar field in its structure called *activation mask*. Activation of entity happens *only when all bits of activation mask are set*. Trigger action which activates an entity makes either bitwise `XOR` operation (for *switch* trigger types — namely, *switch* and *heavy switch* — see further) or bitwise `OR` operation on *activation mask* using *trigger mask*. Trigger action purposed for deactivation (namely, *antitrigger*, *antipad* and *heavy antitrigger* types) don't take its trigger mask into consideration, and instead just reset target entity's activation mask to zero.

Whenever entity's activation mask is changed to anything but 0x1F (all bits set), entity is *automatically deactivated*, excluding the cases when `OneShot` flag was previously set for a given entity — see further.

`OneShot` flag is used *only* for activation of entities (it is also copied to entity's own flag field with same name), and indicates that *after activation, entity state is locked*. It means that even if entity's own activation mask is unset (as with *switch* trigger type — see further), entity will remain activated. However, it doesn't mean that entity couldn't be deactivated at all — because *antitrigger* trigger type (see further) ignores and resets this flag.

① ② In these versions, any *antitriggers* for locked entity have no effect, and engine completely bypasses antitrigger processing for such entities. It means that once entity was activated by trigger with `OneShot` flag, it couldn't be deactivated at all.

③ There's a bit different `OneShot` flag behaviour for TR3 — entity state will be locked *even if activation mask isn't set yet*. For example, if there are two complementary triggers for certain entity (let's say, with activation masks `0x0F` and `0x10`), and each of them has `OneShot` flag, effectively target entity *won't ever be activated*, cause each trigger immediately locks entity state, bypassing further trigger processing.

All other trigger actions, except activation of entities, are *performed continuously*. It's not obvious, because engine uses various workarounds for specific trigger actions to prevent "repeated" execution, like playing same soundtracks over and over again. Such workarounds will be specifically mentioned.

Trigger types and *trigger actions* will be described separately right after listing all FloorData functions.

4.4.5. Function `0x05` — Kill Lara

SubFunction not used

Instantly kills Lara. Usually she is simply set on fire, however, there is one special case in TR3. If current level index is 7 ("Madubu Gorge"), then instead of catching fire, Lara will play drowning animation.

4.4.6. Function `0x06` — Climbable Walls

② ③ ④ ⑤ The `SubFunction` indicates climbability of walls; its value is the bitwise `OR` of the values associated with all the climbable-wall directions (`0x01` = +Z, `0x02` = +X, `0x04` = -Z, `0x08` = -X), e.g. SubFunction `0x09` indicates that the walls on both the +Z and -X sides of this sector are climbable.

4.4.7. Functions `0x07` to `0x12` — Triangulation

③ ④ ⑤ Beginning with TR3, geometry layout of each sector was significantly changed. Engine introduced *triangles* as a minimal collisional unit, compared with *rectangles only* in TR1 and TR2. This advantage allowed to create much more organic and natural terrain (albeit still limited by minimal sector width and depth of 1024 units), but also complicated things a lot, introducing the whole new set of different FloorData collisional functions.

Triangulation functions are never combined with *slant* functions present in TR1 and TR2. Each sector has either *slant* or *triangulation* function assigned to it, and *never both of them*. If there ever will be a paradoxical case of combination, most likely, only *older* function (i.e. *slant*) will be considered for collision calculation.

Similarly to *slant* functions, *triangulation* functions define the floor and ceiling corner heights, but besides, they also specify *dividing up the floors and ceilings into triangles along either of the two diagonals*. Also, one of the triangles may be a collisional portal to the room above (if in the ceiling) or to the room below (if in the floor).

Each triangulation function `uint16_t` must be parsed differently, not like ordinary `FDSetup` entry:

Function	Bits 0..4 (`0x001F`)
$H_{\triangle 1}$	Bits 5..9 (`0x03E0`)
$H_{\triangle 2}$	Bits 10..14 (`0x7C00`)
EndData	Bit 15 (`0x8000`)

$H_{\triangle 1}$ and $H_{\triangle 2}$ are signed values, and replace `FDSetup`'s `SubFunction` field.

Own triangulation function's `uint16_t` is followed by *one extra* `uint16_t` to be parsed as follows:

ΔC_{10}	Bits 0..3 (`0x000F`)
ΔC_{00}	Bits 4..7 (`0x00F0`)
ΔC_{01}	Bits 8..11 (`0x0F00`)
ΔC_{11}	Bits 12..15 (`0xF000`)

All four values here are unsigned.

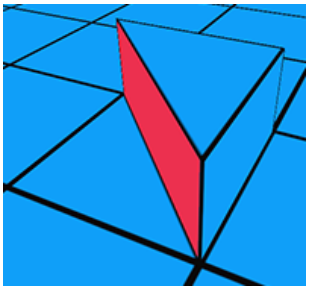
The Triangulation Formula

The idea behind this set up is dividing each sector rectangle into *two independent triangles*, and adjust each triangle height by combination of *corner* and *triangle* heights. To get each triangle's individual corner height, you should use this formula:

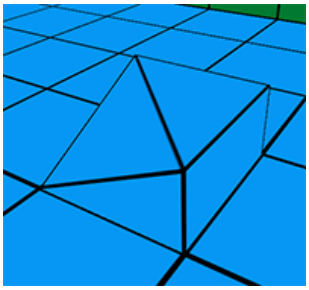
$$H_{\angle} = H_{floor} + \left(\max \left(\Delta C_{10}, \Delta C_{00}, \Delta C_{01}, \Delta C_{11} \right) - \Delta C_n \times 1024 \right)$$

...where $H_{\angle}$ is *absolute floor height* specified in [tr_room_sector]'s `Floor` field, and ΔC_n is triangle's individual corner height.

While four corner height values are shared by both triangles, *triangle height values specify additional overall height of individual triangle*. Therefore, sector corner heights may or may not be shared between two triangles:



Corner heights are not shared

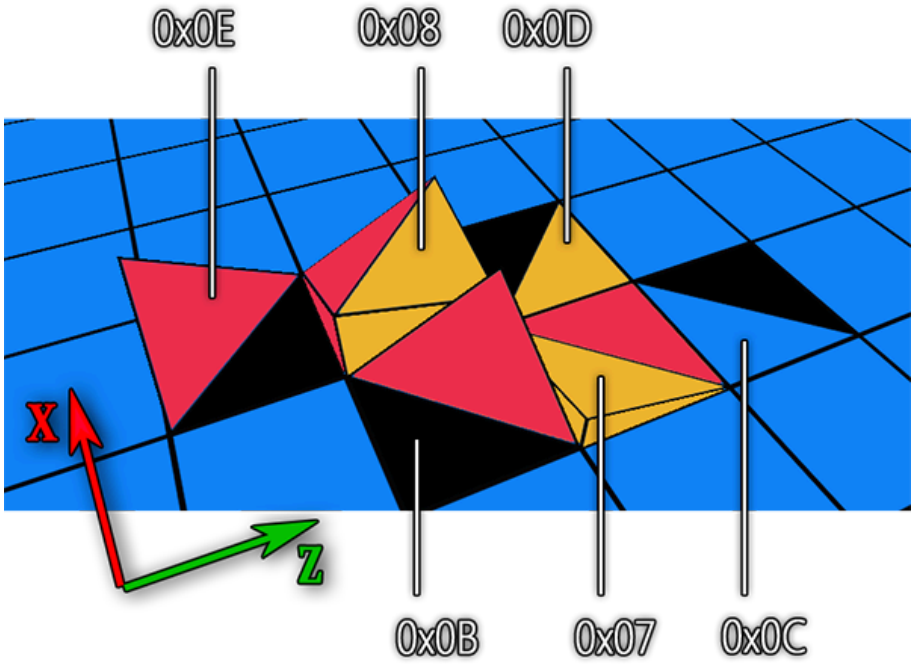


Corner heights are shared

The way engine interprets *triangle height values* $H_{\triangle 1}$ and $H_{\triangle 2}$ is not exactly known — however, *meta2tr* understands them and uses them to create so-called *diagonal steps*, example of which is pictured on the left side. There is no case of diagonal steps in original games, but they may exist in levels edited with *meta2tr*.

Overall, there are 12 different triangulation functions, which can be divided into two pairs of groups — one pair of groups is for floor, and another pair is for ceiling. Each pair is categorized by *split direction*, and each group is categorized if it's floor or ceiling. In each group, there are three functions — first function denotes that *both* triangles in sector are solid, second and third functions denote that *one of triangles is a collisional vertical portal*. When function denotes a vertical portal, target room of a portal is taken from [tr_room_sector] structure — `RoomBelow` for floor functions, and `RoomAbove` for ceiling functions.

Here is an example illustration depicting sectors with all possible floor triangulation functions. Ceiling triangulation happens in similar manner.



Floor sector triangulation types. Black triangles depict vertical collisional portal to different room.

`X` axis in world coordinates also may be considered *north* for more simple reference (because you can always check compass direction in actual game engines, at least in TR1 and TR4).

Functions `0x07`, `0x0B`, `0x0C`

These functions define *floor* triangles split in the *northwest-southeast* direction.

- `0x07` — Both triangles are solid.
- `0x0B` — Triangle pointing its right angle to the *southwest* is a *collisional portal*.
- `0x0C` — Triangle pointing its right angle to the *northeast* is a *collisional portal*.

Functions `0x08`, `0x0D`, `0x0E`

These functions define *floor* triangles split in the *northeast-southwest* direction.

- `0x08` — Both triangles are solid.
- `0x0D` — Triangle pointing its right angle to the *southwest* is a *collisional portal*.
- `0x0E` — Triangle pointing its right angle to the *northwest* is a *collisional portal*.

Functions `0x09`, `0x0F`, `0x10`

These functions define *ceiling* triangles split in the *northwest* direction.

- `0x09` — Both triangles are solid.
- `0x0F` — Triangle pointing its right angle to the *southwest* is a *collisional portal*.
- `0x10` — Triangle pointing its right angle to the *northeast* is a *collisional portal*.

Functions `0x0A`, `0x11`, `0x12`

These functions define *ceiling* triangles split in the *northeast* direction.

- `0x0A` — Both triangles are solid.
- `0x11` — Triangle pointing its right angle to the *northwest* is a *collisional portal*.
- `0x12` — Triangle pointing its right angle to the *southeast* is a *collisional portal*.

4.4.8. Function `0x13` — Monkeyswing (only in TR3-5)

SubFunction is not used

③④⑤ Sets monkey-swingability of the ceiling in specified sector.

4.4.9. Function `0x14`

③④⑤ This function has a different meaning in TR3 and TR4/5.

- In TR3, if Lara approaches sector with this FloorData function inside *minecart* vehicle, it will turn *left* 90 degrees, with a circle radius around 4 sectors (4096 units in world coordinates). If both this and `0x15` functions are set for a given sector, minecart will *stop* there.
- In TR4 and TR5, this function is used together with special entity called *Trigger Triggerer*. The purpose of this entity is to perform *deferred triggering*. That is, if *trigger* FloorData function is placed in the same sector with function `0x14`, trigger won't be activated until there's an activated *Trigger Triggerer* object in the same sector. This allows to create setups where player can cross trigger sector without activating it, until some other event occurs later in level.

4.4.10. Function `0x15`

③④ This function has a different meaning in TR3 and TR4.

- In TR3, if Lara approaches sector with this FloorData function inside *minecart* vehicle, it will turn *right* 90 degrees, with a circle radius around 4 sectors (4096 units in world coordinates). If both this and `0x14` functions are set for a given sector, minecart will *stop* there.
- In TR4, this function is used together with special entity called *Mapper*. If *Mechanical Beetle* is placed in sector with function `0x15` and inactive *Mapper* entity, it rotates in the same direction *Mapper* is pointing to, activates it, and then rolls forward, until next sector with function `0x15` is reached. Then it waits until Lara picks it up.

If Lara places beetle at the very same sector where beetle was already used, it will shake and explode. It happens because beetle checks if *Mapper* entity is active or not, and if it was already activated, it explodes instead of rolling.

4.5. Trigger Types

A *trigger type* specifies the condition of a given *trigger function* to be activated. Condition may be a type of activator (Lara or some other entity), a specific state of activator, specific trigger action (activate or deactivate), and so on.

Trigger type *is placed in* `SubFunction` *field* of `FDSetup` structure, so we will refer to trigger types as *SubFunctions*.

Trigger type names are directly borrowed from TRLE.

4.5.1. SubFunction `0x00` — Trigger

Activated by Lara whenever she enters a given sector — either steps, climbs, jumps over it, and so on.

4.5.2. SubFunction `0x01` — Pad

Activated by Lara *only* if she steps or lands on a given sector.

4.5.3. SubFunction `0x02` — Switch

This particular type of trigger takes first `ActionList` entry's `Parameter` field *as a reference to specific switch entity in level*. It activates *every time the switch state is changed*. For *Object* trigger actions, *activation* means *performing `XOR` operation* on these object's (entities) activation masks. (See next section for description of *Object* trigger action and `Parameter` field.)

Please note that this trigger type (as well as *any other trigger types*) always perform all trigger actions except *Object* in the same manner! Meaning, if there is a *Camera* or *Flipeffect* trigger action, it will be performed every time the switch is flipped on or off.

4.5.4. SubFunction `0x03` — Key

Similar to previous trigger type, it works only if there is a *keyhole entity* listed in the first `ActionList` entry's `Parameter` field. It activates only if a key was inserted into that particular keyhole.

4.5.5. SubFunction `0x04` — Pickup

As above, this type of trigger works only if there is a *pick-up entity* listed in the first `ActionList` entry's `Parameter` field. It activates only if this item was picked up by Lara.

4.5.6. SubFunction `0x05` — Heavytrigger

Activated by *specific entity type* (activator) wherever it enters a specified sector. Entity types which are able to activate *heavytriggers* are hardcoded, and usually include *NPCs (enemies), rolling balls and pushable objects*. Since TR4, heavytriggers may also be activated by destroying *shatter static mesh* which is placed in a given sector.

Note that heavytrigger *does not perform deactivation action*, if activator leaves trigger sector.

4.5.7. SubFunction `0x06` — Antipad

Same as *Pad* — activates only if Lara has landed or stepped onto a given sector. The difference is, *Antipad* performs *deactivation* for each case of *Object* trigger action. What *deactivation* specifically means is it resets entity activation mask to zero (trigger mask is ignored), thus flipping entity activation procedure.

As it was mentioned for *Switch* trigger type, any other trigger actions beside *Object* will perform exactly in the same manner as with normal trigger types. So you shouldn't expect soundtrack to stop, if you have placed *PlayTrack* trigger action for antipad.

4.5.8. SubFunction `0x07` — Combat

Activated by Lara whenever she enters a given sector *with her weapons drawn*. This trigger type was (presumably) never used in original games.

4.5.9. SubFunction `0x08` — Dummy

This type doesn't perform *any trigger action* listed for it except *Object* type — for these trigger actions, it *applies standable collision for Lara on a given entities*, if such entities are in this trigger sector. For particular entity types, it works even if entity is deactivated (e.g. collapsing floor), but for other types it works only if entity was activated (e.g. trapdoors). Selected behaviour is most likely hardcoded.

It's worth noting that *any* trigger type will apply standable collision on such entity types, if they are in the same sector. It's not a bug, rather a way TR engines process FloorData.

4.5.10. SubFunction `0x09` — Antitrigger

Same as *Trigger*, but performs *deactivation* for each case of *Object* trigger action.

3 4 5 Antitrigger type also copies its parent trigger's `OneShot` flag into any entities activated by *Object* trigger action, meaning that after any further entity activation it will be *locked*.

4.5.11. SubFunction `0x0A` — Heavy switch

4 5 Don't be fooled by the name of this trigger type. It is not literally a *switch*, as only similarity between it and *switch* type is XOR operation with activation mask. In fact, this trigger performs action when *specific entity type* (activator) enters a given trigger sector, but *only if trigger mask is equal to activator's activation mask*.

The best example of heavy switch setup is *Planetarium* in "The Lost Library". Trigger mask is only applied to raising block if pushable in trigger sector has a similar activation mask.

4.5.12. SubFunction `0x0B` — Heavy antitrigger

4 5 Same as *Antitrigger*, but performs *deactivation* for each case of *Object* trigger action.

4.5.13. SubFunction `0x0C` — Monkey

4 5 Activated by Lara whenever she enters a given sector *in monkeyswing state*. Best example is locust swarm attacking Lara when she monkeyswings across the street in "Trenches".

4.5.14. SubFunction `0x0D` — Skeleton

⑤ This trigger type temporarily replaces Lara model with a combination of models #25 (Lara skeleton), #26 (see-through body) and #27 (see-through joints). See-through body and joints are applied on top of the skeleton model with additive blending.

4.5.15. SubFunction `0x0E` — Tightrope

⑤ Activated by Lara whenever she enters a given sector *walking on a tightrope*.

4.5.16. SubFunction `0x0F` — Crawl

⑤ Activated by Lara whenever she enters a given sector *crawling or crouching*.

4.5.17. SubFunction `0x10` — Climb

⑤ Activated by Lara whenever she enters a given sector *climbing on a wall*.

This concludes the description of *Trigger* FloorData function *trigger types*.

4.6. Trigger Actions

Trigger function references an additional list of FloorData entries called `ActionList`, which is a "chain" of entries that immediately follows `TriggerSetup` entry. As you maybe already guessed, the `ActionList` contains the list of actions to be performed for a specified trigger.

`ActionList` entry format is:

`Parameter`	bits 0..9 (`0x03FF`) -- *Used bytes may vary*
`TrigAction`	bits 10..14 (`0x7C00`)
`ContBit`	bit 15 (`0x8000`)

`TrigAction` is a type of action to be performed. These will be listed seperately.

`Parameter` is used with certain trigger actions which need a certain numerical argument provided to them.

`ContBit` flag meaning is similar to `EndData` flag described for `FDSetup` structure. It indicates if there is another `ActionList` entry after current one. If `ContBit` is not set, it means we have reached the end of `ActionList`, and there's nothing more to do for a given trigger.

If `ActionList`'s parent trigger type is either *Switch* or *Key*, first entry of `ActionList` is used to get reference entity (switch or keyhole) index. Hence, it is ignored here, as by the time engine reaches `ActionList` offset, its first entry is already parsed by preceding code.

`ContBit` flag is *not the same* as `EndData` flag! When writing a parser, do not overwrite one with another.

4.6.1. TrigAction `0x00` — Object

Activate or deactivate entity (object) with index specified in `Parameter`.

4.6.2. TrigAction `0x01` — Camera

Switches to camera. `Parameter` (bits 0..6 used) serves as index into `Cameras[]` array.

Camera trigger action *uses one extra `uint16_t` entry* after its own entry! Its format is:

`Timer`	bits 0..7 (`0x00FF`)
`Once`	bit 8 (`0x0100`)
`MoveTimer`	bits 9..13 (`0x3E00`)
`ContBit`	bit 15 (`0x8000`)

`Timer` is a number of seconds to wait before automatically switching back to the normal camera. If 0, it never switches back to normal camera, as long as trigger is active.

`Once`: If set, only switch to camera once; otherwise, switch to camera every time trigger is active.

①② `MoveTimer`: Specifies time which is used to smoothly move camera from Lara to desired camera viewpoint. Movement is done via *spline function*. The larger value is, the more time it takes to move camera away from Lara. Therefore, if `MoveTimer` is zero, then camera immediately cuts to new viewpoint.

Note `ContBit` flag *overwrites* the same flag from the preceding `ActionList` entry.

4.6.3. TrigAction `0x02` — Underwater Current

Continuously moves Lara to specifed *sink*. `Parameter` serves as index into `Cameras[]` array. If sink is placed lower than current sector absolute floor height or upper than current sector absolute ceiling height, *Y* coordinate will be ignored when dragging Lara to sink. Since TR3, sink also prevents Lara from surfacing the water.

Note While it may look like `Cameras[]` array was mentioned here by mistake, it is not. TR engines *share the same structure for both cameras and sinks*. The way engine treats it in either case will be discussed in corresponding section.

4.6.4. TrigAction `0x03`: Flip Map

FlipMap is an internal engine array of `uint8_t`s which is used to determine if alternate rooms should be turned on or off (in TRLE terms, *flipped*). It uses *trigger mask* in the same manner as for *Object* activation and deactivation, but in this case, alternate rooms are activated if given `FlipMap` entry mask is set (`0x1F`), and deactivated, if `FlipMap` entry is not set (not `0x1F`).

This trigger action at first applies *trigger mask* to a given `FlipMap` entry using `OR` bitwise operation and then immediately checks if it's already set or not. If FlipMap entry is set, then it immediately switches rooms to alternate mode.

`Parameter` defines which `FlipMap` entry engine should refer to decide should it switch alternate rooms on or off. The size of `FlipMap` array is around 10 (judging by the number of unused `FLIP_MAPn` *flipeffect* entries), but in original levels, number usually never tops 2 or 3.

Note From TR1 to TR3, `FlipMap` array was merely used as a "hint table" to tell the engine if it should flip *all rooms at once*. That is, to check and apply another FlipMap entry, alternate rooms should have been reverted to previous state before — that's the purpose of next two listed trigger actions. However, in TR4 algorithm was changed — each "flippable" room now bears additional parameter called "alternate group", which strictly tells an engine to flip it *only when room alternate group is equal to FlipMap `Parameter` value*. This change in algorithm made next two trigger actions unnecessary in TR4-5 (however, they are still available).

4.6.5. TrigAction `0x04` — Flip On

Tries to turn alternate rooms *on*, judging on current value of a given `FlipMap` entry (entry index is specified by `Parameter`). If corresponding FlipMap is not set (i.e. the value is not `0x1F`), rooms won't be flipped. `Parameter` defines a `FlipMap` entry to work with.

4.6.6. TrigAction `0x05`: — Flip Off

Tries to turn alternate rooms *off*, judging on current value of a given `FlipMap` entry (entry index is specified by `Parameter`). If corresponding FlipMap is not set (i.e. the value is not `0x1F`), rooms won't be flipped. `Parameter` defines a `FlipMap` entry to work with.

4.6.7. TrigAction `0x06` — Look at Item

Specifies an entity which current camera should look at. If current camera is "ordinary" one following Lara, then it will also rotate Lara model in a target direction, creating an illusion of Lara looking at it. If current camera is changed to "triggered" one (by trigger action `0x01` — see above), then this camera's orientation will be changed to a given entity. Note that if such camera change is desired, this action should come first, not the **Camera** one.

`Parameter` specifies an entity index to look at.

4.6.8. TrigAction `0x07` — End Level

Immediately loads next level. In TR1-3 and TR5, `Parameter` field is not used, i.e. engine just loads next level specified in script.

④ In TR4, so called "hub system" was implemented, which allows Lara to jump between levels back and forth. For this reason, `Parameter` field must also explicitly specify level index to jump.

④⑤ Also, since TR4 Lara can have multiple start positions for each level, so `Timer` field in `TriggerSetup` entry specifies an index of *lara start posision AI object* in AI objects array to warp Lara to. That is, if there's an end level trigger

with value `3` in `Timer` field, it means that Lara will be warped to third *start position AI object* in AI objects array. For more info on AI objects, refer to this section.

4.6.9. TrigAction `0x08` — Play Soundtrack

Triggers a playback of a soundtrack specified in `Parameter` field. Type of soundtrack (*looped* or *one-shot*) is hardcoded and assigned automatically.

This trigger action makes use of *trigger mask* **and** *one-shot trigger flag* to mark if this track was already played with a given *trigger mask* or not in a special internal *soundtrack map*. That is, if it is called with *trigger mask* set to, say, `0x01`, then all further calls from triggers with same *trigger mask* will be ignored. However, if same track playback is called with *trigger mask* value of `0x02`, it will play again, as it's another byte in *trigger mask*. Effectively, it allows to play specified track *six times* (five bits of *activation mask* plus one bit of *one-shot flag*). Comparison is done via bitwise `AND` operation, so if playback is called with *trigger mask* + *one-shot* value of `(0x1F + 0x20 = 0x3F)`, then any other playback call to that track will be blocked.

In TR1, soundtrack playback is more complicated. For some reason, in PC version programmers completely disabled playback for majority of soundtracks, leaving only five or six most significant ones to play (like title theme or cutscene audio). *Looped* soundtracks were also completely ignored — instead, background ambience is explicitly specified by script entry, rather than trigger action (that's the reason why PC version has four different ambience types when compared to PSX version).

To overcome this issue and enable complete soundtrack functionality, several patches were created by the community. However, PC version is missing *soundtrack map* structure, which potentially produces bugs when single track could be played independently by both triggers in the same level, although mostly this bug comes unnoticed, as majority of TR1 soundtracks are engaged only once in a level.

4.6.10. TrigAction `0x09` — Flipeffect

By the name of "flipeffect" comes *any non-trivial or special trigger action which should be seperately defined*. This workaround was implemented because TR engines lack any scripting language to program arbitrary trigger, so you can consider a *flipeffect* as a call to some "pre-compiled" scripted function.

Flipeffect does not mean "flip map effect" or so, and has no any direct relation to "flip maps".

For example, in TR2 "Lara's Home", there is a need to control assault course timer, like restarting it while reaching start point or stopping it when Lara is off the course. This task is accomplished via several different flipeffects.

The list of *flipeffects* differs across game versions. For precise info on each flipeffect for each game version, refer to this section.

4.6.11. TrigAction `0x0A` — Secret Found

Plays "secret" soundtrack theme and marks a secret number specified in `Parameter` field as found. For finding each secret, another `Parameter` value must be specified, or else secret won't be counted as found.

4.6.12. TrigAction `0x0B` — Clear bodies

① ② ③ Removes dead bodies of enemies from a level to conserve memory usage. This action has effect only on entities which had *clear body* flag specified in their parameters (see further). `Parameter` field is unused.

This trigger action caused significant confusion in TRLE community. In level editor, action is called *BODYBAG*, and makes no visible effect in game, so various speculations were made regarding action's true purpose. Some people thought it is used to attach a backpack to Lara in "Angkor Wat" cutscene, another people thought it is used for lipsync or dragging SAS troop body in "City of the Dead". All this speculation was proven wrong.

4.6.13. TrigAction `0x0C` — Flyby

④ ⑤ Engages a *flyby camera sequence* specified in `Parameter` field. The feature was added in TR4 and enables to play cinematographic interludes with camera continuously "flying" from one point to another. Such *sequences*, their *points*, properties and order are defined in a level editor, and engine moves camera across them using *spline function*.

`uint16_t` immediately following flyby's own entry contains *one-shot flag* at `0x0100`. If this flag is not set, flyby will infinitely loop. As with *Camera* TrigAction, flag at `0x8000` is a continuation bit, which overrides previous entry's continuation bit.

4.6.14. TrigAction 0x0D — Cutscene

④⑤ Engages a cutscene pre-defined in script file. `Parameter` is taken as cutscene ID. In turn, script file refers to `CUTSEQ.PAK` (TR4) or `CUTSEQ.BIN` (TR5) file to get all the data for a cutscene, such as *actor positions and animations*, *camera movement*, *soundtrack* and many more. There will be a special section describing particular `CUTSEQ.PAK` file format.

This concludes the description of *Trigger* FloorData function *action types*.

5. Meshes and Models

5.1. Overview

Nearly all of the non-geographic visual elements in TR (as well as a few parts of the landscape) consist of as meshes. A *mesh* is simply a list of vertices and how they're arranged. The mesh structure includes a list of vertices as relative coordinates (which allows meshes to easily be placed anywhere in the world geometry), a list of normals (to indicate which side of each face is visible), and lists of Rectangles and Triangles, both textured and coloured. The elements of each [tr_face4] or [tr_face3] (or same version-specific) structure (Rectangles and Triangles) contain an offset into the `Vertices[]` array for the mesh. Other arrays (`Entities[]`, `StaticMeshes[]`) do not reference the array `Meshes[]` directly, but instead reference the array `MeshPointers[]`, which points to locations inside of `Meshes[]`, inside of which the meshes are stored in packed fashion.

Pointer indexing system allows engine to share same mesh for numerous different models, and also easily implement a feature called *meshswap* — used when a puzzle is inserted into a hole, when Lara draws pistols, and so on.

While it may be not obvious, but every time you see mesh look is changed, it means that *meshswap* happened. There was never any other way to modify mesh looks in classic TRs.

5.2. Meshes

The sign of the number of normals specifies which sort of lighting to use. If the sign is positive, then external vertex lighting is used, with the lighting calculated from the room's ambient and point-source lighting values. The latter appears to use a simple Lambert law for directionality: intensity is proportional to $\max\left(\langle(\text{normal direction}),(\text{direction to source})\rangle,0\right)$. If the sign is negative, then internal vertex lighting is used, using the data included with the mesh.

This is not a "real" C/C++ structure, in that the arrays are sized by the `NumXXX` elements that precede them.

```
virtual struct tr_mesh // (variable length)
{
    tr_vertex Centre;
      int32_t CollRadius;

      int16_t NumVertices;           // Number of vertices in this mesh
    tr_vertex Vertices[NumVertices]; // List of vertices (relative coordinates)

      int16_t NumNormals;

  if(NumNormals > 0)
    tr_vertex Normals[NumNormals];
  else
      int16_t Lights[abs(NumNormals)];

     int16_t NumTexturedRectangles; // number of textured rectangles in this mesh
    tr_face4 TexturedRectangles[NumTexturedRectangles]; // list of textured rectangles

     int16_t NumTexturedTriangles;  // number of textured triangles in this mesh
    tr_face3 TexturedTriangles[NumTexturedTriangles]; // list of textured triangles

     int16_t NumColouredRectangles; // number of coloured rectangles in this mesh
    tr_face4 ColouredRectangles[NumColouredRectangles]; // list of coloured rectangles

     int16_t NumColouredTriangles; // number of coloured triangles in this mesh
```

```
    tr_face3 ColouredTriangles[NumColouredTriangles]; // list of coloured triangles
};
```

`Centre` is usually close to the mesh's centroid, and appears to be the center of a sphere used for certain kinds of collision testing.

`CollRadius` appears to be the radius of that aforementioned collisional sphere.

`NumNormals`: If positive, it is a number of normals in this mesh. If negative, it is a number of vertex lighting elements (`abs` value).

Depending on a value of `NumNormals`, next data block is interpreted either as `Normals[]` array (in [tr_vertex] format) or `Lights` array (just standard `int16_t` values).

`NumTexturedTriangles` and `NumTexturedRectangles` are respectively the number of triangular and rectangular faces in this mesh. Corresponding `TexturedTriangles` and `TexturedRectangles` array contain textured triangles and rectangles themselves.

`NumColoredTriangles` and `NumColoredRectangles` are respectively the number of triangular and rectangular faces in this mesh. Corresponding `ColoredTriangles` and `ColoredRectangles` array contain colored triangles and rectangles themselves.

As coloured faces feature was removed since TR4, [tr_mesh] structure was changed, and contain no data for coloured faces anymore:

```
virtual struct tr4_mesh // (variable length)
{
    tr_vertex Centre;
      int32_t CollRadius;

      int16_t NumVertices;           // Number of vertices in this mesh
    tr_vertex Vertices[NumVertices]; // List of vertices (relative coordinates)

      int16_t NumNormals;

  if(NumNormals > 0)
    tr_vertex Normals[NumNormals];
  else
      int16_t Lights[abs(NumNormals)];

     int16_t NumTexturedRectangles; // number of textured rectangles in this mesh
    tr_face4 TexturedRectangles[NumTexturedRectangles]; // list of textured rectangles

     int16_t NumTexturedTriangles;  // number of textured triangles in this mesh
    tr_face3 TexturedTriangles[NumTexturedTriangles]; // list of textured triangles
};
```

5.3. Static Meshes

As the name tells, static meshes are meshes that don't move (e.g. skeletons lying on the floor, spiderwebs, trees, statues, etc.) Usually it implies that static mesh is completely non-interactive, i.e. all it does is sitting there in place serving as an ornament.

Note

④ ⑤ Since TR4, certain static meshes became ***destroyable*** (either by shooting or exploding them), and even gained ability to activate ***heavy triggers***. Such static meshes are called ***shatters***. Engine tells shatter statics from ordinary ones judging by their IDs, i.e. shatter static mesh must be in a specific slot. This behaviour is hardcoded.

StaticMeshes have two *bounding boxes*. First one serves as visibililty box, and other is the collisional box. The former is being used for visibility testing, and the latter is used for collision testing.

```
struct tr_staticmesh   // 32 bytes
{
    uint32_t        ID;   // Static Mesh Identifier
    uint16_t        Mesh; // Mesh (offset into MeshPointers[])
    tr_bounding_box VisibilityBox;
    tr_bounding_box CollisionBox;
    uint16_t        Flags;
};
```

```
struct tr_bounding_box // 12 bytes
{
```

```
    int16_t MinX, MaxX, MinY, MaxY, MinZ, MaxZ;
};
```

`VisibilityBox` and `CollisionBox` boundaries is always stay axis aligned even after applying tr_room_staticmesh::Rotation (always have 90 degrees step). Additionally, the test whether to rotate the box or not relies on the mesh's rotation being an exact multiple of 0x4000 (aka 90 degrees). If this is not the case, the box is not rotated, which results in wrong collision checks.

1 2 In `Flags` field, bit 1 is usually set, which means static mesh is visible. Bit 0 is also set for static meshes *without collision*, like plants and lying skeletons. Since TR3, value is ignored, and no-collision mode is obtained using degenerate collision box (with all-zero or all-one coordinates).

5.4. Models

This defines a list of contiguous meshes that comprise one object, which is called a *model*. This structure also points to the hierarchy and offsets of the meshes (`MeshTree`), and also to the animations used (`Animation`); these will be described in detail below. If the Animation index is -1, that means that there are no predefined animations, and entity's movement is all generated by the engine; an example is Lara's ponytail or rolling balls from TR4 and TR5.

Some entities are really stationary, such as locks and the skybox, and some are not rendered at all, such as "camera target" points to aim the camera at, flame emitters, AI objects and other service entities. Such invisible models are frequently called *nullmeshes*, because usually they have null mesh index specified for them, and never actually use it.

1 2 Sometimes, model may refer to sprite or sprite sequence to draw itself (for example, pick-up items and flame emitters). In this case, model is replaced with sprite in run-time. This behaviour is hardcoded for specific model IDs.

4 5 Sometimes, model may have *two different versions* defined in level files — one is normal, and another is low-detailed one, with the latter used when camera position gets too far from them. These are called *MIP models*, and mostly exist for NPCs (enemies). Usually, their type IDs are one off their normal counterparts (for example, skeleton type ID in TR4 is *35*, and its MIP variation is *36*).

```
struct tr_model  // 18 bytes
{
    uint32_t ID;           // Type Identifier (matched in Entities[])
    uint16_t NumMeshes;    // Number of meshes in this object
    uint16_t StartingMesh; // Stating mesh (offset into MeshPointers[])
    uint32_t MeshTree;     // Offset into MeshTree[]
    uint32_t FrameOffset;  // Byte offset into Frames[] (divide by 2 for Frames[i])
    uint16_t Animation;    // Offset into Animations[]
};
```

5 There is an extra `uint16_t` at the end of [tr_model] structure, which is always `0xFFEF` and used for alignment. Consider it while parsing.

5.5. Entities

Entities are the actual instances of entity types, consisting either of *models* or *sprites* (with the latter existing in TR1-2 only). For an entity to appear in a level, it must be referenced in the `Models[]` array. Multiple instances of the same model are possible (e.g. two identical tigers in different rooms are represented using two entries in `Entities[]`, one for each).

Entity structure has gone through different variations across game versions, so we'll list them all.

5.5.1. TR1 Entity Structure

```
struct tr_entity // 22 bytes
{
    int16_t TypeID;     // Entity type ID (matched in Models[])
    int16_t Room;
    int32_t x;          // Item position in world coordinates
    int32_t y;
    int32_t z;
    int16_t Angle;
    int16_t Intensity1;
    uint16_t Flags;
};
```

5.5.2. TR2-3 Entity Structure

```
struct tr2_entity // 24 bytes
{
    int16_t TypeID;
    int16_t Room;
```

```
    int32_t x;
    int32_t y;
    int32_t z;
    int16_t Angle;
    int16_t Intensity1;
    int16_t Intensity2; // Like Intensity1, and almost always with the same value.
    uint16_t Flags;
};
```

5.5.3. TR4-5 Entity Structure

```
struct tr4_entity // 24 bytes
{
    int16_t TypeID;
    int16_t Room;
    int32_t x;
    int32_t y;
    int32_t z;
    int16_t Angle;
    int16_t Intensity1;
    int16_t OCB;        // Replaces Intensity2, see further for explanations.
    uint16_t Flags;
};
```

`TypeID` is used to assign appropriate action for this entity and/or locate the appropriate sprite sequence or model to draw. If `TypeID` is zero, it means it's playable character (i.e. Lara).

`Room` is a room ID to which this particular entity belongs to. If *room* value was modified incorrectly, entity will glitch and, most likely, won't appear in engine. That is, you can't change entity position without complementary edit or `Room` field.

`Angle` is an *Euler Yaw angle* (i.e. "horizontal" rotation) stored in a special manner. To convert it to ordinary degrees, use this formula:

$$\angle^\circ = \left(Angle \div 16384 \right) \times -90$$

① `Intensity2` field is missing in this game version, so the structure size is 2 bytes less.

`Intensity1`: If not -1, it is a value of constant lighting. -1 means "use mesh lighting".

`Flags` value contain packed list of several parameters:

- **Bit 7** (`0x0080`) — ① ② ③ *Clear Body* flag. It is used together with *Clear Bodies* trigger action to remove the body of dead enemy from the level to conserve resources.
- **Bit 8** (`0x0100`) — *Invisible* flag. If entity has this flag set, it will be invisible on start-up. However, it only works for specific types of entities. It is primarily used with pick-ups or other entities which should appear at certain point only after activation, but are visible by default.
- **Bits 9..13** (`0x3E00`) — *Activation Mask* for this entity. As you already learned in *Trigger Actions* chapter, entity is only activated when *activation mask is all set* (i.e. all 5 bits are set, and value is `0x1F`). However, activation mask doesn't strictly required to be set by trigger — level editor allows to *pre-define* activation mask, so entity will bear specific activation mask layout on level start-up.

If activation mask was pre-set to `0x1F` (all set), entity will activate *immediately after level loading*, and engine will also *reset activation mask to zero* and *mark entity as inactive*, effectively swapping "inactive" state with "active". That is, when player will activate such pre-activated entity with a trigger, it will actually "deactivate", et cetera. Most prominent example of this behaviour is pre-opened grated door in Tomb of Qualopec.

5.5.4. Object Code Bit

In TR4 and TR5, `Intensity2` field was replaced with completely new one, called *Object Code Bit* (or `OCB`). OCB allows to alter entity behaviour based on its value, thus providing very basic "script-like" functionality. For example, flame emitter entities have a case switch for OCB value, and each valid OCB value produces different result — flame emttier acts either as a static flame, as a directional flame, as a lightning, and so on.

More detailed description of OCB is provided in this section.

5.6. Sprites

These are "billboard" objects that are always rendered perpendicular to the view direction. These are used for text and explosion effects and similar things; they are also used for some scenery objects and pickup items, though this use gets less as one goes from TR1 to TR3. The various "Sides" below are the positions of the sprite sides relative to the sprite's overall position, measured in TR's world-coordinate units.

```
struct tr_sprite_texture    // 16 bytes
{
    uint16_t Tile;
     uint8_t x;
     uint8_t y;
    uint16_t Width;         // (ActualWidth  * 256) + 255
    uint16_t Height;        // (ActualHeight * 256) + 255
     int16_t LeftSide;
     int16_t TopSide;
     int16_t RightSide;
     int16_t BottomSide;
};
```

④ ⑤ `x` and `y` values *are not used* in this version. Additionally, formula for `Width` and `Height` is changed: now it's `(ActualWidth - 1) * 256` and `(ActualHeight - 1) * 256` respectively.

5.7. Sprite Sequences

These are collections of sprites that are referred to as a group. The members of this group can be cycled through (animated sprites such as flames, blood splats or explosions) or selected in other ways (text). Some sequences have only one member; this is done so as to access all the sprites in the same way.

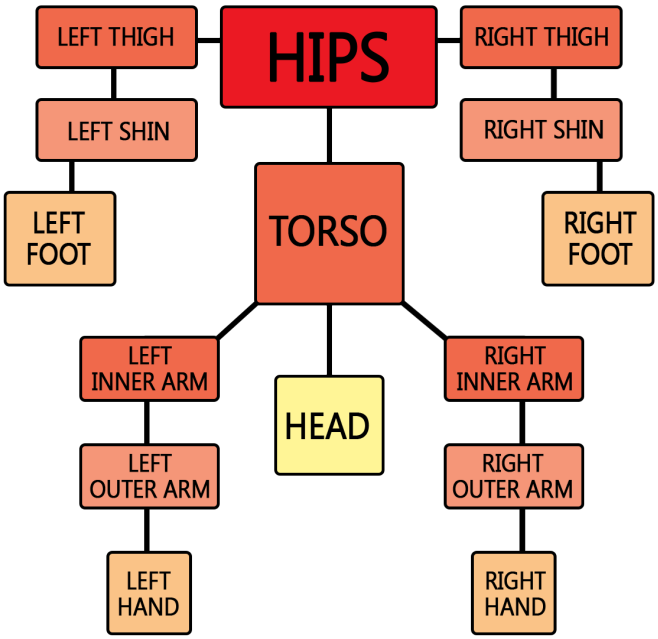
```
struct tr_sprite_sequence  // 8 bytes
{
    int32_t SpriteID;       // Sprite identifier
    int16_t NegativeLength; // Negative of ``how many sprites are in this sequence''
    int16_t Offset;         // Where (in sprite texture list) this sequence starts
};
```

6. Mesh Construction and Animation

6.1. Overview

The animated mesh objects in the Tomb Raider series are sets of meshes that are moved relative to each other, as defined by `Entities[]` entries. Each entry describes which meshes to be used (a contiguous set of them referred to in `MeshPointers[]`), what hierarchy and relative offsets they have (contents of `MeshTree[]` pointed to), and what animations are to be used (contents of `Animations[]` pointed to).

The hierarchy used is a branching one, with the meshes being at the nodes, and with the first mesh being the root node. The `MeshTree[]` values are applied to each of the child meshes in sequence; they are sets of four `int32_t`s, the first being a hierarchy operator, and the remaining three being the coordinates in the parent mesh's system. A hierarchy example is that for the Lara meshes:



Top-down hierarchy of Lara's MeshTree. Hips is a root mesh. Ponytail is not listed, as it is a separate object.

This is implemented by using a stack of meshes and "push" and "pop" operations in `MeshTree[]`. Normally, each mesh's parent is the previous mesh in series. But such meshes can be "remembered" by adding them to a stack of meshes with a "push" operation. This remembered mesh can then be used as the parent mesh with a "pop" operation. It is not clear what the maximum stack depth is; most TR mesh stacks do not extend beyond 2 or 3 meshes.

The animations for each mesh object are selected with some ingenious techniques. Which animations to use are not hardcoded; instead, each entity has some states it can be in, and these states are used to select which animation. For example, locks have only one state (they just sit there), doors have two states (open and closed), and Lara has numerous states, such as standing, walking, running, jumping, falling, being hurt, dying, etc. Each animation has a state ID, which can be used to select it; however, state transitions might seem to require a large number of intermediate states (opening, closing, starting to jump, landing, etc.). The alternative used in the Tomb Raider engine is for each animation to have bridge animations to other states' animations, which are selected using the ID of which state to change to. These bridge animations then lead to the animation with the appropriate state. Thus, a closed door will run a looped closed-door animation as long as its state stays "closed", but when its state becomes "open", it will change to an opening-door bridge animation, which will end in a looped open-door animation. Likewise, closing a door will make it use a closing-door bridge animation. Some bridge animations are chosen with a finer grain of selectivity, however, such as using one for left foot forward and one for right foot forward.

Thus, each animation references a set of `StateChange` structures, each one of which references an `AnimDispatch` structure (called a "range" in some documentation). Each `StateChange` structure contains a new state and which `AnimDispatch` structures to use. When an entity goes into a new state, the `StateChange` structures are scanned for that state's ID, and if one matches, then that `StateChange`'s `AnimDispatch` es are then scanned for a range of frames that contains the ID of the current frame. If such an `AnimDispatch` is found, the animation and the frame are changed to those listed in it.

The ultimate unit of animation is, of course, the frame, and each frame consists of a bounding box, the offset of the root mesh, and rotation angles for all the meshes with respect to their parent meshes. The root mesh is also rotated, but relative to the object's overall coordinates. All rotations are performed around the meshes' origins, and are in order Y, X, Z (yaw, pitch, roll). The reason for the root mesh's displacement is because entities traveling on solid surfaces are likely tracked by having their locations be at ground level, and Lara's hips, for example, are well above the ground. Finally, some of the angles are not specified explicitly, when they are not, they are zero.

Frames are referenced in two ways, either by an offset into the `Frames[]` array that contains them, or by frame index. The values of the latter appear to be unique to each kind of entity, but not between entities; the first frame for each kind is numbered 0. This is likely a convenience when constructing the animations, since the list of animation frames for each entity can be constructed separately. However, using these indices is fairly simple. Each Animation structure has a first-frame index; this index is subtracted from the index of the desired frame in order to find out its index relative to the animation's first frame.

There are also some special *AnimCommands* for doing various additional things. Some of them are for moving entities in absolute coordinates, for example to position Lara at climb location, or specifying jump momentum. Some others define actions per frame, like playing sounds, emitting bubbles, and so forth.

Finally, some entities appear to have incomplete set of animations; their complete animations are "borrowed" from similar entities. Such setup is mostly used in TR2's Venice levels — some of Venice goons them have a full set of animations, while some others have only the standing animation. The ones with only the standing animation borrow their other animations from the fully-animated ones.

6.2. Data Structures

6.2.1. Mesh Tree Structure

```
struct tr_meshtree_node // 4 bytes
{
    uint32_t Flags;
     int32_t Offset_X;
     int32_t Offset_Y;
     int32_t Offset_Z;
};
```

`MeshTree[]` array consists of meshtree nodes.

In 'Flags` field, two bytes are used: * Bit 0 (`0x0001`) indicates *``take the top mesh off of the mesh stack and use as the parent mesh" when set*, otherwise *`'use the previous mesh as the parent mesh''`*. * Bit 1 (0x0002`) indicates "put the parent mesh on the mesh stack".

When both bits are set, the *Bit 0* operation is always done before the *Bit 1* operation. In effect, *read the stack but do not change it*.

`Offset_X`, `Offset_Y` and `Offset_Z` are offsets of the mesh's origin from the parent mesh's origin.

6.2.2. TR1-3 Animation Structure

This describes each individual animation. These may be looped by specifying the next animation to be itself. In TR2 and TR3, one must be careful when parsing frames using the FrameSize value as the size of each frame, since an animation's frame range may extend into the next animation's frame range, and that may have a different FrameSize value.

```
struct tr_animation // 32 bytes
{
    uint32_t  FrameOffset; // Byte offset into Frames[] (divide by 2 for Frames[i])
     uint8_t  FrameRate;   // Engine ticks per frame
     uint8_t  FrameSize;   // Number of int16_t's in Frames[] used by this animation

    uint16_t  State_ID;

       fixed  Speed;
       fixed  Accel;

    uint16_t  FrameStart;  // First frame in this animation
    uint16_t  FrameEnd;    // Last frame in this animation
    uint16_t  NextAnimation;
    uint16_t  NextFrame;

    uint16_t  NumStateChanges;
    uint16_t  StateChangeOffset; // Offset into StateChanges[]

    uint16_t  NumAnimCommands;   // How many of them to use.
    uint16_t  AnimCommand;       // Offset into AnimCommand[]
};
```

`FrameOffset` is a byte offset into Frames[] (divide by 2 for Frames[i]).

`FrameRate` is a multiplier value which defines how many *game frames* will be spent for each actual animation frame. For example, if value is 1, then each animation frame belongs to single game frame. If value is 2, then each animation frame belongs to two game frames, and so on. In latter case, animation frames will be interpolated between game frames using *slerp* function.

Actual game frame rate is always locked to 30 FPS. All engine internal counters, including animation frame counters, are also using 30 FPS timebase.

`State_ID` identifies current state type to be used with this animation. Engine uses current `State_ID` not only to solve state changes, but also to define current Lara behaviour — like collisional routines to be used, controls to be checked, health/air/sprint points to be drained, and so on.

`Speed` and `Accel` values are used to set a specific momentum to a given entity. That is, entity will be accelerated with `Accel` value, until `Speed` value is reached. If `Accel` is negative, speed will be decreased to fit `Speed` value. The direction in which entity is moved using speed value is hardcoded, and mostly is forward.

`NextAnimation` defines which animation should be played after current one is finished. When current animation ends, engine will switch it to `NextAnimation`, not regarding current `State_ID` value. If `NextAnimation` value is the same as animation number itself, it means animation will be looped until loop is broken by state change.

`NextFrame` specifies the frame number to be used when switching to next animation. That is, if `NextFrame` is 5 and `NextAnimation` is 20, it basically means that at the end of current animation engine will switch right to frame 5 of animation 20. If animation is looped, `NextFrame` defines to which frame animation should be rewound. It allows to "eat up" certain start-up frames of some animations and re-use them as looped.

To get number of frames for current animation, use this formula: `NumFrames = (FrameEnd - FrameStart) + 1`.

6.2.3. TR4-5 Animation Structure

For TR4 and TR5, extended version of [tr_animation] is used:

```
struct tr4_animation // 40 bytes
{
    uint32_t  FrameOffset;
     uint8_t  FrameRate;
     uint8_t  FrameSize;

    uint16_t  State_ID;

       fixed  Speed;
       fixed  Accel;
       fixed  SpeedLateral; // New field
```

```
        fixed  AccelLateral; // New field

    uint16_t  FrameStart;
    uint16_t  FrameEnd;
    uint16_t  NextAnimation;
    uint16_t  NextFrame;

    uint16_t  NumStateChanges;
    uint16_t  StateChangeOffset;

    uint16_t  NumAnimCommands;
    uint16_t  AnimCommand;
};
```

④ ⑤ In addition to `Speed` and `Accel` values, TR4 introduced `LateralSpeed` and `LateralAccel` values, which are used to move entity to the sides, rather than forward or backward. However, these values are only used for *any entity but Lara* — engine ignores them in such case.

Lateral speed and acceleration primarily used for "start-up" animations of NPCs — for example, armed baddies in TR4 can roll or jump aside.

6.2.4. State Change Structure

Each state change entry contains the state to change to and which animation dispatches to use; there may be more than one, with each separate one covering a different range of frames.

```
struct tr_state_change // 6 bytes
{
    uint16_t StateID;
    uint16_t NumAnimDispatches; // number of ranges (seems to always be 1..5)
    uint16_t AnimDispatch;      // Offset into AnimDispatches[]
};
```

6.2.5. Animation Dispatch Structure

This specifies the next animation and frame to use; these are associated with some range of frames. This makes possible such specificity as one animation for left foot forward and another animation for right foot forward.

```
struct tr_anim_dispatch    // 8 bytes
{
    int16_t Low;           // Lowest frame that uses this range
    int16_t High;          // Highest frame that uses this range
    int16_t NextAnimation; // Animation to dispatch to
    int16_t NextFrame;     // Frame offset to dispatch to
};
```

6.2.6. AnimCommand Structure

These are various commands associated with each animation. They are varying numbers of `int16_t`s packed into an array. As the *FloorData*, AnimCommands must be parsed sequentially, one by one.

The first AnimCommand entry is the *type*, which also determines how many `int16_t` arguments (operands) follow it (i.e. how many `int16_t` values must be parsed after current one without switching to next AnimCommand). For a given animation, AnimCommands are parsed until `NumAnimCommands` value is reached.

Some of commands refer to the whole animation (jump speed, position change, kill and empty hands commands), while others of them are associated with specific frames (sound, bubbles, etc.). When command refers whole animation, it means that actual command execution will occur on animation transition, i.e. last animation frame.

```
struct tr_anim_command // 2 bytes
{
    int16_t Value;
};
```

Here are all the `AnimCommand` types and their arguments.

1. **Set Position** (3 arguments). Sets relative entity position (x, y, z); found in grab and block-move animations.
2. **Jump Distance** (2 arguments). Vertical and horizontal speed for jumping.
3. **Empty Hands** (No arguments). This command is performed in the end of animation of Lara pulling a switch, inserting a key, grabbing a pushable block, and so on. It is needed because engine "locks" Lara's ability to draw weapons or ignite a flare when such action is performed, and only way to unlock it is to call this command.

4. **Kill** (No arguments). Kill entity. This effectively disables entity and removes it from the world. For switch entities, same command is used to define switching point animation.
5. **Play Sound** (2 arguments). The first argument is a frame number, and the second one is the ID of the sound to play at that frame (internal sound index).

   ② ③ ④ ⑤ Besides Sound ID, second argument may contain one of two "packed" bit flags. Their meanings are:

   - `0x4000` — play this sound when on dry land (example: footsteps)
   - `0x8000` — play this sound when in water (example: running through shallow water)
6. **Flipeffect** (2 arguments). The first one is a frame number, and the second one is flipeffect number. Note that *flipeffect* here is the very same kind of flipeffect used in *trigger action* with the same name. Flipeffect meaning is listed separately.

   ③ ④ ⑤ Usually, when `FOOTPRINT_FX` flipeffect (ID 32) is used, second argument also may contain one of two "packed" bit flags, similar to Play Sound animcommand. However, meaning is different:

   - `0x4000` — apply FOOTPRINT_FX in relation to left foot
   - `0x8000` — apply FOOTPRINT_FX in relation to right foot

6.2.7. Frame Structure

Frames indicate how composite meshes are positioned and rotated. They work in conjunction with Animations[] and MeshTree[]. A given frame has the following format:

```
struct tr_anim_frame    // Variable size
{
     tr_bounding_box box; // Bounding box
     int16_t OffsetX, OffsetY, OffsetZ; // Starting offset for this model
     int16_t NumValues;
    uint16_t AngleSets[];   // Variable size
}
```

`NumValues`: ① Number of angle sets to follow; these start with the first mesh, and meshes without angles get zero angles. ② ③ ④ ⑤ NumValues is implicitly NumMeshes (from model).

`AngleSets` are sets of rotation angles for all the meshes with respect to their parent meshes. In TR2/3, an angle set can specify either one or three axes of rotation.

If either of the high two bits (`0xC000`) of the first angle `uint16_t` are set, it's one axis: only one `uint16_t`, low 10 bits (`0x03FF`), scale is `0x0100` — 90 degrees; the high two bits are interpreted as follows: `0x4000` — X only, `0x8000` — Y only, `0xC000` — Z only.

If neither of the high bits are set, it's a three-axis rotation. The next 10 bits (`0x3FF0`) are the X rotation, the next 10 (including the following `uint16_t`) (`0x000F`, `0xFC00`) are the Y rotation, the next 10 (`0x03FF`) are the Z rotation, same scale as before (`0x0100` — 90 degrees).

Rotations are performed in Y, X, Z order.

① All angle sets are two words and interpreted like the two-word sets in TR2/3, *except* that the word order is reversed.

7. Non-Player Character Behaviour

7.1. Overview

All the Tomb Raider game physics and entity behaviour is hardcoded, with each type ID being associated with some specific sort of behaviour (as Lara, as a boat, as a tiger, as a door, as a boulder, as a lock, etc.). That is, each model refer two internal engine routines — *collisional* one and *control* one. For static entities (like flame emitters), *collisional* routine may contain no functional code, while *control* routine is present. On contrary, "decorative" entities (usually called *animatings* in TRLE) may lack *control* code, while retaining *collisional* code.

Several entity types may share the same collisional and/or control routines — for example, there is one generic collisional routine for almost all enemies, another generic routine for doors, and another one for *standable* entities, like bridge or platform objects.

Lara is unique player character, so she has a large set of both *control* and *collisional* routines, which are switched depending on her current *state*.


Note

In original Tomb Raider source code, notation for collisional and state routines follows two different schemes. For Lara, collisional and control routines are called `lara_col_STATE` and `lara_as_STATE`, where `STATE` is the name of the state, like *walk, run, reach*, and so on.

For other entity types, there is more generic scheme: collisional routines are called `NAMECollision`, where `NAME` is entity type name, like *CreatureCollision*, and control routines

> are called `NAMEControl`, where `NAME` is entity type name. E.g., bear will have a pair of routines linked to it, named *CreatureCollision* and *BearControl*.

7.2. Entity Scripting

Despite the existence of *script files*, here is no any scripting for entity behaviour, like in most contemporary games. This hardcoding makes it difficult to port the earlier Tomb Raider scenarios to the engines of the later games, which could be desirable with their improved hardware support. While textures, models, and animations can be ported, behaviour cannot be.

However, there is a small change in TR4 and TR5 which indicates that specific entity behaviour can be altered — it's called *OCB*. It was briefly described in this section. OCB is a special value defined for each entity instance, based on which entity can switch the way it acts (most prominent examples are flame emitters, which change their size and emit direction based on OCB, and teeth spikes, which change their orientation in space).

Sometimes OCB is interpreted as a "packed" field with several values incorporated — like teeth spike OCB contain information about their horizontal and vertical orientation, and also about their "physical" behaviour (stick out constantly, pop-retract in looped manner, or pop-retract just once).

> For list of valid entity OCBs in TR4, you may refer to TRLE User's Manual, although it was written in a big rush, and thus it lacks many existing OCBs for many entities. There are also fan-made OCB lists which are much more comprehensive.
>
> As for TR5, no proper OCB list exists for its entity types, so it may be considered a big unknown.

However, OCB can't be seriously called "scripting", as it also operates with pre-defined hardcoded behaviour.

> Recent patches for TR4 game engine (used to play custom levels), like *TREP* and *TRNG*, feature some kind of basic scripting functionality. However, there's still no sign of *real scripting language* in them, and such scripting is basically specifying pre-defined variables to alter entity behaviour, just like OCB does.

7.3. Pathfinding

Despite the lack of scripting, the Tomb Raider series does have navigation hints for the Non-Player Characters; those entities that move freely across the maps under the command of the game AI. NPCs find their way in a level by checking "FloorData" collisional functions in the same way Lara does, and also with the help of special data structures which are used for proper pathfinding.

7.3.1. Data Structures

TR engines use three different structures to assist pathfinding. These are *boxes, overlaps, and zones*. Most sectors point to some *box*, the main exceptions being horizontal-portal sectors. Several neighbour sectors may point to the same box. Each box also has a pointer into the list of *overlaps*. Each segment in that list is the list of accessible neighbouring boxes for some box; the NPCs apparently select from this list to decide where to go next.

This selection is done with the help of the *zones*. These structures of 6 (TR1) or 10 (TR2-TR5) `int16_t`s that act as zone IDs; their overall indexing is the same as the boxes, meaning that each box will have an associated set of zone IDs. An NPC will select one of this set to use, and will prefer to go only into the overlaps-list boxes that have the same zone value as the box it is currently in. For example, one can create guard paths by making chains of zone-ID-sharing boxes, with their overlaps pointing to the next boxes in those chains.

Boxes

A box is a horizontal rectangle, with corners and height specified.

This is presumably the way *TRLE* creates boxes for each level:

- For each sector, extend one axis until a height difference is reached.
- Then extend this row (or column) perpendicular until another height difference is reached. This is a rectangle with the same height and it *defines a box*.
- Do the same with the other axis first, and you get another box.
- Repeat this process for every sector, maybe extending into neighbor rooms through the portals.
- Make sure that there are no any duplicate boxes.

There are two variations of box structure — one for TR1 and another for TR2 and any other game version.

```
struct tr_box   // 20 bytes
{
```

```
    uint32_t Zmin;          // Horizontal dimensions in global units
    uint32_t Zmax;
    uint32_t Xmin;
    uint32_t Xmax;
     int16_t TrueFloor;     // Height value in global units
    uint16_t OverlapIndex;  // Bits 0-13 is the index into Overlaps[].
};
```

```
struct tr2_box   // 8 bytes
{
    uint8_t Zmin;          // Horizontal dimensions in sectors
    uint8_t Zmax;
    uint8_t Xmin;
    uint8_t Xmax;
    int16_t TrueFloor;     // Height value in global units
    int16_t OverlapIndex;  // Bits 0-13 is the index into Overlaps[]
};
```

The `OverlapIndex` contains a block mask for path finding by enemies in two highest bits: Bit 15 (blockable) and bit 14 (blocked). The first one marks it as unpassable by large enemies, like the T-Rex (ID 18), the Mutant (ID 20) or the Centaur (ID 23) and is always set behind doors. The second one marks it unpassable for other enemies and is set for movable blocks (if blockable bit is set), for closed doors and for some flip maps (set at start).

Overlaps

This is a set of lists of neighbouring boxes for each box, each member being a `uint16_t`. NPCs apparently use this list to decide where to go next.

Overlaps must be parsed in serial manner, as with *FloorData* functions: the highest bit (`0x8000`) is used to terminate overlap list iteration for a single box.

Zones

This is a set of `int16_t`s, 6 for TR1 and 10 for TR2-5. NPCs prefer to travel to a box with the same zone ID as the one they are currently at. Which of these zone IDs it uses depends on the kind of the NPC and its current state. The first half of the Zones structure is for the *normal* room state, and the second half is for the *alternate* (flipped) room state. TR1 has 2 sets of ground zones and 1 set of fly zones:

```
struct tr_zone   // 12 bytes
{
    uint16_t GroundZone1_Normal;
    uint16_t GroundZone2_Normal;
    uint16_t FlyZone_Normal;
    uint16_t GroundZone1_Alternate;
    uint16_t GroundZone2_Alternate;
    uint16_t FlyZone_Alternate;
};
```

TR2-5 have similar breakdowns, though they have 4 ground zones:

```
struct tr2_zone   // 20 bytes
{
    uint16_t GroundZone1_Normal;
    uint16_t GroundZone2_Normal;
    uint16_t GroundZone3_Normal;
    uint16_t GroundZone4_Normal;
    uint16_t FlyZone_Normal;
    uint16_t GroundZone1_Alternate;
    uint16_t GroundZone2_Alternate;
    uint16_t GroundZone3_Alternate;
    uint16_t GroundZone4_Alternate;
    uint16_t FlyZone_Alternate;
};
```

The ground zones are for NPCs that travel on the ground, while the fly zones are for flying or swimming NPCs.

7.3.2. Moods

Each mobile NPC in TR may be in a certain *mood*. A mood defines the way creature behaves. The way NPCs change their mood is based on several conditions, mainly on certain enemy implementation.

Most obvious example of mood change is wolf, which can sleep, walk slowly, chase Lara and flee. This change of mood is based on Lara's position — if Lara is found in any of the box that NPC can reach, mood is changed to *chase*, which means

that *pathfinding algorithm* is in effect (see further).

There are another examples of mood changes. In TR3, monkeys are calm unless Lara shoots them. However, this is not the case for level 2 (Temple Ruins), where monkeys are hardcoded to chase Lara on start-up.

7.3.3. Pathfinding algorithm

For most of TR NPCs, when they are in *chase* mood, pathfinding (and eventual attack) may be broken down to several steps:

- Collect all boxes that are in the same zone as the NPC.
- Find a path using *Dijkstra algorithm* with respect to the NPC abilities and a *maximum depth of 5 boxes*.
- Calculate a random point in the intersection of the current box and the next box on the waypoint.
- If NPC is finally shortly at arriving at Lara, try to predict the direction in which Lara is running (with different lookahead distances for different types of NPCs).
- Perform an attack based on aforementioned calculations.

7.4. AI Objects

Since TR3, in addition to pathfinding data structures, there are now special *AI objects*, which are used in a node-like manner, defining specific action, like wandering between two points, guarding specific point or running to specific place in case Lara is around. For example, MP Guards in TR3's "Area 51" may patrol specific area when they are limited by special *AI_PATROL* object.

Not every NPC is "taught" to work with AI objects — usually, only "smart" human enemies or friends can take advantage of them. Analyzing level files with utilities like *FexInspect* may help understanding particular AI object setup and learn which NPCs can actually work with them.

Specific set of AI objects and their respective entity type IDs are different across game versions, but types themselves largely remained unchanged from TR3 to TR5. Here are they:

- **AI_GUARD** — Makes the enemy stay on his current position and turn his head, looking left and right, with a 180 degree field of view — so his "viewing cone" is continuously changed, based on current look direction. When Lara gets into his "viewing cone", default entity behaviour is engaged — for example, MP guards will chase Lara and try to beat her.
- **AI_AMBUSH** — Makes the enemy run to a designated square by dropping an AI_AMBUSH object on the same sector with him, and another AI_AMBUSH on the sector where he should run to. He will do that only if he spots Lara (hence the name). After reaching second AI_AMBUSH point, enemy will switch to default behaviour. Best example is MP Guard in "Area 51" who locks out first secret, if you won't manage to kill him in time after he noticed you.
- **AI_PATROL1** and **AI_PATROL2** — Makes the enemy patrol specific path between AI_PATROL1 and AI_PATROL2 locations. To make it work, AI_PATROL1 object must be in the same sector with enemy, and AI_PATROL2 must be in the point to which enemy must go. After reaching AI_PATROL2 point, enemy will return to AI_PATROL1 point, and vice versa. It's also possible to specify another "starting point" for enemy by dropping extra AI_PATROL1 object — then enemy will go to this secondary AI_PATROL1 object just after activation. If enemy spots Lara, he will switch to default behaviour.
- **AI_MODIFY** — When placed in the same sector with *AI_GUARD*, it makes the enemy look straight ahead, instead of turning his head left and right.
- **AI_FOLLOW** — Used primarily with friendly NPCs, and makes them wait for Lara and then "lead" her to specific point. For such behaviour, one AI_FOLLOW object must be placed in the same sector as NPC, and second AI_FOLLOW object must be placed on target point. If Lara shoots NPC affected with AI_FOLLOW behaviour, he will abandon it and become hostile.

TR3 also features two additional AI objects which are used solely with Willard boss in Meteorite Cavern:

- **AI_PATH** — Presumably, Willard spider will use these AI objects as a waypoints, circling around cavern. When certain AI_PATH object is reached, Willard will search for next one in a row, and follow it. When last one is reached, operation repeats from the beginning.
- **AI_CHECK** — Presumably, when such object is in ~2 sectors range, Willard will check if Lara is in proximity range to any of meteorite artifacts, and if so, he will shoot.

If there is a HEAVYTRIGGER under an AI_AMBUSH or AI_PATROL object, the enemy will activate it only when he gets there.

④ ⑤ TR4 introduced three additional AI objects, **AI_X1**, **AI_X2** and **LARA_START_POS**. First two are used, for example, with SAS Guards in *Cairo* story arc. When AI_X1 object is placed in the same sector with SAS Guard, he will

prefer to shoot grenades instead of bullets. If another SAS Guard with AI_X2 is activated nearby, then first one will stop shooting grenades, and second one will shoot them instead.

As for **LARA_START_POS** AI object, it is used to modify Lara's level starting position, according to prior *end level trigger action* configuration. That is, at start Lara will be teleported to any existing **LARA_START_POS** AI object with same OCB value as in `Timer` field of *end level* trigger in previous level.

7.4.1. AI Object IDs

Here are all AI Object type IDs in each TR version which has them:

	TR3	TR4	TR5
AI_GUARD	74	398	378
AI_AMBUSH	75	399	379
AI_PATROL1	76	400	380
AI_PATROL2	79	403	383
AI_MODIFY	77	401	381
AI_FOLLOW	78	402	382
AI_PATH	80	402	382
AI_CHECK	81		
AI_X1		404	384
AI_X2		405	385
LARA_START_POS		406	386

7.4.2. AI Data Block in TR4-5

Beginning with TR4, AI objects are *not kept along with other entities*. Instead, they have their own structure, which is basically simplified [tr4_entity] structure, and moved to separate data block. This seems reasonable, as the only purpose of AI objects is to serve as "waypoints", and they have neither *collisional* nor *control* code attached to them.

The format of AI object structure as follows:

```
struct tr4_ai_object   // 24 bytes
{
    uint16_t TypeID     // Object type ID (same meaning as with tr4_entity)
    uint16_t Room;      // Room where AI object is placed
     int32_t x, y, z;   // Coordinates
     int16_t OCB;       // Same meaning as with tr4_entity
    uint16_t Flags;     // Activation mask, bitwise-shifted left by 1
     int32_t Angle;
};
```

8. Music and Sound

As it was described in the beginning, all sound in TR engines can be separated into two distinctive sections — *audio tracks* and *sounds*.

Audio tracks are long separate files which are loaded by streaming, and usually they contain background ambience, music or voiceovers for cutscenes.

Sounds are short audio samples, which are frequently played on eventual basis. While engine can usually play one audio track at a time, it can play lots of sounds in the same time, and also play numerous copies of the same sound (for example, when two similar enemies are roaming around).

8.1. Audio Tracks

Audio tracks can be *looped* or *one-shot*. Looped tracks are usually contain background ambience (these creepy sounds heard in the beginning of "Caves" and so on), but occasionally they can use music (e. g., "Jeep theme" from TR4). One-shot tracks are used for musical pieces which are usually triggered on certain event, and also for "voice chatting" (e. g. approaching the monk from "Diving Area" in TR2).

As both looped and one-shot tracks use the same audio playing routine, *there's no chance both looped and one-shot tracks could be played simultaneously*. This is the reason why background ambience stops and restarts every time

another (one-shot) track is triggered. However, this limitation was lifted in *TREP* and *TRNG*.

The audio tracks are stored in different fashions in the various versions of the TR series:

8.1.1. TR1 and TR2

TR1 and TR2 used *CD-Audio* tracks for in-game music, and therefore, they needed auxiliary CD-audio fed into the soundcard. That's the reason why most contemporary PCs have issues with audiotrack playback in these games — such setup is no longer supported in modern CD/DVD/BD drives, and digital pipeline is not always giving the same result. Currently, various modernized game repacks (such as *Steam* or *GOG* releases) officially features no-CD cracks with embedded MP3 player, which takes place of deprecated CD-Audio player.

In the Macintosh versions, the CD audio tracks are separate files in AIFF format.

8.1.2. TR3

In TR3, we have somewhat special audiotrack setup. Audio format was changed to simple *WAV (MS-ADPCM codec)*, but all tracks were embedded into `CDAUDIO.WAD` file, which also contained a header with a list of all tracks and their durations. So, when game requests an audiotrack to play, it takes info on needed track from `CDAUDIO.WAD` header, and then goes straight to an offset for this track into it. The format of `CDAUDIO.WAD` header entry is:

```
struct tr3_cdaudio_entry    // 0x10C bytes
{
        char Name[260];     // C string with track name
    uint32_t WavLength;     // Wave file size
    uint32_t WavOffset;     // Absolute offset in CDAUDIO.WAD
};
```

The number of header entries is always 130 (meaning the whole size of header should be `0x10C * 130`). Header is immediately followed by embedded audio files in *WAV* format.

In the Macintosh version of TR3, these tracks are separate files in *WAV* format. The Macintosh version of TR3 contains an additional file, `CDAudio.db`, which contains the names of all the track files as 32-byte zero-padded C strings with no extra contents.

8.1.3. TR4 and TR5

In TR4-5, track format remained the same (MS-ADPCM), but tracks were no longer embedded into `CDAUDIO.WAD`. Instead, each track was saved as simple `.WAV` file, and file names themselves were embedded into executable. Hence, when TR4-5 plays an audiotracks, it refers to internal filename table, and then loads an audiotrack with corresponding name.

8.2. Sounds

In TR engines, sounds appear in a variety of contexts.

They can be either *continuous* or *triggered*. Continuous ones are usually produced by *sound source* object, which make sound in a range around some specific point (range appears to be hardcoded, and is equal to around 8 sectors). Likewise, triggered ones can be triggered by a variety of events. The triggering can be hardcoded in the engine (for example, gunshots) or by reaching some animation frame (footsteps, Lara's somewhat unladylike sounds). *Flipeffects* can also be used to play certain sound sample in specific circumstances, and either called by triggers or from animations.

Sounds may be *looped* or *one shot*, with looped ones playing until specifically untriggered by some in-game event. For example, Uzi and M16 sounds are looped and will be played until Lara stops firing these weapons — in such case, engine sends a command to stop this particular sound.

Sounds may be *global* or *local*. *Global* sounds have no 3D positioning in world space, they always have constant volume and usually not linked to any object in level. These are primarily menu sounds. *Local* sounds are usually produced by entities or sound source objects. They have certain coordinates in space, and could be affected by their position and environment. *Local* sounds, when emitted by entities, may travel along with these entities.

Sounds are referred to by an *internal sound index*; this is translated into which sound sample with the help of three layers of indexing, to allow for a suitable degree of abstraction. Internal sound indices for various sounds are consistent across all the level files in a game; a gunshot or a passport opening in one level file will have the same internal sound index as in all the others. The highest level of these is the `SoundMap[]` array, which translates the internal sound index into an index into `SoundDetails[]`. Each `SoundDetails` record contains such details as the sound volume, pitch and volume randomization, looping configuration, how many samples to select from, and an index into `SampleIndices[]`. This allows for selecting among multiple samples to produce variety; that index is the index to the `SampleIndices[]` value of first of these, with the rest of them being having the next indices in series of that array. Thus, if the number of samples is 4, then the TR engine looks in `SampleIndices[]` locations *Index*, *Index+1*, *Index+2*, and *Index+3*. Finally, the `SampleIndices[]` array references some arrays of sound samples.

Wave format used in TR1/TR2 and TR3/TR4/TR5 is different. While TR1 and TR2 used 8-bit 11 kHz data, TR3 onwards switched to 16-bit 22 kHz data. However, PlayStation versions of TR1 and TR2 used 16-bit samples as well, which generally made PlayStation version sound quality better, without dithering artifacts.

Additionally, TR4 and TR5 introduced usage of *MS-ADPCM* codec to store sample data, which was compressed and loaded into buffers on level loading. However, *TR4 engine version bundled with TRLE* used uncompressed wave data, as in TR1-TR3.

In TR1, TR4 and TR5 samples themselves are embedded in the level files. In TR1, `SampleIndices[]` array contains the displacements of each sample in bytes from the beginning of that embedded block. In TR4 and TR5, way to access sample data was changed — each sample data is preceded by *uncompressed size* and *compressed size* `uint32_t` values, which are used to extract given sample and load it into DirectSound buffer.

```
struct tr4_sample // (variable length)
{
    uint32_t UncompSize;
    uint32_t CompSize;
    uint8_t SoundData[CompSize]; // zlib-compressed sound data (CompSize bytes)
};
```

While *compressed size* defines the whole size of embedded `.WAV` file, *uncompressed size* defines the size of raw PCM data size in *16-bit, 22050 kHz, mono* format. However, *uncompressed size* does not necessarily equal to a value derived from *compressed size* by wave type conversion, because MS-ADPCM codec tends to leave a bit of silence in the end of the file (which produces audible interruption in looped samples).

In TR2 and TR3, these samples are concatenated in the file `MAIN.SFX` with no additional information; `SampleIndices[]` contains sequence numbers (0, 1, 2, 3, ...) in `MAIN.SFX`. Finally, the samples themselves are all in Microsoft WAVE format.

8.3. Sound Data Structures

8.3.1. Sound Sources

This structure contains the details of continuous-sound sources. Although a SoundSource object has a position, it has no room membership; the sound seems to propagate omnidirectionally for about 8 horizontal-grid sizes without regard for the presence of walls.

```
struct tr_sound_source // 16 bytes
{
     int32_t x;          // absolute X position of sound source (world coordinates)
     int32_t y;          // absolute Y position of sound source (world coordinates)
     int32_t z;          // absolute Z position of sound source (world coordinates)
    uint16_t SoundID;    // internal sound index
    uint16_t Flags;      // 0x40, 0x80, or 0xC0
};
```

`Flags` field defines sound source behaviour, if it was placed in room which can be flipped to alternate room:

- `0x40`: Play sound only when room is in alternate state.
- `0x80`: Play sound only when room is in original state.
- `0xC0`: Always play sound (in both original and alternate rooms).

8.3.2. Sound Map

`SoundMap` is used for mapping from internal-sound index to `SoundDetails` index; it is 256 `int16_t` in TR1, 370 `int16_t` in TR2, TR3 and TR4, and 450 `int16_t` in TR5. A value of `-1 (0xFFFF)` indicates “none”, meaning the sample is not used in current level.

Each `SoundDetails` entry can be described as such:

```
struct tr_sound_details // 8 bytes
{
   uint16_t Sample; // (index into SampleIndices)
   uint16_t Volume;
   uint16_t Chance; // If !=0 and ((rand()&0x7fff) > Chance), this sound is not played
```

```
    uint16_t Characteristics;
};
```

`Characteristics` is a packed field containing various options for this particular sound detail:

- Bits 0-1: Looping behaviour: either normal playback (value `00`), *one-shot rewound* (`01` in TR1/TR2, `10` in other games), meaning the sound will be rewound if triggered again, or *looped* (value `10` in TR1, `11` in other games), meaning the sound will be looped until strictly stopped by an engine event. Since TR3, *one-shot wait* mode is introduced (value `10`), meaning the same sound will be ignored until current one stops.
- Bits 2-7: Number of sound samples in this group. If there are more than one samples, then engine will select one to play based on randomizer (for example, listen to Lara footstep sounds).
- Bit 12: Meaning unknown. Set when *N* value is defined in sound script used with TRLE.
- Bit 13: Randomize pitch. When this flag is set, sound pitch will be slightly varied with each playback event.
- Bit 14: Randomize gain. When this flag is set, sound volume (gain) will be slightly varied with each playback event.

In TR3 onwards, [tr_sound_details] structure was rearranged:

```
struct tr3_sound_details  // 8 bytes
{
    uint16_t Sample; // (index into SampleIndices)
     uint8_t Volume;
     uint8_t Range;
     uint8_t Chance;
     uint8_t Pitch;
      int16_t Characteristics;
};
```

`Range` now defines radius (in sectors), on which this sound can be heard. Previously (in TR1 and TR2), each sound had a predefined range about 8 sectors.

`Pitch` specifies *absolute* pitch volume for this sound (may be also varied by bit 13 of *Characteristics*). Mainly, this value was used to "speed-up" certain samples, thus allowing to keep high-quality samples with lower sample rate, or on contrary, "slow down" sample, making it sound longer than its native sample rate, thus conserving some memory.

8.4. Sample Indices

In TR1, this is an offset value array, each offset of which points into the embedded sound-samples block, which follows this array in the level file. In TR2 and TR3, this is a list of indices into the file 'MAIN.SFX` file; the indices are the index numbers of that file's embedded sound samples, rather than the samples' starting locations. That file itself is a set of concatenated sound files with no catalogue info present.


Note

Sample indices are not used in TR4 and TR5, and this data block is missing from level file, replaced by six zero bytes, which finalize *zlib compressed level block* followed by embedded sound sample data.

9. Miscellany

These are various odds and ends that do not fit into the earlier categories.

9.1. Version

Every level file begins with a `uint32_t` version number. This seems to be used by the engine to guarantee compatibility between various level editor versions and the game engine version. More generally, it can be used to determine what sort of level is being read.

Here are the known (observed) values for the version header:

- `0x00000020` — Tomb Raider 1, Gold, Unfinished Business
- `0x0000002D` — Tomb Raider 2
- `0xFF080038` — Tomb Raider 3
- `0xFF180038` — Tomb Raider 3
- `0x00345254` — Tomb Raider 4 and Tomb Raider 5
- `0x63345254` — Tomb Raider 4 (demo versions)

Early TR4 demos (e.g. *September 15 demo*) have whole level file packed into a single zlib chunk. Therefore, there is no header.

TR5 version header is equal to TR4 version header. So there is no way to tell TR4 level from TR5 level judging only by this header — you need to check filename extension as well.

As it was noted, *retail* version of TR4 expects to load sound samples compressed in MS-ADPCM format, while *TRLE* version of TR4 loads uncompressed samples only. There is no way to tell *retail* version from *TRLE* version, as their version numbers are equal.

9.2. Palette

This consists of 256 [tr_colour] structs, one for each palette entry. However, the individual colour values range from 0 to 63; they must be multiplied by 4 to get the correct values. Palette is used for all 8-bit colour, such as 8-bit textures.

❶ First entry in palette is treated as *transparent colour* used for textures with alpha testing. In later games, transparent colour was replaced by so-called 'magenta transparency', meaning that any pixel with red and blue values at maximum and green value at zero, is treated as completely transparent.

9.3. Object Textures

Object texture (or *texture details* in TRLE terms) keeps detailed information about each texture independently used in game. While it's not texture image itself (these are kept inside *texture tiles*), it's rather a reference to particular texture tile zone kept with all other necessary information to display this texture.

9.3.1. Object Texture Vertex Structure

This sub-structure used by object textures specifies a vertex location in texture tile coordinates. The Xcoordinate and Ycoordinate are the actual coordinates of the vertex's pixel. If the object texture is used to specify a triangle, then the fourth vertex's values will all be zero.

```
struct tr_object_texture_vert // 4 bytes
{
    ufixed16 Xcoordinate;
    ufixed16 Ycoordinate;
};
```

Actual texture coordinade format was unknown before the end of 2017, when *TE* developer MontyTRC uncovered that used format is similar to fixed-point format used for fractional values in animation structures, yet it uses 2 bytes instead of 4 (i. e. one byte for whole part and another for fractional part). However, since classic TR games built with native tools produced only whole coordinates (e.g. 64x64, 16x32, and so on) and there was no occurence of seeing fractional coordinates in levels, for many years it was believed that *low byte* in each field must always be of specific value (not 0 as expected, but either 1 or 255 which is probably caused by rounding error in Core's native conversion tools).

9.3.2. Object Texture Structure (TR1-3)

It's object texture structure itself. These, thee contents of `ObjectTextures[]`, are used for specifying texture mapping for the world geometry and for mesh objects.

```
struct tr_object_texture  // 20 bytes
{
    uint16_t Attribute;
    uint16_t TileAndFlag;
    tr_object_texture_vert Vertices[4]; // The four corners of the texture
};
```

`TileAndFlag` is a combined field:

- *Bits 0..14* specify *texture tile* to use.
- *Bit 15*: ❹ ❺ if set, it indicates that texture is used on a triangle face.

`Attribute` specifies transparency mode (i.e. *blending mode*) used for face with this texture applied. There are several ones available:

- **0** — Texture is *all-opaque*, and that transparency information is ignored.

- **1** — Texture uses *alpha testing*, i.e. it may contain opaque and completely transparent regions. In 8-bit colour, index 0 is the transparent colour, while in 16-bit colour, the top bit (0x8000) is the alpha channel (1 = opaque, 0 = transparent). In 32-bit textures, transparency is specified by *full magenta colour value* (RGB = 255,0,255) — i.e. pixel has to be magenta to be transparent.
- **2** — ③④⑤ Texture uses *alpha blending* with *additive operation*. No depth sorting is done on alpha-blended textures.

While blending modes 0, 1 and 2 were the only ones directly available for implementation in original level and animation editors, and therefore, only ones which can be encountered in object textures, there are actually several *internal blending modes*, which were primarily used for different sprite and particle types. These will be listed below:

- **3** — Not implemented properly in PC version, but on PlayStation this type produces alpha blending with *inversion operation*, thus converting all the bright zones to dark, and dark zones to bright. This blending mode was used for smooth textured shadows, footprints and black smoke sprites. There is a remnant of this blending mode in the form of entity type named *smoke emitter black*.
- **4** — Alpha-tested face *without Z testing*, i.e. depth information is ignored. Used for GUI elements (such as fonts) and skyboxes.
- **5** — Unused. Possibly was used in PlayStation versions.
- **6** — Wireframe mode. Used for "line particles", such as gun sparks, water drops and laser beams. Possibly was also used for debug purposes.
- **7** — ④⑤ Forced alpha value. It's ordinary alpha-tested face, but alpha value for this face is overridden with global variable. Used to "fade out" specific meshes, like vanishing enemy bodies or Semerkhet ghost in "Tomb of Semerkhet" level.

9.3.3. Object Texture Structure (TR4-5)

The structure introduced many new fields in TR4, partly related to new *bump mapping feature*.

For *bump mapping*, TR4 used fairly simple approach, which was actually not a true bump mapping, but multitexturing with additive operation. Therefore, bump maps were not *normal maps* mainly used for bump-mapping nowadays, but simple monochrome *heightmaps* automatically generated by level editor. This is a test screenshot comparison demonstrating same scene with and without bump mapping:

Bump mapping turned off

Bump mapping turned on

Assignation of bump maps happened inside level editor, where each texture piece could be marked as either *level 1* or *level 2* degree of bump map effect. When level was converted, all texture pieces with bumpmaps were placed into separate texture tiles after all other texture tiles, following by the same amount of texture tiles with auto-generated bump maps arranged in the same manner as original texture tiles. Number of bumped texture tiles was kept in separate variable as well (see TR4 Level Format section).

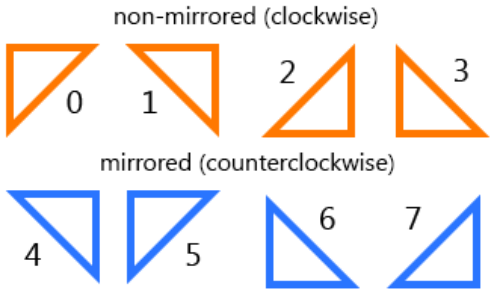
So, when engine rendered a face with texture marked as *bumped*, it rendered original texture at first, then it jumped to the texture tile *plus number of bumped texture tiles*, and rendered one more texture pass on this face using texture from resulting texture tile and the same UV coordinates.

```
struct tr4_object_texture // 38 bytes
{
    uint16_t Attribute;
    uint16_t TileAndFlag;
    uint16_t NewFlags;

    tr_object_texture_vert Vertices[4]; // The four corners of the texture

    uint32_t OriginalU;
```

```
    uint32_t OriginalV;
    uint32_t Width;      // Actually width-1
    uint32_t Height;     // Actually height-1
};
```

`NewFlags` is a bit field with flags:

- **Bit 15** — If set, the texture is for a triangle/quad from a room geometry. If not set, the texture is for a static mesh or model.
- **Bits 9..10** — Specifies bump mapping level (see above), so can be either `00 = 0` (no bump mapping), `01 = 1` (level 1) or `10 = 2` (level 2).
- **Bits 0..2** — Mapping correction. This value is used by internal `AdjustUV` function which crops the texture in specific way to prevent *border bleeding issue* happening because of texture atlas packing. Value meaning depends on texture face type (triangle or quad). For quads, only types `0` and `1` are actually used (`0` being normal and `1` being mirrored quad texture), while other types (2-7) produce same result as 0. For triangles, all possible values (0-7) are used for each possible right triangle type (including mirrored coordinates):



Triangle mapping correction types. Orange shapes indicate normal (non-mirrored) texture coordinates, while blue shapes indicate mirrored ones. Mirrored coordinates mean that they are placed in counterclockwise order.

`Width` and `Height` are helper values which specify width and height for a given object texture.

`OriginalU` and `OriginalV` are unused values, which seem to identify *original UV coordinates* of object texture in TRLE texture page listings. These coordinates are getting messed up when level is compiled, so one shouldn't bother about parsing them correctly.

❺ There is also null `uint16_t` filler in the end of each [tr4_object_texture].

9.4. Animated Textures

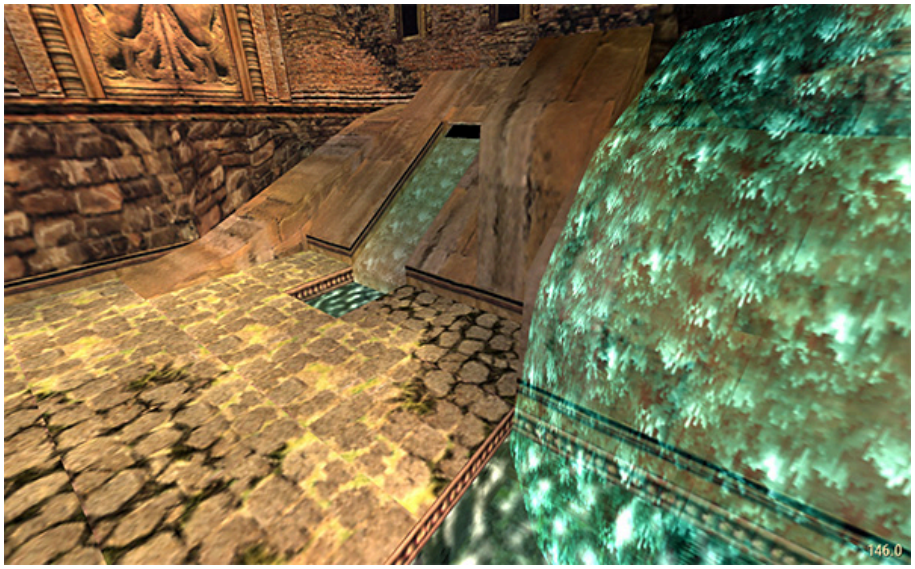
Animated textures describe sets of object textures that are cycled through to produce texture animations; they are a set of int16_t's with the following format (not a "real" C/C++ structure):

```
int16_t NumAnimatedTextures

virtual struct
{
    int16_t NumTextureIDs; // Actually, this is the number of texture ID's - 1.
    int16_t TextureIDs[NumTextureIDs + 1]; // offsets into ObjectTextures[], in
animation order.
} AnimatedTextures[NumAnimatedTextures];
```

If a texture belongs to an animated-texture group, it will automatically be animated by the engine.

There are two types of animated textures — *classic frames* and *UVRotate*:

- **Classic frames:** These are ordinary animated textures, and the only type displayed prior to TR4. It is simply a list of textures that are cycled through in an endless loop; they are normally used as geographic elements of the levels (e.g. water surface, bubbling lava, Atlantean flesh walls), but practically, Tomb Raider engines are capable of applying animated textures to mesh geometry (this feature is primarily used in custom levels). The speed (interval) of animation is hardcoded, and varies from version to version. While in TR1-2 textures were animated relatively slowly, in TR3 onwards they were sped up.
- **UV Rotate:** Beginning from TR4, there is a new scheme for animated textures, called *UVRotate*. According to its name, it continuously shifts vertical texture coordinate while preserving texture size, which creates an effect of moving texture. For example, you can see it in action in TR4's `angkor1.tr4`, room #76:



In foreground, you can see alpha-blended waterfall object animated with UVRotate.
In background, UVRotate animation is also applied to room mesh.

UVRotate mode is engaged by specifying `UVRotate` command in level script entry, which takes rotation speed as an argument, where speed is amount of pixel shift per each frame, considering fixed 30 FPS framerate (speed value may be negative, and in such cases pixel shift occurs in reverse direction). If such command is found (and argument is not zero — for example, `UVRotate = 4`), engine uses special variable value kept in level file, `NumUVRotates`, to determine if animation range belongs to UVRotate mode or classic frames mode. Then, if it belongs to UVRotate mode, each frame of this range is treated as individual rotating texture.

Note

There is also special case when UVRotate texture mode is engaged. When a texture is applied to a model with specific ID (so-called *waterfall objects*), then it is also considered UVRotate animated texture, even if it doesn't belong to animated texture range, *but only if it is a texture applied to a first face in the first mesh of the model*. If there are other textures applied to other faces of a waterfall object, they won't be considered as UVRotate.

The speed of animation for waterfall objects is not affected by `UVRotate` script command. Instead, it is hardcoded value of 7.

9.5. Cameras and Sinks

This data block serves for two different purposes, albeit keeping the same structure for both. First purpose is to provide positions to switch the camera to using *Camera* trigger action, and the second purpose is to *move Lara to specified position* when she is underwater, and *Underwater Current* trigger action was used.

```
struct tr_camera // 16 bytes
{
    int32_t x;
    int32_t y;
    int32_t z;
    int16_t Room;
   uint16_t Flag;
};
```

`X`, `Y` and `Z` values are coordinates of a given camera or sink. When used with camera, it is an origin point of a camera. When used with sink, it is a point, towards which Lara is pushed.

`Room` value specifies the room where camera is placed. For *sink* cases, this value is used to define *strength of the current* which moves Lara underwater.

`Flag` value *for cameras* specifies whether it's possible to breakout from fixed camera angle. If first bit of this field is set, camera becomes persistent, and it's not possible to bypass it with look or draw weapon buttons. For *sinks*, `Flag` value contains *Box index* — which is used as pathfinding reference when Lara is pushed towards sink via underwater current trigger action.

9.6. Flyby Cameras

④ ⑤ Flyby cameras are cinematic interludes, in which camera flies from one point to another using spline trajectory. Each point in such sequence is a *single flyby camera*, and current camera properties (position, direction, roll, FOV,

speed, and some more) are calculated by interpolating corresponding values from such flyby camera points — for example, if *camera 0* has speed value of 10, and *camera 1* has speed value of 5, then speed will gradually change from 10 to 5 when moving from one to another.

```
struct tr4_flyby_camera  // 40 bytes
{
    int32_t x;     // Camera position
    int32_t y;
    int32_t z;
    int32_t dx;    // Camera angles (so called "look at" vector)
    int32_t dy;
    int32_t dz;

    uint8_t Sequence;
    uint8_t Index;

   uint16_t FOV;
    int16_t Roll;
   uint16_t Timer;
   uint16_t Speed;
   uint16_t Flags;

   uint32_t Room_ID;
};
```

`Sequence` is a number of flyby camera "chain" this particular camera belongs to. Maximum amount of flyby sequences in single level is 8 (however, this limit was raised to 64 in *TREP*).

`Index` specifies order of the cameras in this particular sequence. Camera with `index` 0 will be first one in sequence, `index` 1 means camera will be second in sequence, and so on.

`Room_ID` should be valid for a given flyby camera, so it will display properly, as well as have the ability to activate *heavy triggers*.

`FOV` changes this particular camera's field of view. The value is 182 times higher than the value entered in the TRLE.

`Roll` changes roll factor of a particular camera. When this parameter is not zero, camera will rotate either left or right along roll axis, creating so-called "dutch angle". The value is 182 times higher than the value entered in the TRLE.

`Timer` field mainly used to stop camera movement for a given time (in game frames). As this parameter is temporal, it won't be interpolated between two cameras.

`Speed` specifies movement speed for this particular camera. The value is 655 times higher than the value entered in the TRLE.

`Flags` is an array of bit flags specifying different camera options:

- **Bit 0** — Make a cut to flyby from Lara camera position. Without it, it'll pan smoothly.
- **Bit 1** — ④ Tracks specified entity position (from `Entities[]` array). ⑤ Creates a vignette around the picture, giving impression of "subjective" camera.
- **Bit 2** — Infinitely loop sequence.
- **Bit 3** — *Used only with first camera in a sequence:* whole sequence is treated merely as a camera "rails", and camera itself focuses on Lara, thus creating "tracking" camera. Best example is "tracking" view in `ALEXHUB2.TR4`, rooms #23 and #31.
- **Bit 4** — ④ Camera focuses on Lara's last head position. ⑤ For TR5, this flag is now used to hide Lara for this camera.
- **Bit 5** — Camera continuously focuses on Lara's head, overriding own angle.
- **Bit 6** — *Used only with last camera in a sequence:* camera smoothly pans back to Lara camera position.
- **Bit 7** — When flyby arrives to this position, cuts to specific camera in same sequence. Next camera number is specified in *Timer* field of this camera.
- **Bit 8** — Stops camera movement for a given time (see *Timer* field).
- **Bit 9** — Disables look keypress breakout.
- **Bit 10** — Disables all Lara controls *for all next camera points*. Also engages *widescreen bars* to create cinematic feel.
- **Bit 11** — Overrides *Bit 10* controls lock, enabling them back. Widescreen bars remain unaffected.
- **Bit 12** — ⑤ Make screen fade-in.
- **Bit 13** — ⑤ Make screen fade-out.
- **Bit 14** — Camera can activate *heavy triggers*, just like particular kinds of entities (boulders, pushables, etc.). When camera is moving right above heavy trigger sector, it will be activated.

- **Bit 15** — ❺ TRLE for TR5 says this flag is used to make camera one-shot, but it's not true. Actual one-shot flag is placed in extra `uint16_t` field at `0x0100` for flyby camera *TrigAction*.

9.7. Cinematic Frames

These are camera positionings and properties for cutscene frames. All the entity animations are specified separately, and they are not synced with actual camera positions.

❶ For each cutscene, game applies certain hardcoded set of parameters:

```
switch (CutLevelID) {
    case 0: // CUT1.PHD
        levelPosX = 36668;  // X pivot position
        levelPosZ = 63180;  // Z pivot position
        levelRotY = -23312; // Y rotation
        trackID = 23;   // Audio track index
        break;
    case 1: // CUT2.PHD
        levelPosX = 51962;
        levelPosZ = 53760;
        levelRotY = 16380;
        trackID = 25;
        break;
    case 2: // CUT3.PHD
        levelRotY = 0x4000; // Default rotation, 90 degrees
        FlipMap();      // Do a flipmap
        trackID = 24;
        break;
    case 3: // CUT4.PHD
        levelRotY = 0x4000;
        trackID = 22;
        break;
}
```

`levelPosX`, `levelPosZ` and `levelRotY` parameters are used, if defined, to set-up *initial camera pivot position and Y axis rotation*. If some of these parameters are not defined (which is the case for CUT3.PHD and CUT4.PHD), they are borrowed from X and Z position and Y rotation of entity with ID #77 (slot used for main cutscene actor, usually Lara). Also, same parameters are used as *master model matrix* (i. e. multiplied by them instead of using their own position and rotation) for models with IDs #77-79 (which are slots for cutscene actors).

```
struct tr_cinematic_frame // 16 bytes
{
    int16_t targetX; // Camera look at position about X axis,
    int16_t targetY; // Camera look at position about Y axis
    int16_t target2; // Camera look at position about Z axis
    int16_t posZ;    // Camera position about Z axis
    int16_t posY;    // Camera position relative to something (see posZ)
    int16_t posX;    // Camera position relative to something (see posZ)
    int16_t fov;
    int16_t roll;    // Rotation about X axis
};
```

All `target` and `pos` parameters, as well as `roll` parameter, are encoded in the same manner as `Angle` parameter for tr_entity structure.

9.8. LightMap

A 32*256 array of `uint8_t` which is apparently for applying light to 8-bit colour, in some documentation called `ColourMap`. The current palette index and lighting value are used to calcuate an index to this table, which is a table of palette indices.

The Tomb Raider series' software rendering, like that of most real-time-3D games, uses 8-bit colour for speed and low bulk; however, there is the serious problem of how to do lighting with 8-bit colour, because doing it directly is computationally expensive. The usual solution is to arrange the palettes' colours in ramps, which the engine then follows in the appropriate directions. However, the TR series' palettes generally lack such neat ramps.

But the TR series has a more general solution, one that does not require palettes to have colour ramps. It uses precalculated lighting tables, the `ColourMap` objects. These contain translations of a colour value and a lighting value, listed by palette index. The translation goes as follows:

```
n = ColourMap[256 * k + i];
```

where `i` is the original palette index, `k` is determined from the lighting value, and `n` is the new palette index. The lighting index `k` varies from 0 to 31, and the corresponding lighting value is, for TR1,

```
2 - k / 16
```

and for TR2 and TR3,

```
2 - (k + 1) / 16
```

This may be associated with the curious fact of the lighting values in the data files increasing in the "wrong" direction in TR1 and TR2, with 0 being full brightness and greater values being darker.

9.9. Flipeffects

9.9.1. The Concept

As it was briefly mentioned earlier, *flipeffect* is a special pre-compiled routine which is called when some non-trivial event occurs.

The concept of flipeffect is somewhat similar to *task*, i.e. when some flipeffect is engaged, it could be flagged by engine to call *every game frame* (however, there are primarily one-shot flipeffects present). Such setup is needed for some complex flipeffect events, like flickering lights in TR1 Atlantis (see `FLICKER_FX` description), which stops automatically after some time.

If flipeffect is flagged to execute every game frame, this flag can only be unset by own current flipeffect code (when its task is done — for this purpose, special internal *flip timer* is used to count how much time have passed since flipeffect activation) or replaced by any other flipeffect call (however, newly called flipeffect doesn't necessarily overwrite current flipeffect flag, so you can have one-shot flipeffect executed with another one queued for continuous execution). Ergo, *it's not possible to queue more than one _continuous* flipeffect at a time, but it's possible to have one *one-shot* and another *continuous* flipeffect executed every game frame.

Continuous flipeffects are mostly present in TR1 and TR2. In TR3, only two "legacy" continuous flipeffects remained, and in TR4 and TR5 there are no continuous flipeffects at all. However, there's still legacy code that checks if there's any continuous flipeffect queued.

9.9.2. Complete Flipeffect List

In this chapter, we'll try to describe each flipeffect for every TR engine version. Given the fact that flipeffect listing changed from version to version, yet retaining common ones, the easiest way to lay them down is to create a table with flipeffect indexes corresponding to each game version.

There are some guidelines to flipeffect table:

- It's possible that same flipeffect goes under different names in different game versions. In this case, legacy flipeffect name will be preserved (for historical *[sic]* reasons), and description will point to a flipeffect with more recent name. Legacy flipeffect names would be colored in green.
- Flipeffect names are directly brought from native SDK or debug listings, where available (namely TR1, TR2, and TR4). When native names are wrong (which happens in TR4 and TR5 listings), new ones will be coined. New flipeffect names would be colored in purple.
- It's possible that legacy flipeffect code could migrate to later engine version without changes, but could be broken due to missing code in another part of engine or changes in internal structures. In this case, flipeffect name would be colored in red.
- If there's an entry in engine's flipeffect list, but no actual code for it, it would be marked as (-).
- If actual flipeffect's purpose is unknown, it would be marked as (?).
- If flipeffect ought to be *continuous*, it will be marked in **bold**.

As mentioned here, flipeffect could be called in two ways — either by an entity via *AnimCommand*, or by *trigger action*. However, there are certain flipeffect which strictly require caller entity ID to work with (see effect descriptions for that). In such case, if flipeffect is called by trigger action, *resulting outcome is undefined* in original engine. The most sane way to deal with this situation is to pass an ID of entity which activated given trigger.

On contrary, some flipeffects may require *certain trigger action* and/or *certain trigger type* to be called at the moment. In such case, if flipeffect is called via AnimCommand, *resulting outcome is undefined* in original engine.

Index	TR1	TR2	TR3	TR4	TR5
0	TURN180	TURN180	TURN180	ROTATE_180	ROTATE_180

Index	TR1	TR2	TR3	TR4	TR5
1	DINO_STOMP	FLOOR_SHAKE	FLOOR_SHAKE	FLOOR_SHAKE	FLOOR_SHAKE
2	LARA_NORMAL	LARA_NORMAL	LARA_NORMAL	FLOOD_FX	FLOOD_FX
3	LARA_BUBBLES	LARA_BUBBLES	LARA_BUBBLES	LARA_BUBBLES	LARA_BUBBLES
4	FINISH_LEVEL	FINISH_LEVEL	FINISH_LEVEL	FINISH_LEVEL	FINISH_LEVEL
5	**EARTHQUAKE_FX**	**FLOOD_FX**	**FLOOD_FX**	ACTIVATE_CAMERA	ACTIVATE_CAMERA
6	**FLOOD_FX**	**CHANDELIER_FX**	**CHANDELIER_FX**	ACTIVATE_KEY	ACTIVATE_KEY
7	RAISINGBLOCK_FX	RUBBLE_FX	RUBBLE_FX	RUBBLE_FX	RUBBLE_FX
8	**STAIRS2SLOPE_FX**	PISTON_FX	PISTON_FX	SWAP_CROWBAR	SWAP_CROWBAR
9	**SAND_FX**	CURTAIN_FX	CURTAIN_FX	-	-
10	**POWERUP_FX**	SETCHANGE_FX	SETCHANGE_FX	TIMER_FIELD_FX	TIMER_FIELD_FX
11	EXPLOSION_FX	EXPLOSION_FX	EXPLOSION_FX	EXPLOSION_FX	EXPLOSION_FX
12	LARA_HANDSFREE	LARA_HANDSFREE	LARA_HANDSFREE	LARA_HANDSFREE	LARA_HANDSFREE
13	FLIP_MAP	FLIP_MAP	FLIP_MAP	-	-
14	DRAW_RIGHTGUN	DRAW_RIGHTGUN	DRAW_RIGHTGUN	DRAW_RIGHTGUN	-
15	**CHAINBLOCK_FX**	DRAW_LEFTGUN	DRAW_LEFTGUN	DRAW_LEFTGUN	-
16	**FLICKER_FX**	-	SHOOT_RIGHTGUN	SHOOT_RIGHTGUN	SHOOT_RIGHTGUN
17		-	SHOOT_LEFTGUN	SHOOT_LEFTGUN	SHOOT_LEFTGUN
18		MESH_SWAP1	MESH_SWAP1	MESH_SWAP1	-
19		MESH_SWAP2	MESH_SWAP2	MESH_SWAP2	-
20		MESH_SWAP3	MESH_SWAP3	MESH_SWAP3	-
21		INV_ON	INV_ON	INV_ON	INV_ON
22		INV_OFF	INV_OFF	INV_OFF	INV_OFF
23		DYN_ON	DYN_ON	-	-
24		DYN_OFF	DYN_OFF	-	-
25		STATUE_FX	STATUE_FX	-	-
26		RESET_HAIR	RESET_HAIR	RESET_HAIR	RESET_HAIR
27		BOILER_FX	BOILER_FX	-	-
28		ASSAULT_RESET	ASSAULT_RESET	SETFOG	SETFOG
29		ASSAULT_STOP	ASSAULT_STOP	GHOSTTRAP	-
30		ASSAULT_START	ASSAULT_START	LARALOCATION	LARALOCATION
31		ASSAULT_FINISHED	ASSAULT_FINISHED	CLEARSCARABS	RESET_TEST (?)
32			FOOTPRINT_FX	FOOTPRINT_FX	FOOTPRINT_FX
33			ASSAULT_PENALTY_8	-	CLEAR_SPIDERS_PATCH (?)
34			RACETRACK_START	-	-
35			RACETRACK_RESET	-	-
36			RACETRACK_FINISHED	-	-
37			ASSAULT_PENALTY_30	-	-

Index	TR1	TR2	TR3	TR4	TR5
38			GYM_HINT_1	-	-
39			GYM_HINT_2	-	-
40			GYM_HINT_3	-	-
41			GYM_HINT_4	-	-
42			GYM_HINT_5	-	-
43			GYM_HINT_6	POURSWAP_ON	-
44			GYM_HINT_7	POURSWAP_OFF	-
45			GYM_HINT_8	LARALOCATIONPAD	LARALOCATIONPAD
46			GYM_HINT_9	KILLACTIVEBADDIES	KILLACTIVEBADDIES
47			GYM_HINT_10		TUT_HINT_1
48			GYM_HINT_11		TUT_HINT_2
49			GYM_HINT_12		TUT_HINT_3
50			GYM_HINT_13		TUT_HINT_4
51			GYM_HINT_14		TUT_HINT_5
52			GYM_HINT_15		TUT_HINT_6
53			GYM_HINT_16		TUT_HINT_7
54			GYM_HINT_17		TUT_HINT_8
55			GYM_HINT_18		TUT_HINT_9
56			GYM_HINT_19		TUT_HINT_10
57			GYM_HINT_RESET		TUT_HINT_11
58					TUT_HINT_12

In original engines, all flipeffects which name begins with `LARA_` prefix automatically take Lara character as an entity to work with. Also, most flipeffects with `_FX` postfix are simple sound effect events.

- `ROTATE_180` — Rotates an entity 180 degrees around yaw axis *and also around pitch axis for underwater cases*. Mostly used in Lara roll animations. This flipeffect needs special approach if original animation frames are interpolated, because usually rotation is done on animation transition (e.g., frame 5 of Lara animation 48, which is second and final part of her roll movement). To prevent stray misaligned interpolated frames, this flipeffect must be performed only in the end of frame-to-frame interpolated sequence.
- `TURN180` — Same as `ROTATE_180`.
- `LARA_NORMAL` — Resets certain internal Lara parameters to default ones, including movement modes, FOV and camera position.
- `FLOOR_SHAKE` — If entity producing this effect is in less than 8 sector range, send *shake effect* to camera. Shake effect is a variable which is inversely proportional to entity distance, and, when sent to camera, makes it shake with corresponding amplitude gradually fading out. If there are multiple FLOOR_SHAKE events constantly occuring nearby camera, *shake effect* won't accumulate, but rather overwrite previous value.
- `DINO_STOMP` — Same as `FLOOR_SHAKE`.
- `LARA_BUBBLES` — When underwater, emit bubble sound (ID #37) and produce bubble particle for Lara. Position of bubble is linked to model's last mesh (which is headmesh in case of Lara).
- `FINISH_LEVEL` — Same effect as *TrigAction* `0x07` — immediately loads next level. For TR4, (which requires explicit level index to jump), current level index is increased and passed as level index to jump to.
- `FLIP_MAP` — Equal to TrigAction `0x03`.
- `ACTIVATE_CAMERA` — If there is a trigger type *Key* (SubFunction `0x03`) being queued at the moment, and there are any *Camera* TrigActions (`0x01`) present in `ActionList`, these TrigActions will be forced to activate at a given

frame of *keyhole entity* current animation, rather than at the ending frame of it. Works only for *keyhole entities* which have complex activation animations, not single-frame ones. It can be used to change camera POV before keyhole animation is finished.

- `ACTIVATE_KEY` — Same as above, but works for *Object* TrigAction. That is, any entities to be activated from `ActionList` will be activated at a given frame of *keyhole entity* current animation, rather than at the ending frame of it. Can be used to activate entities before actual keyhole animation is finished.
- `LARA_HANDSFREE` — Functionally removes any weapon from Lara's hands. If called during holstering or unholstering operation, immediately aborts it. Note that holstering animation won't be automatically performed, and weapon model meshswaps won't be swapped back to normal hands.
- `DRAW_RIGHTGUN` — Swaps given entity's mesh #10 index with same mesh's index from *PISTOLS_ANIM* model (model ID #1 in all TR versions). Calling this effect again swaps mesh #10 back to native. Used primarily in cutscenes to create an illusion of Lara getting pistol in her right hand.
- `DRAW_LEFTGUN` — Swaps given entity's mesh #13 index with same mesh's index from *PISTOLS_ANIM* model (model ID #1 in all TR versions). Calling this effect again swaps mesh #13 back to native. Used primarily in cutscenes to create an illusion of Lara getting pistol in her left hand.
- `SHOOT_RIGHTGUN` — Activates given entity's muzzle flash effect and dynamic light near mesh #10. Muzzle flash position and orientation, as well as effect duration and intensity is hardcoded. Used primarily in cutscenes.
- `SHOOT_LEFTGUN` — Activates given entity's muzzle flash effect and dynamic light near mesh #13. Muzzle flash position and orientation, as well as effect duration and intensity is hardcoded. Used primarily in cutscenes.
- `MESH_SWAP1` — Swaps all given entity meshes with *MESH_SWAP1* model meshes (model ID varies across TR versions). Each mesh is swapped only if source meshswap model mesh is not null, otherwise swap is ignored for a given mesh. Calling this flipeffect again swaps all meshes back to native. Used primarily in cutscenes.
- `MESH_SWAP2` — Swaps all given entity meshes with *MESH_SWAP2* model meshes (model ID varies across TR versions). Each mesh is swapped only if source meshswap model mesh is not null, otherwise swap is ignored for a given mesh. Calling this flipeffect again swaps all meshes back to native. Used primarily in cutscenes.
- `MESH_SWAP3` — Swaps all given entity meshes with *MESH_SWAP3* model meshes (model ID varies across TR versions). Each mesh is swapped only if source meshswap model mesh is not null, otherwise swap is ignored for a given mesh. Calling this flipeffect again swaps all meshes back to native. Used primarily in cutscenes.
- `SWAP_CROWBAR` — Swaps given entity's mesh #10 index with same mesh's index from *CROWBAR_ANIM* model (either model ID #246 in TR4, or model ID #240 in TR5). Calling this flipeffect again swaps mesh #10 back to native. Used primarily in cutscenes to create an illusion of Lara getting crowbar in her hand.
- `POURSWAP_ON` — Swaps given entity's mesh #10 index with same mesh's index from *LARA_WATER_MESH* model (TR4, modei ID #25). Used in Lara's waterskin animations used in late TR4 levels with waterskin puzzle.
- `POURSWAP_OFF` — Swaps given entity's mesh #10 back to native. Used in Lara's waterskin animations used in late TR4 levels with waterskin puzzle.
- `INV_ON` — Hides given entity.
- `INV_OFF` — Shows given entity, if it was hidden.
- `DYN_ON` — Turns dynamic lights on for a given entity. Actual result is unclear.
- `DYN_OFF` — Turns dynamic lights off for a given entity. Actual result is unclear.
- `RESET_HAIR` — Presumably used to save Lara's ponytail from potential stuck during cutscenes by resetting all hair parameters to "identity".
- `SETFOG` — When called by trigger action, changes global colour for volumetric fog effect. Takes `TriggerSetup` *Timer* field as an index into hardcoded RGB table of colours (see this section for more info). If specified index is 100, engine temporarily turns off volumetric fog effect (possibly, this was used for debug purposes).
- `GHOSTTRAP` — Kills all the living *WRAITH3* entities (model ID #88 in TR4) this way: the wraith starts falling towards given entity. Reaching it or not, the wraith will die if it hits the floor of the room.
- `CLEARSCARABS` — Removes all swarms of scarabs currently wandering in level.
- `KILLACTIVEBADDIES` — Disable and remove all active NPCs from level.
- `CLEAR_SPIDERS_PATCH` — Present only in TR5. It seems it's same as `KILLACTIVEBADDIES`, but some other processing is done. Never used in actual levels.
- `RESET_TEST` — Present only in TR5. No visible or significant effect on gameplay. If there are any NPCs in level, then this flipeffect will fill certain memory zone with zero bytes. This flipeffect seems like last-minute fix-up for some memory leak bug. Used in RICH1.TRC level (The 13th Floor)
- `LARALOCATION` — When activated, makes *Guide* NPC (TR4, model ID #37) or *Von Croy* NPC (TR4, model ID #39) to move to specific AI_FOLLOW object. Takes `TriggerSetup` *Timer* field as an index to search for such OCB within AI objects array. When AI_FOLLOW AI object with same OCB index is found, NPC is then directed to this AI_FOLLOW object. This flipeffect also stores this index in additional global variable which is used to prevent NPC to get back to AI_FOLLOW objects with lower OCB indexes that were already passed — for example, if NPC already passed AI_FOLLOW with OCB 2, he won't return to AI_FOLLOW with OCB 1, even if he hasn't been there before.
- `LARALOCATIONPAD` — Same action as `LARALOCATION`, but with one difference - *Timer* field is checked for certain values to engage either specific soundtrack and/or cinematic dialogue with *Von Croy* NPC (for demonstration, look

for Angkor Wat level walkthrough). This additional behaviour is hardcoded for TR4's first level index only.

- `ASSAULT_RESET` — Resets assault course clock (for ex., when Lara stepped out of assault course).
- `ASSAULT_STOP` — Stops assault course clock.
- `ASSAULT_START` — Starts assault course clock.
- `ASSAULT_FINISHED` — Finishes assault course clock and fixes the record. Depending on record time, plays either unbeat record ("I'm sure you can do better", track ID #24 in TR2) soundtrack or best record ("Gosh, that was my best time yet", track ID #22 in TR2, #95 in TR3) soundtrack. Record time is hardcoded to 100 seconds in TR2 and to 180 seconds in TR3. In TR3, flipeffect also checks if all targets in shooting range were hit by Lara, and if not, applies penalty of 10 seconds for each unhit target. Also, TR3 lacks "unbeat record" soundtrack.
- `ASSAULT_PENALTY_8` — 8-second penalty for losing track on assault course.
- `ASSAULT_PENALTY_30` — 30-second penalty for losing track on assault course.
- `RACETRACK_START` — Prepare racetrack timer for counting lap time. *Only works when Lara is on a quadbike!* As soon as quadbike leaves sector with this flipeffect, timer will start counting.
- `RACETRACK_RESET` — Resets current lap time. *Only works when Lara is on a quadbike!*
- `RACETRACK_FINISHED` — Finishes racetrack timer and fixes the record. *Only works when Lara is on a quadbike!*
- `GYM_HINT_1-19` — Sequence of Lara's voice hints on how to complete gym training. Reason why these are activated via flipeffects rather than normal soundtrack is they must be engaged in predefined order, e.g. voice hint #8 can't play before #7 was played, and so on.
- `GYM_HINT_RESET` — Resets gym training progress, so all voice hints will be played once again.
- `TUT_HINT_1-12` — Sequence of Lara's voice hints on how to complete tutorial on Streets of Rome (TR5). Setup is similar to `GYM_HINT` flipeffects, but seems that there's no reset flipeffect to restart tutorial.
- `RAISINGBLOCK_FX` — Plays *global* sound with ID 117. Used in TR1, Palace Midas.
- `CHAINBLOCK_FX` — Plays *global* sounds with ID 173 and ID 33 with predefined interval. Used in TR1, Tomb of Tihocan.
- `EARTHQUAKE_FX` — Shakes screen violently and plays sounds with ID 99 and 70 *globally* with predefined intervals. Used in TR1, Palace Midas.
- `STAIRS2SLOPE_FX` — Plays *global* sound with ID 119 with predefined delay. Used in TR1, City of Khamoon.
- `SAND_FX` — Plays *global* sounds with ID 161, 118 and 155 with predefined intervals. Used in TR1, City of Khamoon.
- `POWERUP_FX` — Plays *global* sound with ID 155 for 1 second. Presumably used in TR1, one of the Atlantis levels, but never appears on map.
- `FLICKER_FX` — Flips alternate rooms back and forth several times with predefined intervals, creating illusion of flickering light. Used in TR1, first room of Atlantis.
- `CHANDELIER_FX` — Plays *global* sound with ID 278 for 1 second. Used in TR2, Bartoli's Hideout.
- `BOILER_FX` — Plays *global* sound with ID 338. Used in TR2, Wreck of the Maria Doria.
- `PISTON_FX` — Plays *global* sound with ID 190. Used in TR2, Living Quarters.
- `CURTAIN_FX` — Plays *global* sound with ID 191. Used in TR2, Living Quarters.
- `SET_CHANGE_FX` — Plays *global* sound with ID 330. Used in TR2, Opera House and Temple of Xian.
- `STATUE_FX` — Plays *global* sound with ID 331. Used in TR2, Barkhang Monastery.
- `RUBBLE_FX` — Plays *global* rumble sound FX and holds camera shake effect for some time, then finishes it with "shutting" sound. ④ ⑤ If there are any *earthquake type* objects in a level, engine engages same behaviour *locally* for these objects.
- `TIMER_FIELD_FX` — If this flipeffect is called by trigger action, play *global* sound FX, taking `TriggerSetup` *Timer* field as a sound ID.
- `EXPLOSION_FX` — Plays *global* explosion sound (ID #105) and produce full-screen flash graphical FX (TR3-5) or camera shake effect (TR1-2).
- `FLOOD_FX` — Plays *global* flooding sound (TR1 — ID #81, TR2 — ID #79, TR3 — ID #163, TR4 — ID #238). Implementation differs from version to version — in TR1 and TR2 looped waterfall sound is used (which is then stopped by an engine after 1 second), while in TR3 and TR4 one-shot sound is engaged.
- `FOOTPRINT_FX` — Plays random footprint sound effect, taking current block's **material index** into consideration. On PlayStation, also applies footprint sprite under left or right Lara foot (target foot is selected based on packed flag which is stored in animcommand argument — look here for details).

10. Entire level File Formats

10.1. TR1 Level Format

What follows is the physical `.PHD` file layout, byte for byte.


Caution

This is not a "real" C/C++ structure, in that some arrays are variable-length, with the length being defined by another element of the structure.

```
uint32_t Version; // version (4 bytes)
uint32_t NumTextiles; // number of texture tiles (4 bytes)
tr_textile8 Textile8[NumTextiles]; // 8-bit (palettized) textiles (NumTextiles * 65536
bytes)
uint32_t Unused; // 32-bit unused value (4 bytes)
uint16_t NumRooms; // number of rooms (2 bytes)
tr_room Rooms[NumRooms]; // room list (variable length)
uint32_t NumFloorData; // number of floor data uint16_t's to follow (4 bytes)
uint16_t FloorData[NumFloorData]; // floor data (NumFloorData * 2 bytes)
uint32_t NumMeshData; // number of uint16_t's of mesh data to follow (=Meshes[]) (4
bytes)
tr_mesh Meshes[NumMeshPointers]; // note that NumMeshPointers comes AFTER Meshes[]
uint32_t NumMeshPointers; // number of mesh pointers to follow (4 bytes)
uint32_t MeshPointers[NumMeshPointers]; // mesh pointer list (NumMeshPointers * 4
bytes)
uint32_t NumAnimations; // number of animations to follow (4 bytes)
tr_animation Animations[NumAnimations]; // animation list (NumAnimations * 32 bytes)
uint32_t NumStateChanges; // number of state changes to follow (4 bytes)
tr_state_change StateChanges[NumStateChanges]; // state-change list (NumStructures * 6
bytes)
uint32_t NumAnimDispatches; // number of animation dispatches to follow (4 bytes)
tr_anim_dispatch AnimDispatches[NumAnimDispatches]; // animation-dispatch list list
(NumAnimDispatches * 8 bytes)
uint32_t NumAnimCommands; // number of animation commands to follow (4 bytes)
tr_anim_command AnimCommands[NumAnimCommands]; // animation-command list
(NumAnimCommands * 2 bytes)
uint32_t NumMeshTrees; // number of MeshTrees to follow (4 bytes)
tr_meshtree_node MeshTrees[NumMeshTrees]; // MeshTree list (NumMeshTrees * 4 bytes)
uint32_t NumFrames; // number of words of frame data to follow (4 bytes)
uint16_t Frames[NumFrames]; // frame data (NumFrames * 2 bytes)
uint32_t NumModels; // number of models to follow (4 bytes)
tr_model Models[NumModels]; // model list (NumModels * 18 bytes)
uint32_t NumStaticMeshes; // number of StaticMesh data records to follow (4 bytes)
tr_staticmesh StaticMeshes[NumStaticMeshes]; // StaticMesh data (NumStaticMesh * 32
bytes)
uint32_t NumObjectTextures; // number of object textures to follow (4 bytes) (after
AnimatedTextures in TR3)
tr_object_texture ObjectTextures[NumObjectTextures]; // object texture list
(NumObjectTextures * 20 bytes) (after AnimatedTextures in TR3)
uint32_t NumSpriteTextures; // number of sprite textures to follow (4 bytes)
tr_sprite_texture SpriteTextures[NumSpriteTextures]; // sprite texture list
(NumSpriteTextures * 16 bytes)
uint32_t NumSpriteSequences; // number of sprite sequences records to follow (4 bytes)
tr_sprite_sequence SpriteSequences[NumSpriteSequences]; // sprite sequence data
(NumSpriteSequences * 8 bytes)
uint32_t NumCameras; // number of camera data records to follow (4 bytes)
tr_camera Cameras[NumCameras]; // camera data (NumCameras * 16 bytes)
uint32_t NumSoundSources; // number of sound source data records to follow (4 bytes)
tr_sound_source SoundSources[NumSoundSources]; // sound source data (NumSoundSources *
16 bytes)
uint32_t NumBoxes; // number of box data records to follow (4 bytes)
tr_box Boxes[NumBoxes]; // box data (NumBoxes * 20 bytes [TR1 version])
uint32_t NumOverlaps; // number of overlap records to follow (4 bytes)
uint16_t Overlaps[NumOverlaps]; // overlap data (NumOverlaps * 2 bytes)
uint16_t GroundZone[2*NumBoxes]; // ground zone data
uint16_t GroundZone2[2*NumBoxes]; // ground zone 2 data
uint16_t FlyZone[2*NumBoxes]; // fly zone data
uint16_t GroundZoneAlt[2*NumBoxes]; // ground zone data (alternate rooms?)
uint16_t GroundZoneAlt2[2*NumBoxes]; // ground zone 2 data (alternate rooms?)
uint16_t FlyZoneAlt[2*NumBoxes]; // fly zone data (alternate rooms?)
uint32_t NumAnimatedTextures; // number of animated texture records to follow (4
bytes)
uint16_t AnimatedTextures[NumAnimatedTextures]; // animated texture data
(NumAnimatedTextures * 2 bytes)
uint32_t NumEntities; // number of entities to follow (4 bytes)
tr_entity Entities[NumEntities]; // entity list (NumEntities * 22 bytes [TR1 version])
uint8_t LightMap[32 * 256]; // light map (8192 bytes)
tr_colour Palette[256]; // 8-bit palette (768 bytes)
uint16_t NumCinematicFrames; // number of cinematic frame records to follow (2 bytes)
```

```
tr_cinematic_frame CinematicFrames[NumCinematicFrames]; // (NumCinematicFrames * 16
bytes)
uint16_t NumDemoData; // number of demo data records to follow (2 bytes)
uint8_t DemoData[NumDemoData]; // demo data (NumDemoData bytes)
int16_t SoundMap[256]; // sound map (512 bytes)
uint32_t NumSoundDetails; // number of sound-detail records to follow (4 bytes)
tr_sound_details SoundDetails[NumSoundDetails]; // sound-detail list (NumSoundDetails
* 8 bytes)
uint32_t NumSamples; // number of uint8_t's in Samples (4 bytes)
uint8_t Samples[NumSamples]; // array of uint8_t's -- embedded sound samples in
Microsoft WAVE format (NumSamples bytes)
uint32_t NumSampleIndices; // number of sample indices to follow (4 bytes)
uint32_t SampleIndices[NumSampleIndices]; // sample indices (NumSampleIndices * 4
bytes)
```

10.2. TR2 Level Format

What follows is the physical `.TR2` file layout, byte for byte.

This is not a “real” C/C++ structure, in that some arrays are variable-length, with the length being defined by another element of the structure.

```
uint32_t Version; // version (4 bytes)
tr_colour Palette[256]; // 8-bit palette (768 bytes)
tr_colour4 Palette16[256]; //  (1024 bytes)
uint32_t NumTextiles; // number of texture tiles (4 bytes)
tr_textile8 Textile8[NumTextiles]; // 8-bit (palettized) textiles (NumTextiles * 65536
bytes)
tr_textile16 Textile16[NumTextiles]; // 16-bit (ARGB) textiles (NumTextiles * 131072
bytes)
uint32_t Unused; // 32-bit unused value (4 bytes)
uint16_t NumRooms; // number of rooms (2 bytes)
tr2_room Rooms[NumRooms]; // room list (variable length)
uint32_t NumFloorData; // number of floor data uint16_t's to follow (4 bytes)
uint16_t FloorData[NumFloorData]; // floor data (NumFloorData * 2 bytes)
uint32_t NumMeshData; // number of uint16_t's of mesh data to follow (=Meshes[]) (4
bytes)
tr_mesh Meshes[NumMeshPointers]; // note that NumMeshPointers comes AFTER Meshes[]
uint32_t NumMeshPointers; // number of mesh pointers to follow (4 bytes)
uint32_t MeshPointers[NumMeshPointers]; // mesh pointer list (NumMeshPointers * 4
bytes)
uint32_t NumAnimations; // number of animations to follow (4 bytes)
tr_animation Animations[NumAnimations]; // animation list (NumAnimations * 32 bytes)
uint32_t NumStateChanges; // number of state changes to follow (4 bytes)
tr_state_change StateChanges[NumStateChanges]; // state-change list (NumStructures * 6
bytes)
uint32_t NumAnimDispatches; // number of animation dispatches to follow (4 bytes)
tr_anim_dispatch AnimDispatches[NumAnimDispatches]; // animation-dispatch list list
(NumAnimDispatches * 8 bytes)
uint32_t NumAnimCommands; // number of animation commands to follow (4 bytes)
tr_anim_command AnimCommands[NumAnimCommands]; // animation-command list
(NumAnimCommands * 2 bytes)
uint32_t NumMeshTrees; // number of MeshTrees to follow (4 bytes)
tr_meshtree_node MeshTrees[NumMeshTrees]; // MeshTree list (NumMeshTrees * 4 bytes)
uint32_t NumFrames; // number of words of frame data to follow (4 bytes)
uint16_t Frames[NumFrames]; // frame data (NumFrames * 2 bytes)
uint32_t NumModels; // number of models to follow (4 bytes)
tr_model Models[NumModels]; // model list (NumModels * 18 bytes)
uint32_t NumStaticMeshes; // number of StaticMesh data records to follow (4 bytes)
tr_staticmesh StaticMeshes[NumStaticMeshes]; // StaticMesh data (NumStaticMesh * 32
bytes)
uint32_t NumObjectTextures; // number of object textures to follow (4 bytes)
tr_object_texture ObjectTextures[NumObjectTextures]; // object texture list
(NumObjectTextures * 20 bytes) (after AnimatedTextures in TR3)
uint32_t NumSpriteTextures; // number of sprite textures to follow (4 bytes)
tr_sprite_texture SpriteTextures[NumSpriteTextures]; // sprite texture list
(NumSpriteTextures * 16 bytes)
uint32_t NumSpriteSequences; // number of sprite sequences records to follow (4 bytes)
tr_sprite_sequence SpriteSequences[NumSpriteSequences]; // sprite sequence data
(NumSpriteSequences * 8 bytes)
uint32_t NumCameras; // number of camera data records to follow (4 bytes)
tr_camera Cameras[NumCameras]; // camera data (NumCameras * 16 bytes)
uint32_t NumSoundSources; // number of sound source data records to follow (4 bytes)
```

```
tr_sound_source SoundSources[NumSoundSources]; // sound source data (NumSoundSources *
16 bytes)
uint32_t NumBoxes; // number of box data records to follow (4 bytes)
tr2_box Boxes[NumBoxes]; // box data (NumBoxes * 8 bytes)
uint32_t NumOverlaps; // number of overlap records to follow (4 bytes)
uint16_t Overlaps[NumOverlaps]; // overlap data (NumOverlaps * 2 bytes)
int16_t Zones[10*NumBoxes]; // zone data (NumBoxes * 20 bytes)
uint32_t NumAnimatedTextures; // number of animated texture records to follow (4
bytes)
uint16_t AnimatedTextures[NumAnimatedTextures]; // animated texture data
(NumAnimatedTextures * 2 bytes)
uint32_t NumEntities; // number of entities to follow (4 bytes)
tr2_entity Entities[NumEntities]; // entity list (NumEntities * 24 bytes)
uint8_t LightMap[32 * 256]; // light map (8192 bytes)
uint16_t NumCinematicFrames; // number of cinematic frame records to follow (2 bytes)
tr_cinematic_frame CinematicFrames[NumCinematicFrames]; // (NumCinematicFrames * 16
bytes)
uint16_t NumDemoData; // number of demo data records to follow (2 bytes)
uint8_t DemoData[NumDemoData]; // demo data (NumDemoData bytes)
int16_t SoundMap[370]; // sound map (740 bytes)
uint32_t NumSoundDetails; // number of sound-detail records to follow (4 bytes)
tr_sound_details SoundDetails[NumSoundDetails]; // sound-detail list (NumSoundDetails
* 8 bytes)
uint32_t NumSampleIndices; // number of sample indices to follow (4 bytes)
uint32_t SampleIndices[NumSampleIndices]; // sample indices (NumSampleIndices * 4
bytes)
```

10.3. TR3 Level Format

What follows is the physical Tomb Raider III `.TR2` file layout, byte for byte.


Caution

This is not a “real” C/C++ structure, in that some arrays are variable-length, with the length being defined by another element of the structure.

```
uint32_t Version; // version (4 bytes)
tr_colour Palette[256]; // 8-bit palette (768 bytes)
tr_colour4 Palette16[256]; //  (1024 bytes)
uint32_t NumTextiles; // number of texture tiles (4 bytes)
tr_textile8 Textile8[NumTextiles]; // 8-bit (palettized) textiles (NumTextiles * 65536
bytes)
tr_textile16 Textile16[NumTextiles]; // 16-bit (ARGB) textiles (NumTextiles * 131072
bytes) (absent from TR1)
uint32_t Unused; // 32-bit unused value (4 bytes)
uint16_t NumRooms; // number of rooms (2 bytes)
tr3_room Rooms[NumRooms]; // room list (variable length)
uint32_t NumFloorData; // number of floor data uint16_t's to follow (4 bytes)
uint16_t FloorData[NumFloorData]; // floor data (NumFloorData * 2 bytes)
uint32_t NumMeshData; // number of uint16_t's of mesh data to follow (=Meshes[]) (4
bytes)
tr_mesh Meshes[NumMeshPointers]; // note that NumMeshPointers comes AFTER Meshes[]
uint32_t NumMeshPointers; // number of mesh pointers to follow (4 bytes)
uint32_t MeshPointers[NumMeshPointers]; // mesh pointer list (NumMeshPointers * 4
bytes)
uint32_t NumAnimations; // number of animations to follow (4 bytes)
tr_animation Animations[NumAnimations]; // animation list (NumAnimations * 32 bytes)
uint32_t NumStateChanges; // number of state changes to follow (4 bytes)
tr_state_change StateChanges[NumStateChanges]; // state-change list (NumStructures * 6
bytes)
uint32_t NumAnimDispatches; // number of animation dispatches to follow (4 bytes)
tr_anim_dispatch AnimDispatches[NumAnimDispatches]; // animation-dispatch list list
(NumAnimDispatches * 8 bytes)
uint32_t NumAnimCommands; // number of animation commands to follow (4 bytes)
tr_anim_command AnimCommands[NumAnimCommands]; // animation-command list
(NumAnimCommands * 2 bytes)
uint32_t NumMeshTrees; // number of MeshTrees to follow (4 bytes)
tr_meshtree_node MeshTrees[NumMeshTrees]; // MeshTree list (NumMeshTrees * 4 bytes)
uint32_t NumFrames; // number of words of frame data to follow (4 bytes)
uint16_t Frames[NumFrames]; // frame data (NumFrames * 2 bytes)
uint32_t NumModels; // number of models to follow (4 bytes)
tr_model Models[NumModels]; // model list (NumModels * 18 bytes)
uint32_t NumStaticMeshes; // number of StaticMesh data records to follow (4 bytes)
tr_staticmesh StaticMeshes[NumStaticMeshes]; // StaticMesh data (NumStaticMesh * 32
bytes)
```

```
uint32_t NumSpriteTextures; // number of sprite textures to follow (4 bytes)
tr_sprite_texture SpriteTextures[NumSpriteTextures]; // sprite texture list
(NumSpriteTextures * 16 bytes)
uint32_t NumSpriteSequences; // number of sprite sequences records to follow (4 bytes)
tr_sprite_sequence SpriteSequences[NumSpriteSequences]; // sprite sequence data
(NumSpriteSequences * 8 bytes)
uint32_t NumCameras; // number of camera data records to follow (4 bytes)
tr_camera Cameras[NumCameras]; // camera data (NumCameras * 16 bytes)
uint32_t NumSoundSources; // number of sound source data records to follow (4 bytes)
tr_sound_source SoundSources[NumSoundSources]; // sound source data (NumSoundSources *
16 bytes)
uint32_t NumBoxes; // number of box data records to follow (4 bytes)
tr2_box Boxes[NumBoxes]; // box data (NumBoxes * 8 bytes)
uint32_t NumOverlaps; // number of overlap records to follow (4 bytes)
uint16_t Overlaps[NumOverlaps]; // overlap data (NumOverlaps * 2 bytes)
int16_t Zones[10*NumBoxes]; // zone data (NumBoxes * 20 bytes)
uint32_t NumAnimatedTextures; // number of animated texture records to follow (4
bytes)
uint16_t AnimatedTextures[NumAnimatedTextures]; // animated texture data
(NumAnimatedTextures * 2 bytes)
uint32_t NumObjectTextures; // number of object textures to follow (4 bytes) (after
AnimatedTextures in TR3)
tr_object_texture ObjectTextures[NumObjectTextures]; // object texture list
(NumObjectTextures * 20 bytes)
uint32_t NumEntities; // number of entities to follow (4 bytes)
tr2_entity Entities[NumEntities]; // entity list (NumEntities * 24 bytes)
uint8_t LightMap[32 * 256]; // light map (8192 bytes)
uint16_t NumCinematicFrames; // number of cinematic frame records to follow (2 bytes)
tr_cinematic_frame CinematicFrames[NumCinematicFrames]; // (NumCinematicFrames * 16
bytes)
uint16_t NumDemoData; // number of demo data records to follow (2 bytes)
uint8_t DemoData[NumDemoData]; // demo data (NumDemoData bytes)
int16_t SoundMap[370]; // sound map (740 bytes)
uint32_t NumSoundDetails; // number of sound-detail records to follow (4 bytes)
tr3_sound_details SoundDetails[NumSoundDetails]; // sound-detail list (NumSoundDetails
* 8 bytes)
uint32_t NumSampleIndices; // number of sample indices to follow (4 bytes)  +
uint32_t SampleIndices[NumSampleIndices]; // sample indices (NumSampleIndices * 4
bytes)
```

10.4. TR4 Level Format

What follows is the physical Tomb Raider IV `.TR4` file layout, byte for byte.

This is not a “real” C/C++ structure, in that some arrays are variable-length, with the length being defined by another element of the structure.

```
uint32_t Version; // version (4 bytes)
uint16_t NumRoomTextiles; // number of non bumped room tiles (2 bytes)
uint16_t NumObjTextiles; // number of object tiles (2 bytes)
uint16_t NumBumpTextiles; // number of bumped room tiles (2 bytes)
uint32_t Textile32_UncompSize; // uncompressed size (in bytes) of the 32-bit textures
chunk (4 bytes)
uint32_t Textile32_CompSize; // compressed size (in bytes) of the 32-bit textures
chunk (4 bytes)
uint8_t Textile32_Compressed[Textile32_CompSize]; // zlib-compressed 32-bit textures
chunk (Textile32_CompSize bytes)
{
    tr4_textile32 Textile32[NumRoomTextiles + NumObjTextiles + NumBumpTextiles];
}
uint32_t Textile16_UncompSize; // uncompressed size (in bytes) of the 16-bit textures
chunk (4 bytes)
uint32_t Textile16_CompSize; // compressed size (in bytes) of the 16-bit textures
chunk (4 bytes)
uint8_t Textile16_Compressed[Textile32_CompSize]; // zlib-compressed 16-bit textures
chunk (Textile16_CompSize bytes)
{
    tr_textile16 Textile16[NumRoomTextiles + NumObjTextiles + NumBumpTextiles];
}
uint32_t Textile32Misc_UncompSize; // uncompressed size (in bytes) of the 32-bit misc
textures chunk (4 bytes), should always be 524288
uint32_t Textile32Misc_CompSize; // compressed size (in bytes) of the 32-bit misc
textures chunk (4 bytes)
```

```
uint8_t Textile32Misc_Compressed[Textile32Misc_CompSize]; // zlib-compressed 32-bit
misc textures chunk (Textile32Misc_CompSize bytes)
{
    tr4_textile32 Textile32Misc[2];
}
uint32_t LevelData_UncompSize; // uncompressed size (in bytes) of the level data chunk
(4 bytes)
uint32_t LevelData_CompSize; // compressed size (in bytes) of the level data chunk (4
bytes)
uint8_t LevelData_Compressed[LevelData_CompSize]; // zlib-compressed level data chunk
(LevelData_CompSize bytes)
{
    uint32_t Unused; // 32-bit unused value, always 0 (4 bytes)
    uint16_t NumRooms; // number of rooms (2 bytes)
    tr4_room Rooms[NumRooms]; // room list (variable length)
    uint32_t NumFloorData; // number of floor data uint16_t's to follow (4 bytes)
    uint16_t FloorData[NumFloorData]; // floor data (NumFloorData * 2 bytes)
    uint32_t NumMeshData; // number of uint16_t's of mesh data to follow (=Meshes[])
(4 bytes)
    tr4_mesh Meshes[NumMeshPointers]; // note that NumMeshPointers comes AFTER
Meshes[]
    uint32_t NumMeshPointers; // number of mesh pointers to follow (4 bytes)
    uint32_t MeshPointers[NumMeshPointers]; // mesh pointer list (NumMeshPointers * 4
bytes)
    uint32_t NumAnimations; // number of animations to follow (4 bytes)
    tr4_animation Animations[NumAnimations]; // animation list (NumAnimations * 40
bytes)
    uint32_t NumStateChanges; // number of state changes to follow (4 bytes)
    tr_state_change StateChanges[NumStateChanges]; // state-change list (NumStructures
* 6 bytes)
    uint32_t NumAnimDispatches; // number of animation dispatches to follow (4 bytes)
    tr_anim_dispatch AnimDispatches[NumAnimDispatches]; // animation-dispatch list
list (NumAnimDispatches * 8 bytes)
    uint32_t NumAnimCommands; // number of animation commands to follow (4 bytes)
    tr_anim_command AnimCommands[NumAnimCommands]; // animation-command list
(NumAnimCommands * 2 bytes)
    uint32_t NumMeshTrees; // number of MeshTrees to follow (4 bytes)
    tr_meshtree_node MeshTrees[NumMeshTrees]; // MeshTree list (NumMeshTrees * 4
bytes)
    uint32_t NumFrames; // number of words of frame data to follow (4 bytes)
    uint16_t Frames[NumFrames]; // frame data (NumFrames * 2 bytes)
    uint32_t NumModels; // number of models to follow (4 bytes)
    tr_model Models[NumModels]; // model list (NumModels * 18 bytes)
    uint32_t NumStaticMeshes; // number of StaticMesh data records to follow (4 bytes)
    tr_staticmesh StaticMeshes[NumStaticMeshes]; // StaticMesh data (NumStaticMesh *
32 bytes)
    uint8_t SPR[3]; // S P R (0x53, 0x50, 0x52)
    uint32_t NumSpriteTextures; // number of sprite textures to follow (4 bytes)
    tr_sprite_texture SpriteTextures[NumSpriteTextures]; // sprite texture list
(NumSpriteTextures * 16 bytes)
    uint32_t NumSpriteSequences; // number of sprite sequences records to follow (4
bytes)
    tr_sprite_sequence SpriteSequences[NumSpriteSequences]; // sprite sequence data
(NumSpriteSequences * 8 bytes)
    uint32_t NumCameras; // number of camera data records to follow (4 bytes)
    tr_camera Cameras[NumCameras]; // camera data (NumCameras * 16 bytes)
    uint32_t NumFlybyCameras; // number of flyby camera data records to follow (4
bytes)
    tr4_flyby_camera FlybyCameras[NumFlybyCameras]; // flyby camera data
(NumFlybyCameras * 40 bytes)
    uint32_t NumSoundSources; // number of sound source data records to follow (4
bytes)
    tr_sound_source SoundSources[NumSoundSources]; // sound source data
(NumSoundSources * 16 bytes)
    uint32_t NumBoxes; // number of box data records to follow (4 bytes)
    tr2_box Boxes[NumBoxes]; // box data (NumBoxes * 8 bytes)
    uint32_t NumOverlaps; // number of overlap records to follow (4 bytes)
    uint16_t Overlaps[NumOverlaps]; // overlap data (NumOverlaps * 2 bytes)
    int16_t Zones[10*NumBoxes]; // zone data (NumBoxes * 20 bytes)
    uint32_t NumAnimatedTextures; // number of animated texture records to follow (4
bytes)
    uint16_t AnimatedTextures[NumAnimatedTextures]; // animated texture data
(NumAnimatedTextures * 2 bytes)
    uint8_t AnimatedTexturesUVCount;
    uint8_t TEX[3]; // T E X (0x54, 0x45, 0x58)
    uint32_t NumObjectTextures; // number of object textures to follow (4 bytes)
(after AnimatedTextures in TR3)
```

```
    tr4_object_texture ObjectTextures[NumObjectTextures]; // object texture list
(NumObjectTextures * 38 bytes)
    uint32_t NumEntities; // number of entities to follow (4 bytes)
    tr4_entity Entities[NumEntities]; // entity list (NumEntities * 24 bytes)
    uint32_t NumAIObjects; // number of AI objects to follow (4 bytes)
    tr4_ai_object AIObjects[NumAIObjects]; // AI objects list (NumAIObjects * 24
bytes)
    uint16_t NumDemoData; // number of demo data records to follow (2 bytes)
    uint8_t DemoData[NumDemoData]; // demo data (NumDemoData bytes)
    int16_t SoundMap[370]; // sound map (740 bytes)
    uint32_t NumSoundDetails; // number of sound-detail records to follow (4 bytes)
    tr3_sound_details SoundDetails[NumSoundDetails]; // sound-detail list
(NumSoundDetails * 8 bytes)
    uint32_t NumSampleIndices; // number of sample indices to follow (4 bytes)  +
    uint32_t SampleIndices[NumSampleIndices]; // sample indices (NumSampleIndices * 4
bytes)
    uint8_t Separator[6]; // 6 0x00 bytes
}
uint32_t NumSamples; // number of sound samples (4 bytes)
tr4_sample Samples[NumSamples]; // sound samples (this is the last part, so you can
simply read until EOF)
```

10.5. TR5 Level Format

What follows is the physical Tomb Raider V `.TRC` file layout, byte for byte.


Caution

This is not a "real" C/C++ structure, in that some arrays are variable-length, with the length being defined by another element of the structure.

```
uint32_t Version; // version (4 bytes)
uint16_t NumRoomTextiles; // number of non bumped room tiles (2 bytes)
uint16_t NumObjTextiles; // number of object tiles (2 bytes)
uint16_t NumBumpTextiles; // number of bumped room tiles (2 bytes)
uint32_t Textile32_UncompSize; // uncompressed size (in bytes) of the 32-bit textures
chunk (4 bytes)
uint32_t Textile32_CompSize; // compressed size (in bytes) of the 32-bit textures
chunk (4 bytes)
uint8_t Textile32_Compressed[Textile32_CompSize]; // zlib-compressed 32-bit textures
chunk (Textile32_CompSize bytes)
{
    tr4_textile32 Textile32[NumRoomTextiles + NumObjTextiles + NumBumpTextiles];
}
uint32_t Textile16_UncompSize; // uncompressed size (in bytes) of the 16-bit textures
chunk (4 bytes)
uint32_t Textile16_CompSize; // compressed size (in bytes) of the 16-bit textures
chunk (4 bytes)
uint8_t Textile16_Compressed[Textile32_CompSize]; // zlib-compressed 16-bit textures
chunk (Textile16_CompSize bytes)
{
    tr_textile16 Textile16[NumRoomTextiles + NumObjTextiles + NumBumpTextiles];
}
uint32_t Textile32Misc_UncompSize; // uncompressed size (in bytes) of the 32-bit misc
textures chunk (4 bytes), should always be 786432
uint32_t Textile32Misc_CompSize; // compressed size (in bytes) of the 32-bit misc
textures chunk (4 bytes)
uint8_t Textile32Misc_Compressed[Textile32Misc_CompSize]; // zlib-compressed 32-bit
misc textures chunk (Textile32Misc_CompSize bytes)
{
    tr4_textile32 Textile32Misc[3];
}
uint16_t LaraType;
uint16_t WeatherType;
uint8_t Padding[28];
uint32_t LevelData_UncompSize; // uncompressed size (in bytes) of the level data chunk
(4 bytes)
uint32_t LevelData_CompSize; // compressed size (in bytes) of the level data chunk,
equal to LevelData_UncompSize (4 bytes)
// NOT COMPRESSED
uint32_t Unused; // 32-bit unused value, always 0 (4 bytes)
uint16_t NumRooms; // number of rooms (2 bytes)
tr5_room Rooms[NumRooms]; // room list (variable length)
uint32_t NumFloorData; // number of floor data uint16_t's to follow (4 bytes)
uint16_t FloorData[NumFloorData]; // floor data (NumFloorData * 2 bytes)
```

```
uint32_t NumMeshData; // number of uint16_t's of mesh data to follow (=Meshes[]) (4
bytes)
tr4_mesh Meshes[NumMeshPointers]; // note that NumMeshPointers comes AFTER Meshes[]
uint32_t NumMeshPointers; // number of mesh pointers to follow (4 bytes)
uint32_t MeshPointers[NumMeshPointers]; // mesh pointer list (NumMeshPointers * 4
bytes)
uint32_t NumAnimations; // number of animations to follow (4 bytes)
tr4_animation Animations[NumAnimations]; // animation list (NumAnimations * 40 bytes)
uint32_t NumStateChanges; // number of state changes to follow (4 bytes)
tr_state_change StateChanges[NumStateChanges]; // state-change list (NumStructures * 6
bytes)
uint32_t NumAnimDispatches; // number of animation dispatches to follow (4 bytes)
tr_anim_dispatch AnimDispatches[NumAnimDispatches]; // animation-dispatch list list
(NumAnimDispatches * 8 bytes)
uint32_t NumAnimCommands; // number of animation commands to follow (4 bytes)
tr_anim_command AnimCommands[NumAnimCommands]; // animation-command list
(NumAnimCommands * 2 bytes)
uint32_t NumMeshTrees; // number of MeshTrees to follow (4 bytes)
tr_meshtree_node MeshTrees[NumMeshTrees]; // MeshTree list (NumMeshTrees * 4 bytes)
uint32_t NumFrames; // number of words of frame data to follow (4 bytes)
uint16_t Frames[NumFrames]; // frame data (NumFrames * 2 bytes)
uint32_t NumModels; // number of models to follow (4 bytes)
tr_model Models[NumModels]; // model list (NumModels * 18 bytes)
uint32_t NumStaticMeshes; // number of StaticMesh data records to follow (4 bytes)
tr_staticmesh StaticMeshes[NumStaticMeshes]; // StaticMesh data (NumStaticMesh * 32
bytes)
uint8_t SPR[4]; // S P R \0 (0x53, 0x50, 0x52, 0x00)
uint32_t NumSpriteTextures; // number of sprite textures to follow (4 bytes)
tr_sprite_texture SpriteTextures[NumSpriteTextures]; // sprite texture list
(NumSpriteTextures * 16 bytes)
uint32_t NumSpriteSequences; // number of sprite sequences records to follow (4 bytes)
tr_sprite_sequence SpriteSequences[NumSpriteSequences]; // sprite sequence data
(NumSpriteSequences * 8 bytes)
uint32_t NumCameras; // number of camera data records to follow (4 bytes)
tr_camera Cameras[NumCameras]; // camera data (NumCameras * 16 bytes)
uint32_t NumFlybyCameras; // number of flyby camera data records to follow (4 bytes)
tr4_flyby_camera FlybyCameras[NumFlybyCameras]; // flyby camera data (NumFlybyCameras
* 40 bytes)
uint32_t NumSoundSources; // number of sound source data records to follow (4 bytes)
tr_sound_source SoundSources[NumSoundSources]; // sound source data (NumSoundSources *
16 bytes)
uint32_t NumBoxes; // number of box data records to follow (4 bytes)
tr2_box Boxes[NumBoxes]; // box data (NumBoxes * 8 bytes)
uint32_t NumOverlaps; // number of overlap records to follow (4 bytes)
uint16_t Overlaps[NumOverlaps]; // overlap data (NumOverlaps * 2 bytes)
int16_t Zones[10*NumBoxes]; // zone data (NumBoxes * 20 bytes)
uint32_t NumAnimatedTextures; // number of animated texture records to follow (4
bytes)
uint16_t AnimatedTextures[NumAnimatedTextures]; // animated texture data
(NumAnimatedTextures * 2 bytes)
uint8_t AnimatedTexturesUVCount;
uint8_t TEX[4]; // T E X \0 (0x54, 0x45, 0x58, 0x00)
uint32_t NumObjectTextures; // number of object textures to follow (4 bytes) (after
AnimatedTextures in TR3)
tr4_object_texture ObjectTextures[NumObjectTextures]; // object texture list
(NumObjectTextures * 38 bytes)
uint32_t NumEntities; // number of entities to follow (4 bytes)
tr4_entity Entities[NumEntities]; // entity list (NumEntities * 24 bytes)
uint32_t NumAIObjects; // number of AI objects to follow (4 bytes)
tr4_ai_object AIObjects[NumAIObjects]; // AI objects list (NumAIObjects * 24 bytes)
uint16_t NumDemoData; // number of demo data records to follow (2 bytes)
uint8_t DemoData[NumDemoData]; // demo data (NumDemoData bytes)
int16_t SoundMap[450]; // sound map (740 bytes)
uint32_t NumSoundDetails; // number of sound-detail records to follow (4 bytes)
tr3_sound_details SoundDetails[NumSoundDetails]; // sound-detail list (NumSoundDetails
* 8 bytes)
uint32_t NumSampleIndices; // number of sample indices to follow (4 bytes)  +
uint32_t SampleIndices[NumSampleIndices]; // sample indices (NumSampleIndices * 4
bytes)
uint8_t Separator[6]; // 6 0xCD bytes
uint32_t NumSamples; // number of sound samples (4 bytes)
tr4_sample Samples[NumSamples]; // sound samples (this is the last part, so you can
simply read until EOF)
```

LaraType:

- **0** — Normal
- **3** — Catsuit
- **4** — Divesuit
- **6** — Invisible

`WeatherType`:

- **0** — Normal
- **1** — Rain
- **2** — Snow

10.6. Changes in TR1 vs. TR2

- TR1 has no colour table or 16-bit palette before the start of the textures; it also lacks 16-bit textures.
- In TR1, [tr2_room_vertex] has after its [tr_vertex] struct only the first light intensity, and not the attributes or the second intensity.
- In TR1, after SectorData, there is only the first light intensity, and not the second one or the lighting mode.
- In TR1, tr2_room_light has only one of:
  - `uint16_t` Diffuse1/2
  - `uint32_t` Unknown1/2
- In TR1, tr_room_staticmesh does not have two light intensities, but only one.
- "Boxes" objects are rectangles whose four horizontal-coordinate values are `uint8_t`s in TR2 and `int32_t`'s in TR1.
- "Zones" objects have 10 `int16_t`s in TR2, but 6 `int16_t`s in TR1
- In TR1, [tr_entity] is like the TR2 version, but with only one light intensity.
- The TR1 colour table has the same format as the TR2 colour table, but it is located between the LightMap and the cinematic frames.
- SoundMap is 370 `int16_t`s in TR2, but 256 `int16_t`s in TR1.
- Between SoundDetails and SampleIndices, TR1 has all the level's sound samples, in the form of embedded Microsoft WAVE files. Just before these samples is the total number of bytes in those sound samples, which is a int32_t.

10.7. Changes in TR2 vs. TR3

- After the two room-light intensities, TR2 has a lighting-mode value, which TR3 lacks.
- Also in [tr3_room], TR3 has 3 extra bytes at the end, which are `WaterScheme`, `ReverbInfo` and null filler.
- Finally, in TR2, the [tr_object_texture] data is before the [tr_sprite_texture] data. In TR3, it is before the [tr2_entity] data.

10.8. Changes in TR3 vs. TR4

- There are no more 8-bit and 16-bit palettes.
- There are no more 8-bit textures.
- There are now 32-bit textures.
- Texture tiles are now divided into three parts: *non-bumped room texture tiles*, *model texture tiles* and *bumped room texture tiles*.
- Level file divided in several chunks, with each chunk compressed using *zlib*:
  - Chunk 1: 32-bit texture tiles.
  - Chunk 2: 16-bit texture tiles.
  - Chunk 3: 32-bit *sky and font graphics*.
  - Chunk 4: Level data.
- Each compressed chunk is preceded by its *uncompressed size* and *compressed size* `uint32_t`s.
- After last compressed chunk, there are now all audio samples, sequentially stored in this manner:

```
struct tr4_sample
{
    uint32_t  UncompressedSize;
    uint32_t  CompressedSize;
```

```
        char  WaveFile[];       // Embedded sample in MS-ADPCM or PCM WAV format.
}
```

- Room Light structure has completely changed:
  - Colour is no longer stored in [tr_colour4] format, rather [tr_colour].
  - There is new field `LightType`, which specifies light mode or fog bulb mode.
  - After `LightType`, there is a `uint8_t Filler` value of `0xFF`.
  - `Intensity` is now `uint8_t`.
  - Instead of `Fade`, there is a set of 4 float values: `In`, `Out`, `Length` and `CutOff`.
  - There are also three float values defining *light direction*.
- There are now two dedicated structures for *mesh faces*, bearing extra field `Lighting`.
- There is now *FlybyCameras* block before *SoundSources* block.
- *Cinematic Frames* are replaced with *AI Data* block.
- Meaning of fields in [tr_sprite_texture] has changed.
- In addition, the `NumSpriteTextures` field is preceeded by the 3 ASCII bytes `SPR`.
- Meshes have no longer colored tris / quads. So, `NumColoredRectangles`, `ColoredRectangles[]`, `NumColoredTriangles`, `ColoredTriangles[]` no longer exist in the tr4_mesh structure.
- The `NumObjectTextures` field is now preceeded by 4 ASCII bytes `\0TEX`
- [tr4_object_texture] struct is used instead of [tr_object_texture].
- [tr4_animation] struct is used instead of [tr_animation].
- There is no lightmap.
- TR4 levels have an additional 6 bytes at the end of the uncompressed *Level data* that seem to be always 0.

10.9. Changes in TR4 vs. TR5

- There is no more *bumped room texture tiles* block.
- There are now two extra `uint16_t` values after last texture block specifying *Lara type* and *weather type*. Weather type may be either *0* (no weather), *1* (raining) or *2* (snowing).
- Also, it is followed by 28 bytes zero padding.
- *uncompressed size* and *compressed size* `uint32_t` values for *Level data* block are equal (reason below).
- *Level data* block is not compressed.
- [tr5_room] struct is used instead of [tr4_room].
- [tr5_room_info] struct is used instead of [tr_room_info].
- [tr5_room_vertex] struct is used instead of [tr3_room_vertex].
- [tr5_room_light] struct is used instead of [tr4_room_light].
- Each ends with extra null `uint16_t` value.
- SoundMap is 450 `int16_t`s in TR5, but 370 `int16_t`s in TR4.

10.10. Differences between “normal” TRs and Demos

- Presumably as a form of copy protection, the demo versions of some of the TR games use levels that are slightly different from those in the retail versions. However, those that have been found are all data rearrangements, as explained below.
- The TR1 and Unfinished Business (`.TUB`) demos have their palettes moved to between the SpriteSequences and the Cameras.
- The TR2 “Wall” demo, and maybe also its “Venice” demo, has its LightMap (8K) moved to between the SpriteSequences and the Cameras. It also has its SampleIndices content replaced by the soundfiles, though the associated number of them remains unchanged (the number of indices becomes the number of samples).
- That demo also has its own version of `TOMBPC.DAT`, called `DEMOPC.DAT`, which appears to have the exact same format as `TOMBPC.DAT`.
- The `Version` field of TR4 levels is `0x00345254` (`TR4\0`) for normal game and `0x63345254` (`TR4c`).

No rearrangements are known for the TR3 demos.

11. Scripting in TR2/TR3 for PC/PSX

11.1. Overview

The internal gameflow, which levels come in what order, what item(s) Lara has at the beginning of each level, the filenames of the level and cut-scene files, all the visible text (e.g. “Save Game,” “Rusty Key,” etc.), and various other options are controlled by a script file called TOMBPC.DAT/TOMBPSX.DAT. The scripts were compiled using a utility known as GAMEFLOW.EXE which was distributed by Eidos in the German release of Tomb Raider II Gold. Both TR2 and TR3 use these script files. From both games the format remained unchanged. TR1’s gameflow is hardcoded thus there is no external file controlling this resulting in loss of flexibility.

```
uint32_t Version;              // The Script Version (Always 3 for TR2/3)
uint8_t Description[256];      // Null-terminated string describing the script
copyright info etc. Not encrypted.
uint16_t GameflowSize;         // Size in bytes of the game flow data, always 128 bytes
int32_t FirstOption;           // What to do when the game starts
int32_t TitleReplace;          // What to do when EXIT_TO_TITLE is requested
int32_t OnDeathDemoMode;       // What to do when Lara dies during the demo mode
int32_t OnDeathInGame;         // What to do when Lara dies during the game
uint32_t DemoTime;             // Time in game ticks (1/30th of a second) to wait
before starting a demo
int32_t OnDemoInterrupt;       // What to do when the demo mode is interrupted
int32_t OnDemoEnd;             // What to do when the demo mode ends
uint8_t Unknown1[36];          // Filler
uint16_t NumLevels;            // Number of levels in the game, including the training
level, not including the title level.
uint16_t NumChapterScreens;    // Chapter screens (Present in TR2, first used in TR3)
uint16_t NumTitles;            // Number of title elements (TITLE.TR2 level + the
legal/title pictures in *.PCX format)
uint16_t NumFMVs;              // Number of FMV cutscenes PC - (*.RPL), PSX - (*STR)
uint16_t NumCutscenes;         // Number of in-game (engine-rendered) cutscenes
(CUT*.TR2)
uint16_t NumDemoLevels;        // Number of demo levels
uint16_t TitleSoundID;         // ID of title soundtrack
uint16_t SingleLevel;          // If doing only a single level, the level ID (starting
at 1). -1 means disabled.
uint8_t Unknown2[32];          // Filler
uint16_t Flags;                // Various flags, see below
uint8_t Unknown3[6];           // Filler
uint8_t XORKey;                // Key used to encrypt/decrypt strings
uint8_t LanguageID;            // Script Language ID, see below
uint16_t SecretSoundID;        // ID of soundtrack to play when a secret is found
uint8_t Unknown4[4];           // Filler

// If Flags & UseXor true each character (except null-terminator) must be ^ XorKey to
decrypt the string.

TPCStringArray[NumLevels] LevelStrings;                  // level name strings
TPCStringArray[NumChapterScreens] ChapterScreenStrings;  // chapter screen strings
TPCStringArray[NumTitles] TitleStrings;                  // title strings
TPCStringArray[NumFMVs] FMVStrings;                      // FMV path strings
TPCStringArray[NumLevels] LevelPathStrings;              // level path strings
TPCStringArray[NumCutscenes] CutscenePathStrings;        // cutscene path strings

uint16_t SequenceOffsets[NumLevels + 1];                 // Relative offset to
sequence info (the +1 is because the first one is the FrontEnd sequence, for when the
game starts)
uint16_t SequenceNumBytes;                               // Size of SequenceOffsets in
bytes
uint16_t[] Sequences[NumLevels + 1];                     // Sequence info see
explanation below (SIZE is dependant on first opcode)

uint16_t DemoLevelIDs[NumDemoLevels];

#if PSX
    PSXFMVInfo[NumFMVs];
#endif

uint16_t NumGameStrings;
TPCStringArray[NumGameStrings] GameStrings;

#if PSX
    TPCStringArray[size] PSXStrings; // size is 79 for the TR2 beta, 80 for all other
versions
#else
    TPCStringArray[41] PCStrings;
#endif
```

```
TPCStringArray[NumLevels] PuzzleStrings[4];
#if PSX && TR2_BETA
    TPCStringArray[NumLevels] SecretsStrings[4];
    TPCStringArray[NumLevels] SpecialStrings[2];
#endif
TPCStringArray[NumLevels] PickupStrings[2];
TPCStringArray[NumLevels] KeyStrings[4];
```

11.1.1. String arrays

```
struct TPCStringArray // (variable length)
{
    uint16_t Offsets[Count]; // List containing for each string an offset in the Data block (Count * 2 bytes)
    uint16_t TotalSize; // Total size, in bytes (2 bytes)
    uint8_t Data[TotalSize]; // Strings block, usually encrypted (XOR-ed with XORKey, see above)
}
```

11.2. PSX FMV Info

```
struct PSXFMVInfo // 8 bytes
{
    uint32_t Start;     // Start frame
    uint32_t End;       // End frame
};
```

This specific info is exclusive to `TOMBPSX.DAT`.

11.3. Script Flags

- *Bit 0* (`0x01`) — DemoVersion. If set, it indicates that the game is a demo distribution.
- *Bit 1* (`0x02`) — TitleDisabled. If set, it indicates that the game has no Title Screen.
- *Bit 2* (`0x04`) — CheatModeCheckDisabled. If set, it indicates that the game does not look for the cheat sequence keystrokes and events.
- *Bit 3* (`0x08`) — NoInputTimeout. If set, it indicates that the game waits forever if there is no input (won't enter demo mode).
- *Bit 4* (`0x10`) — LoadSaveDisabled. If set, it indicates that the game does not allow save games.
- *Bit 5* (`0x20`) — ScreenSizingDisabled. If set, it indicates that the game does not allow screen resizing (with the function keys).
- *Bit 6* (`0x40`) — LockoutOptionRing. If set, it indicates that the user has no access to the Option Ring while playing the game.
- *Bit 7* (`0x80`) — DozyCheatEnabled. If set, it indicates that the game has the DOZY cheat enabled (only present in the final build of TR2 on PSX).
- *Bit 8* (`0x100`) — UseXor. If set, it indicates that a cypher byte was used to encrypt the strings in the script file, and is stored in the XorKey field.
- *Bit 9* (`0x200`) — GymEnabled. Is Gym available on title screen.
- *Bit 10* (`0x400`) — SelectAnyLevel. If set, it enables level select when New Game is selected.
- *Bit 11* (`0x800`) — EnableCheatCode. It apparently has no effect on the PC game.

11.4. Script Language

- **0** — English
- **1** — French
- **2** — German
- **3** — American
- **4** — Japanese

11.5. Script Sequencing & Opcodes/Operands

Each script has “sequence information”, Opcodes and Operands are all stored as `uint16_t`. Sequences contain a set of commands to execute where an additional value (operand) is usually passed as a parameter to the function the command needs to call. Note: that if a level is a demo level, its level ID will be 1024 higher than a *normal* level ID.

11.5.1. Script Opcodes

- 0 — `Picture` — Unused. Compiles but does not show in-game. Maybe PSX. Operand is picture ID.
- 1 — `ListStart` — Unused. Maybe PSX.
- 2 — `ListEnd` — Unused. Maybe PSX.
- 3 — `FMV` — Display Full Motion Video. Operand is FMV ID.
- 4 — `Level` — Start a playable level. Operand is level ID.
- 5 — `Cine` — Display cut scene sequence. Operand is cutscene ID.
- 6 — `Complete` — Display level-completion statistics panel.
- 7 — `Demo` — Display demo sequence. Operand is demo level ID.
- 8 — `JumpToSequence` — Jump to another sequence. Operand is sequence ID.
- 9 — `End` — Close script sequence.
- 10 — `Track` — Play Soundtrack (it precedes opcodes of associated levels). Operand is track ID.
- 11 — `Sunset` — Gradually dim all lights in rooms with `LightMode` set to `sunset`. Used in Bartoli’s Hideout.
- 12 — `LoadPic` — Show chapter screen (under TR3). Operand is picture ID.
- 13 — `DeadlyWater` — Unknown. Nothing changes in-game. Used in Temple of Xian. Maybe not-implemented ancestor of TR3 Death_by_Drowning?
- 14 — `RemoveWeapons` — Lara starts the level with no weapons.
- 15 — `GameComplete` — End of game, show the final statistics and start the credits sequence.
- 16 — `CutAngle` — Match the North-South orientation of the Room Editor and the North-South orientation of the 3D animated characters from a CAD application. Operand is horizontal rotation (angle in degrees * 65536 / 360)
- 17 — `NoFloor` — Lara dies when her feet reach the given depth. If falling, 4 to 5 extra blocks are added to Depth. Operand is depth (blocks * 1024), relative to where Lara starts the level.
- 18 — `StartInv` / `Bonus` — Give item to lara at level-start (`StartInv`) or at all-secrets-found (`Bonus`). Operand is item ID (see below).
- 19 — `StartAnim` — Lara starts the level with the given animation. Operand is animation ID.
- 20 — `Secrets` — If zero, the level does not account for secrets. Non-zero value means the level must be accounted for secrets.
- 21 — `KillToComplete` — Kill all enemies to finish the level.
- 22 — `RemoveAmmo` — Lara starts the level without ammunition or medi packs.

The correct way to parse a sequence is to first read a `uint16_t` opcode specifying what this command within the sequence does. In reference to the list above, certain commands MUST have an additional `uint16_t` read from the sequence data directly after the opcode that’s the pairing operand to this opcode. Not all opcodes have an operand so this must be done correctly. The original games execute each sequence command 1 by 1 until it reaches `End` (9), where it then runs the next sequence.

11.5.2. Opcode-18 `StartInv` and `Bonus`

(repeat means give another)

By default, the item is given at level start (`StartInv`). Adding 1000 to the item ID means it will be given when all secrets are found (`Bonus`).

Tomb Raider 2

- 0 — Pistols
- 1 — Shotgun
- 2 — Automatic pistols
- 3 — Uzis
- 4 — Harpoon gun
- 5 — M-16
- 6 — Grenade launcher
- 7 — Pistol clip (no effect, infinite by default)
- 8 — Shotgun-shell box (adds 2 shells)
- 9 — Automatic-pistol clip (adds 2 shells)

- 10 — Uzi clip (adds 2 shells)
- 11 — Harpoon bundle (adds 2 harpoons)
- 12 — M-16 clip (add 2 shells)
- 13 — Grenade pack (adds 1 grenade)
- 14 — Flare box (adds 1 flare)
- 15 — Small medipack (adds 1 pack)
- 16 — Big medipack (adds 1 pack)
- 17 — Pickup 1
- 18 — Pickup 2
- 19 — Puzzle 1
- 20 — Puzzle 2
- 21 — Puzzle 3
- 22 — Puzzle 4
- 23 — Key 1
- 24 — Key 2
- 25 — Key 3
- 26 — Key 4

Tomb Raider 3

- 0 — Pistols
- 1 — Shotgun
- 2 — Desert Eagle
- 3 — Uzis
- 4 — Harpoon gun
- 5 — MP5
- 6 — Rocket launcher
- 7 — Grenade launcher
- 8 — Pistol clip (no effect, infinite by default)
- 9 — Shotgun-shell box (adds 2 shells)
- 10 — Desert eagle clip (adds 5 shells)
- 11 — Uzi clip (adds 2 shells)
- 12 — Harpoon bundle (adds 2 harpoons)
- 13 — MP5 clip (add 2 shells)
- 14 — Rocket pack (adds 1 rocket)
- 15 — Grenade pack (adds 1 grenade)
- 16 — Flare box (adds 1 flare)
- 17 — Small medipack (adds 1 pack)
- 18 — Big medipack (adds 1 pack)
- 19 — Pickup 1
- 20 — Pickup 2
- 21 — Puzzle 1
- 22 — Puzzle 2
- 23 — Puzzle 3
- 24 — Puzzle 4
- 25 — Key 1
- 26 — Key 2
- 27 — Key 3
- 28 — Key 4
- 29 — Save crystal

11.5.3. Tomb Raider 2 Identifications

Note | TR2 only information here. These lists are virtually colored blue.

FMV IDs

- 0 — LOGO (everybody's corporate logos)
- 1 — ANCIENT (monks vs. dragon)
- 2 — MODERN (Lara drops in from helicopter)
- 3 — LANDING (Seaplane lands at rig)
- 4 — MS (Lara hitchhikes on a minisub)
- 5 — CRASH (Lara goes to Tibet and has a rough landing there)
- 6 — JEEP (Lara steals it and outruns Bartoli's goons)
- 7 — END (Lara escaping the collapsing lair)

Cutscene IDs

- 0 — CUT1 (At the end of the Great Wall)
- 1 — CUT2 (Lara the stowaway)
- 2 — CUT3 (Bartoli vs. goon)
- 3 — CUT4 (Bartoli stabs himself)

Soundtrack IDs

- 0 — BLANK (no sound)
- 3 — CUT1 ("at the fancy door" soundtrack)
- 4 — CUT2 ("Lara the stowaway" soundtrack)
- 5 — CUT3 ("Bartoli vs. goon" soundtrack)
- 30 — CUT4 ("Bartoli stabs himself" soundtrack)
- 31 — DERELICT (eerie choppy/echo-y synths)
- 32 — WATER (dripping/pouring water sounds)
- 33 — WIND (Blowing wind)
- 34 — HEARTBT (musical embellishment of one)
- 52 — SHOWER (that infamous shower scene)
- 58 — MACHINES (in the offshore rig)
- 59 — FLOATING (wispy synths)

11.6. Other Script Commands

`FirstOption`, `TitleReplace`, `OnDeathDemoMode`, `OnDeathInGame`, `OnDemoInterrupt` and `OnDemoEnd` can also be setup to perform specific actions. For example, `OnDeathInGame` will be set to "0x500" which loads the title screen when Lara dies in-game.

Commands

- **Level** / **Sequence** + operand — `0x000` — Load specified **script sequence** (0 means Frontend, 1 means Gym, 2 means first level)
- **Demo** + operand — `0x400` — Load specified demo level
- **ExitToTitle** — `0x500` — Exit to Title Screen
- **ExitGame** — `0x700` — Exit entire game?
- **TitleDeselect** — `0x900` — Unknown

12. Scripting in TR4 and TR5

In this chapter we will describe full gameflow script specification for TR4/TR5 *script file* (usually called `SCRIPT.DAT`) and *language file*, which contains all the strings used in game for specific language (e.g., `ENGLISH.DAT`, `FRENCH.DAT`, and so on).

12.1. The Script File

The script is divided into several blocks (or *headers*), some of them are global (applicable to whole game instance), and some are per-level only.

12.1.1. Global Header

This header contains general information not specific to particular level.

```
struct tr4_script_header // 9 bytes
{
    uint8_t  Options;
    uint8_t  Filler[3];     // Unused
    uint32_t InputTimeout;
    uint8_t  Security;
}
```

`Options` is a set of bit flags with several global game settings (name of the settings directly borrowed from original text scripts distributed with TRLE):

- *Bit 0* (`0x01`) — FlyCheat. Enables debug fly mode activated by typing `DOZY` ingame.
- *Bit 1* (`0x02`) — LoadSave. When this bit is not set, load and save features are disabled. This option was used for demo versions.
- *Bit 2* (`0x04`) — Title. Specifies if title screen should be displayed or not. If not set, game will start right away after user has launched an application.
- *Bit 3* (`0x08`) — PlayAnyLevel. Gives an access to any level from the title screen.
- *Bit 7* (`0x80`) — DemoDisc. Unknown feature, probably related to game versions deployed on promotional CDs.

`InputTimeout`: in early TR4 demos (for example, version dated September 15, 1999) this parameter specified time interval, after which game will engage pre-recorded rolling demo, in case there was no user input. This feature became useless in final version.

`Security` parameter meant to be a special “key” value used to encrypt script data. Encryption is done with simple XOR operation against the data. However, this value was never used, and instead, hardcoded one was specified. This matter will be discussed later.

12.1.2. Level Header

This section defines platform-specific information, such as *file extensions* used in PC an PlayStation versions of the game. All the mentioned strings are null-terminated.

```
struct tr4_script_levelheader
{
     uint8_t NumTotalLevels;
    uint16_t NumUniqueLevelPaths;

    uint16_t LevelpathStringLen;
    uint16_t LevelBlockLen;

    uint8_t  PSXLevelString [5];    //  typically ".PSX"
    uint8_t  PSXFMVString   [5];    //  typically ".FMV"
    uint8_t  PSXCutString [5];    //  typically ".CUT"
    uint8_t  Filler [5];            //  Possibly for some additional extension type?

    uint8_t  PCLevelString  [5];    //  typically ".TR4"
    uint8_t  PCFMVString    [5];    //  typically ".BIK"
    uint8_t  PCCutString    [5];    //  typically ".TR4"
    uint8_t  Unused [5];
}
```

`NumTotalLevels` is an amount of levels included in script. Title flyby is also counted.

`LevelpathStringLen` is a sum of lengths of all *level path strings*, including `0x00`s (empty ones).

`LevelBlockLen` is a sum of lengths of each level script data length.

12.1.3. Level Listing Block

```
struct tr4_script_levellisting
{
    uint16_t OffsetsToLevelpathString[NumTotalLevels];
     uint8_t LevelpathStringBlock [LevelpathStringLen];

    uint16_t OffsetsToLevelData [NumTotalLevels];
}
```

Note that the offsets in the offset table themselves **are not** relative to the file address `0`. The level-path offsets are relative to the first path string's starting byte address `(56 + NumTotalLevels * 2)`, while the level-data offsets are relative to the first level data's starting byte address `(56 + NumTotalLevels * 2 + LevelpathStringLen + NumTotalLevels * 2)`.

It is also worth noting that the level-path strings in `SCRIPT.DAT` are ordered the same way they were ordered in corresponding `[Level]` blocks in uncompiled *SCRIPT.TXT*. For example, if the first *[Level]* in `SCRIPT.TXT` defines `Level=DATA\TEST1,101` and the second `Level=DATA\TEST2,101` — then there will be 2 level-paths in `SCRIPT.DAT`, in the order such as this: `DATA\\TEST1.DATA\\TEST2;` where `.` is the null-terminator (`0x00`) byte.

To get to a certain level's path within `SCRIPT.DAT` knowing only its number, just look-up at `OffsetsToLevelpathString[LevelNum]` and go to that offset (remember, it is *not relative* to file address `0`!).

12.1.4. Level Block

Inside the level block, each level stores its own data describing certain parameters, such as level name, puzzle item names, load camera position, default background ambience soundtrack, and so on (the title level is no exception!).

While in `SCRIPT.TXT` each parameter was given its own line and position within the file itself, in `SCRIPT.DAT` this is not the case. Rather, bitfields are used for bool options (enabled/disabled; such as *Lightning* option) and the rest of the usually multi-byte data uses an *opcode data structure*.

That is, preceding a certain type of data you usually find a byte. That is the *opcode byte* — depending on its value, it can be determined what kind and how many arguments follow that need parsing. For example, chunk `0x81` indicates the level description opcode; with that info, the parser knows that 4 arguments follows: the string index, etc. This structure is somewhat akin to the *AnimCommands* structure of level files (see description above). The chunk order *does* matter; the original `tomb4.exe` binary seems to crash if something is not ordered the way it should be.

The title screen is special in that it uses the `0x82` opcode the indicate the level-name and audio track information and it, naturally, lacks the string index integer as the title level has no name associated with it.

```
struct tr4_script_leveldata
{
    uint8_t LevelData [LevelDataLen];
}
```

`LevelData` is all of the level's data continuously stored in memory. Number of level data sections is equal to overall amount of levels in game, and overall size of all level data sections comprise *Level Block*.

To get to a certain level's data section, follow that particular level's offset from inside the offset table you loaded (described above). The data sections themselves are ordered the very same way levels were ordered in `SCRIPT.TXT`. For more info on the types of all available TR4 chunks and how to parse them, see the Script Opcodes section.

12.1.5. Language File Listing Block

After the level block follows a simple array of ASCII strings which define *all the language files the game can choose from*. There are, however, no offset tables for this one, so one must simply read until a null-byte is reached, and then take that as the string and repeat onwards until EOF. Therefore, the last byte of `SCRIPT.DAT` must always be the null-terminator (`0x00`).


Note

This setup is valid only for standard TR4 scripts generated by original TRLE script utility. *TRNG* scripts have their own special footer and data block appended to the bottom of the file, which contain all the extra information it needs.

12.1.6. Script Opcodes

Here is a list of all available TR4 opcodes, their meaning and their corresponding arguments (order of arguments matters!):

```
0x81  Level           bitu8 stringIndex, uint16_t levelOptions, bitu8 pathIndex, bitu8
audio
0x82  [Title] Level   bitu8 pathIndex, uint16_t titleOptions, bitu8 audio
0x8C  Legend          bitu8 stringIndex
0x91  LoadCamera      bit32 srcX, bit32 srcY, bit32 srcZ, bit32 targX, bit32 targY,
bit32 targZ, bitu8 room
0x89  Layer1          bitu8 red, bitu8 green, bitu8 blue, bit8 speed
0x8A  Layer2          bitu8 red, bitu8 green, bitu8 blue, bit8 speed
0x8E  Mirror          bitu8 room, bit32 xAxis
0x8F  Fog             bitu8 red, bitu8 green, bitu8 blue
0x84  Cut             bitu8 cutIndex
0x8B  UVrotate        bit8 speed
0x85  ResidentCut1    bitu8 cutIndex
0x86  ResidentCut2    bitu8 cutIndex
0x87  ResidentCut3    bitu8 cutIndex
0x88  ResidentCut4    bitu8 cutIndex
```

```
0x80  FMV             bitu8: 4 least significant bits represent the FMV index; 4 most
significant bits (y) represent the FMV trigger bitfield as in y=1<->bit 8 set
0x92  ResetHUB        bitu8 levelIndex
0x90  AnimatingMIP    bitu8: 4 least significant bits represent animatingObjectIndex -
1; 4 most significant bits represent the distance
0x8D  LensFlare       uint16_t yClicks, bit16 zClicks, uint16_t xClicks, bitu8 red,
bitu8 green, bitu8 blue
0x93  KEY_ITEM1       uint16_t stringIndex, uint16_t height, uint16_t size, uint16_t
yAngle, uint16_t zAngle, uint16_t xAngle, uint16_t unknown
0x94  KEY_ITEM2   -=-  (All the same)
0x95  KEY_ITEM3   -=-
0x96  KEY_ITEM4   -=-
0x97  KEY_ITEM5   -=-
0x98  KEY_ITEM6   -=-
0x99  KEY_ITEM7   -=-
0x9A  KEY_ITEM8   -=-
0x9B  KEY_ITEM9   -=-
0x9C  KEY_ITEM10  -=-
0x9D  KEY_ITEM11  -=-
0x9E  KEY_ITEM12  -=-
0x9F  PUZZLE_ITEM1  -=-
0xA0  PUZZLE_ITEM2  -=-
0xA1  PUZZLE_ITEM3  -=-
0xA2  PUZZLE_ITEM4  -=-
0xA3  PUZZLE_ITEM5  -=-
0xA4  PUZZLE_ITEM6  -=-
0xA5  PUZZLE_ITEM7  -=-
0xA6  PUZZLE_ITEM8  -=-
0xA7  PUZZLE_ITEM9  -=-
0xA8  PUZZLE_ITEM10  -=-
0xA9  PUZZLE_ITEM11  -=-
0xAA  PUZZLE_ITEM12  -=-

0xAB  PICKUP_ITEM1  -=-
0xAC  PICKUP_ITEM2  -=-
0xAD  PICKUP_ITEM3  -=-
0xAE  PICKUP_ITEM4  -=-

0xAF  EXAMINE1 -=-
0xB0  EXAMINE2 -=-
0xB1  EXAMINE3 -=-

0xB2  KEY_ITEM1_COMBO1 -=-
0xB3  KEY_ITEM1_COMBO2 -=-
0xB4  KEY_ITEM2_COMBO1 -=-
0xB5  KEY_ITEM2_COMBO2 -=-
0xB6  KEY_ITEM3_COMBO1 -=-
0xB7  KEY_ITEM3_COMBO2 -=-
0xB8  KEY_ITEM4_COMBO1 -=-
0xB9  KEY_ITEM4_COMBO2 -=-
0xBA  KEY_ITEM5_COMBO1 -=-
0xBB  KEY_ITEM5_COMBO2 -=-
0xBC  KEY_ITEM6_COMBO1 -=-
0xBD  KEY_ITEM6_COMBO2 -=-
0xBE  KEY_ITEM7_COMBO1 -=-
0xBF  KEY_ITEM7_COMBO2 -=-
0xC0  KEY_ITEM8_COMBO1 -=-
0xC1  KEY_ITEM8_COMBO2 -=-

0xC2  PUZZLE_ITEM1_COMBO1 -=-
0xC3  PUZZLE_ITEM1_COMBO2  -=-
0xC4  PUZZLE_ITEM2_COMBO1  -=-
0xC5  PUZZLE_ITEM2_COMBO2  -=-
0xC6  PUZZLE_ITEM3_COMBO1  -=-
0xC7  PUZZLE_ITEM3_COMBO2  -=-
0xC8  PUZZLE_ITEM4_COMBO1  -=-
0xC9  PUZZLE_ITEM4_COMBO2  -=-
0xCA  PUZZLE_ITEM5_COMBO1  -=-
0xCB  PUZZLE_ITEM5_COMBO2  -=-
0xCC  PUZZLE_ITEM6_COMBO1  -=-
0xCD  PUZZLE_ITEM6_COMBO2 -=-
0xCE  PUZZLE_ITEM7_COMBO1 -=-
0xCF  PUZZLE_ITEM7_COMBO2 -=-
0xD0  PUZZLE_ITEM8_COMBO1 -=-
0xD1  PUZZLE_ITEM8_COMBO2 -=-

0xD2  PICKUP_ITEM1_COMBO1 -=-
```

```
0xD3  PICKUP_ITEM1_COMBO2 -=-
0xD4  PICKUP_ITEM2_COMBO1 -=-
0xD5  PICKUP_ITEM2_COMBO2 -=-
0xD6  PICKUP_ITEM3_COMBO1 -=-
0xD7  PICKUP_ITEM3_COMBO2 -=-
0xD8  PICKUP_ITEM4_COMBO1 -=-
0xD9  PICKUP_ITEM4_COMBO2 -=-

0x83  level-data-end  no arguments - this opcode appears at the end of every level
(incl. title) block
```

The `uint16_t` values `levelOptions` and `titleOptions` are actually *bit fields* containing several boolean options, and are laid out as follows (per-bit description):

- *Bit 0* (`0x0001`) — YoungLara
- *Bit 1* (`0x0002`) — Weather
- *Bit 2* (`0x0004`) — Horizon
- *Bit 4* (`0x0010`) — Layer2 used (?)
- *Bit 3* (`0x0008`) — Horizon (has to be paired with 3)
- *Bit 5* (`0x0020`) — Starfield
- *Bit 6* (`0x0040`) — Lightning
- *Bit 7* (`0x0080`) — Train
- *Bit 8* (`0x0100`) — Pulse
- *Bit 9* (`0x0200`) — ColAddHorizon
- *Bit 10* (`0x0400`) — ResetHUB used
- *Bit 11* (`0x0800`) — ColAddHorizon (has to be paired with 10)
- *Bit 12* (`0x1000`) — Timer
- *Bit 13* (`0x2000`) — Mirror used
- *Bit 14* (`0x4000`) — RemoveAmulet
- *Bit 15* (`0x8000`) — NoLevel

12.2. The Language File

In contrary to TR2 and TR3, TR4 uses a more sophisticated language-handling scheme. Instead of storing the strings in `SCRIPT.DAT` for every different language, TR4 splits the string definition (`{LANGUAGE}.DAT`) and script definition (`SCRIPT.DAT`) data into the two mentioned files. This allows for smaller files, finer grain of selectivity and easy localization.

This means that, within `SCRIPT.DAT`, strings are always given as string indices, i.e. numbers that correspond to the array positions of the corresponding strings within `{LANGUAGE}.DAT`, where `{LANGUAGE}` can be any supported language filename.

From these files, the game will choose the first one that is available and use that as the *string resource*. See below for details on string selection.

12.2.1. Language File Priority

The number of supported language files depends on what was defined in `SCRIPT.TXT`, in the *[Language]* section. Also, the priority of loading is specified there (the first number before the comma). For example, if we have defined:

```
[Language]
File= 0,ENGLISH.TXT
File= 1,FRENCH.TXT
File= 2,GERMAN.TXT
File= 3,ITALIAN.TXT
File= 4,SPANISH.TXT
File= 5,US.TXT
```

...that would mean that the game will first look for `ENGLISH.DAT` for loading. If that's not present, it will look for `FRENCH.DAT`. If not, it'll look for `GERMAN.DAT`, and so on. If none of the files are present, the game will crash. In `SCRIPT.DAT`, these numbers reflect on the order of file name strings: in the above situation, the *language file listing block* at the end of `SCRIPT.DAT` would look like this (highest→lowest priority):

```
ENGLISH.DAT FRENCH.DAT GERMAN.DAT ITALIAN DAT SPANISH.DAT US.DAT.
```

...where the splitting space between filenames specifies the null-terminator (0x00) byte.

12.2.2. Language File Structure

The Header

The header of the language file follows this structure:

```
struct tr4_lang_header
{
    uint16_t NumGenericStrings;
    uint16_t NumPSXStrings;
    uint16_t NumPCStrings;

    uint16_t GenericStringsLen; //  including the null-terminator bytes
    uint16_t PSXStringsLen;     //  including the null-terminator bytes
    uint16_t PCStringsLen;      //  including the null-terminator bytes

    uint16_t StringOffsetTable[];
}
```

`StringOffsetTable` is a table holding offsets which point to corresponding strings. Therefore, its size is `NumGenericStrings + NumPSXStrings + NumPCStrings`.

Offsets in the offset table themselves *are not* relative to the file address 0! They are actually relative to the first string's starting byte address!

In order to get an absolute offset of a string whose relative offset you retrieved from the offset table, do the following:

`absoluteOffset = relativeOffset + sizeof(tr4_lang_header)`

`sizeof(tr4_lang_header)` depends, of course, on the number of strings in each group. Therefore, the header size is `sizeof(uint16_t) * 6 + sizeof(OffsetTable)`.

String Data

In the usual TR4 situation, there are typically *359 strings* (that is, usually *NumTotalStrings = NumGenericStrings + NumPSXStrings + NumPCStrings = 359*) defined. This, however, is *not* a limit nor rule of any kind.

All the strings defined within `{LANGUAGE}.DAT` files are ASCII null-terminated strings. Every character (byte) contained in such a string is XOR-ed with byte `0xA5` (as mentioned above, it is done regardless of what byte was specified in `SCRIPT.TXT` under the *Security* option).

The null-termination byte is *not* being XOR-ed!

After the above defined header section goes an array of strings, in a predefined order: *Generic → PSX → PC*.

The length of this array of total *(NumTotalStrings)* strings is therefore *TotalStringsLen = GenericStringsLen + PSXStringsLen + PCStringsLen*.

Hence the string array has the following format:

```
struct tr4_lang_stringdata
{
    string_entry Strings[NumTotalStrings];
}
```

where `string_entry` is simply a `char` array, whose length depends on the corresponding string's length. That can be calculated by subtracting the next string's by the current string's offset.

13. PAK file format (TR4-TR5)

13.1. Overview

TR4 and TR5 use a file format with the extension `PAK` for certain files (mostly pictures). This file format is actually a container for raw binary content, compressed using zlib.

13.2. Layout

```
struct pak_file
{
  uint32_t UncompressedSize; // Uncompressed size of data (4 bytes)
  uint8_t CompressedData[]; // zlib-compressed data (read until EOF)
}
```

The `UncompressedSize` field is used by the game to allocate the buffer for uncompressed data. Do not put a wrong value here, or it'll result in unexpected and wrong behaviour.

14. CUTSEQ file format (TR4-TR5)

14.1. Overview

The `CUTSEQ.BIN` file is a file containing information about all the engine-rendered cutscenes (as opposite to FMVs, which are pre-rendered videos). In TR4, this file is contained in a PAK file, whose format is described above, and the resulting file is called `CUTSEQ.PAK`. In TR5, like many other things (e.g. level files), the file is not compressed, and is called `CUTSEQ.BIN`.

14.2. Layout

```
uint8_t DEL[8]; // "(C) DEL!", for Derek Leigh-Gilchrist
cutscene_header Cutscenes[N]; // N = 30 for TR4, 44 for TR5, 4 for Times Demo
uint8_t Padding[]; // Empty space between header and data
uint8_t CutsceneData[];

struct cutscene_header // 8 bytes
{
  uint32_t Offset; // Offset relative to start of file
  uint32_t Size; // Size in bytes
}

struct cutscene_data
{
  uint16_t NumActors; // Actor 1 is always Lara (slot ID 0)
  uint16_t NumFrames;
  int32_t OriginX; // Origin coordinates are in TR world coordinates
  int32_t OriginY; // Negative Y is up
  int32_t OriginZ;
  int32_t AudioTrackIndex; // -1 means no audio track
  uint32_t CameraDataOffset;
  actor_slot_header Actors[NumActors];
  camera_data CameraData;
  uint8_t Padding[];
  uint8_t ActorData[];
  uint8_t Padding[];
}

struct actor_slot_header // 8 bytes
{
  uint32_t DataOffset;
  uint16_t SlotNumber; // TR model slot ID number
  uint16_t NumNodes;   // Same as number of meshes in model
}

struct camera_data
{
  position_header TargetHeader;
  position_header CameraHeader;
  packed_coord TargetPosition;
  packed_coord CameraPosition;
}

struct actor_data
{
  mesh_header Meshes[NumNodes];
  mesh_data MeshData[NumNodes];
}
```

```
struct mesh_data
{
  packed_coord PositionData;
  packed_coord RotationData;
}

struct position_header // 14 bytes
{
  int16_t StartX;
  int16_t StartY;
  int16_t StartZ;
  uint16_t AxisBitsizes; // X = bits 14-11, Y = 9-6, Z = 4-1
  uint16_t NumValuesX;
  uint16_t NumValuesY;
  uint16_t NumValuesZ;
}

struct rotation_header // 14 bytes
{
  // 1024 = 360 degrees
  int16_t StartX;
  int16_t StartY;
  int16_t StartZ;
  uint16_t AxisBitsizes; // X = bits 14-11, Y = 9-6, Z = 4-1
  uint16_t NumValuesX;
  uint16_t NumValuesY;
  uint16_t NumValuesZ;
}

struct packed_coord // (variable length)
{
  dynamic Xaxis; // todo: explain better
  dynamic Yaxis; // core design, why did you make this
  dynamic Zaxis;
}
```

14.2.1. Notes

In TR4 CUTSEQ.PAK, DEL (Derek Leigh-Gilchrist) left a hidden message in the first Padding section:

```
Cutseq.JIZ , Compiled by Del using the one and only 'ASMLE.EXE'
Ok, I`ve got about 1.5k of padding here, so enjoy my ramblings...
Keep your greasy mits off my packed data...
Greets to...
Alex,Damon,Rich,Charlie,Jon,Dan,Dude,Martin,Jens,DaveS,DaveM,ZeoGrad and all the
usual...
Tombraider IV Delta-Packed Animation Data (C) 1999 Core Design.
Sector padded for hotness...
Format:
dc.w num_actors
dc.w num_frames
dc.l orgx,orgy,orgz
dc.l audio_track
dc.l packed_camera_data_offset
dc.l packed_actor_data_offset
dc.w object_slot
dc.w num_nodes
nice eh?
hack away my friends...
NUDE CHEAT ALERT... NUDE CHEAT ALERT...
maybe...
EMAIL: del@nlights.demon.co.uk
OR del@core-design.com
Developer Credits:
Coding: Del,Gibby,Chris,Rich & Tom
Delta Compressor: MJ
Animation: Jerr
Art: Jibber,Pete,Phil,Andy,Rich,Jamie
Sound: Pete
FMV: Pete,Dave and some others...
Thanks to...
PsyQ,SCEE,MartinJ and the GNU people...
Don`t forget, ** PC-Engine RULES **
BTW people, 30% of the entire game is MIPS.
The rest is 'C' , but luckily GNU isn`t as dry as it used to be...
```

```
Some decent(ish) links:
http://www.nlights.demon.co.uk
http://www.core-design.com
http://www.hu6280.com
http://www.geeknews.com
http://www.hotmail.com
http://www.hitbox.com
http://www.tombraider.com
http://www.ign64.com
http://www.rareware.com
http://www.eidos.com
Special greet to my baby girl Abigail, and my Wife(?) Caroline...
See you in TR5.... bwhahahah
```

TR5 CUTSEQ.BIN also contains a message:

```
'cutseq.asm' Compiled by Del - 18:08:53 Thursday 26th of October 2000
```

15. Catalogues

This section contains reference catalogues of different game assets. Primarily it's entity types, but in the future this section may be extended to include audiotracks, sound samples, animations, state numbers, and so on.

15.1. Entity Types

There are some guidelines to entity table:

- Pick-up items will be marked in blue.
- Nullmeshes (service entities with no render and collision) will be marked in red.
- Helper entities never placed in map (e.g. additional Lara animations) will be marked in green.
- Unused entities (with no code attached to them) will be marked in purple.
- Sprite entities will be marked as **bold**.
- Menu items will be marked as *italic*.

In all games, Lara is always an entity with ID #0.

15.1.1. Tomb Raider 1

ID	Entity Name	Notes
0	Lara	Including Lara skin
1	Lara pistols animation	Animations used for pistol shooting
2	Lara shotgun animation	As above, for shotgun
3	Lara magnums animation	As above, for magnums
4	Lara uzis animation	As above, for uzis
5	Lara misc	Various additional anims and models used across the game (Home suit, wounded Lara, Gold Lara etc.)
6	Doppelganger	Mirrors Lara behaviour
7	Wolf	
8	Bear	
9	Bat	
10	Crocodile (on land)	
11	Crocodile (in water)	
12	Lion (male)	

ID	Entity Name	Notes
13	Lion (female)	
14	Panther	
15	Gorilla	
16	Rat (on land)	
17	Rat (in water)	
18	T-Rex	
19	Raptor	
20	Mutant	Flying Atlantean mutant
21	Mutant spawn point 1	Requires model ID #20 present. Spawns same ID, but with on-land and shooting behaviour.
22	Mutant spawn point 2	As above, but without shooting behaviour.
23	Centaur mutant	
24	Mummy	
25	DinoWarrior	Leftover from beta versions, unused in final game
26	Fish	Leftover from beta versions, unused in final game
27	Larson	Full name: **Larson Conway**
28	Pierre	Full name: **Pierre Dupont**
29	Skateboard	Linked to entity ID# 30 at runtime
30	Skateboard Kid	Full name: **Jerome Johnson**
31	The Cowboy	
32	Kold	Full name: **Kin Kade**, previously known as **Mr. T**
33	Winged Natla	
34	Torso Boss	
35	Falling block	Hard collision above floor level, trigger should be in sector to activate
36	Swinging blade	
37	Teeth spikes	
38	Rolling ball	
39	Dart	Projectile, dynamically generated by entity ID #40
40	Dart emitter	
41	Lifting door	Acts in reverse with activation mask set on start-up
42	Slamming doors	
43	Sword of Damocles	
44	Thor's hammer's handle	
45	Thor's hammer's block	Linked to handle at runtime
46	Thor's lightning ball	Only first mesh is rendered, others are nullmesh pointers for lighting strikes
47	Barricade	Used to block final door in LEVEL4.PHD
48	Pushable block 1	Adds value of (4 x 256 = 1024) to floordata height below

ID	Entity Name	Notes
49	Pushable block 2	As above
50	Pushable block 3	As above
51	Pushable block 4	As above
52	Moving block	Adds value of (8 x 256 = 2048) to floordata height below
53	Falling ceiling	
54	Sword of Damocles	Duplicate of entity ID #43
55	Wall switch	
56	Underwater switch	
57	Door 1	When closed, puts WALL (0x81) property to sector(s) behind, recursively including sector in neighbour room, if collisional portal is present
58	Door 2	As above
59	Door 3	As above
60	Door 4	As above
61	Door 5	As above
62	Door 6	As above
63	Door 7	As above
64	Door 8	As above
65	Trapdoor 1	When closed, blocks portal below, if exists
66	Trapdoor 2	As above
68	Bridge (flat)	Trigger should be in sector to be standable
69	Bridge tilt 1	Trigger should be in sector to be standable
70	Bridge tilt 2	Trigger should be in sector to be standable
71	*Passport (opening)*	
72	*Compass*	
73	*Lara's Home photo*	
74	Animating 1	Used as cogs in LEVEL3A.PHD
75	Animating 2	As above
76	Animating 3	As above
77	Cutscene actor 1	
78	Cutscene actor 2	
79	Cutscene actor 3	
80	Cutscene actor 4	
81	*Passport (closed)*	
82	*Map*	Present only in beta versions
83	Savegame crystal	Unused in PC versions
84	**Pistols**	
85	**Shotgun**	

ID	Entity Name	Notes
86	**Magnums**	
87	**Uzis**	
88	**Pistol ammo**	No actual effect on inventory
89	**Shotgun ammo**	
90	**Magnum ammo**	
91	**Uzi ammo**	
92	**Explosive**	Present only in beta versions
93	**Small medipack**	Restores 1/2 of Lara HP
94	**Large medipack**	Restores Lara HP to maximum
95	*Sunglasses*	
96	*Cassette player*	
97	*Direction keys*	
98	*Flashlight*	
99	*Pistols*	
100	*Shotgun*	
101	*Magnums*	
102	*Uzis*	
103	*Pistol ammo*	
104	*Shotgun ammo*	
105	*Magnum ammo*	
106	*Uzi ammo*	
107	*Explosive*	Present only in beta versions
108	*Small medipack*	
109	*Large medipack*	
110	**Puzzle 1**	
111	**Puzzle 2**	
112	**Puzzle 3**	
113	**Puzzle 4**	
114	*Puzzle 1*	
115	*Puzzle 2*	
116	*Puzzle 3*	
117	*Puzzle 4*	
118	Puzzle hole 1	Swaps to entity ID #122 when entity ID #114 is used
119	Puzzle hole 2	Swaps to entity ID #123 when entity ID #115 is used
120	Puzzle hole 3	Swaps to entity ID #124 when entity ID #116 is used
121	Puzzle hole 4	Swaps to entity ID #125 when entity ID #117 is used
122	Puzzle done 1	

ID	Entity Name	Notes
123	Puzzle done 2	
124	Puzzle done 3	
125	Puzzle done 4	
126	**Lead bar**	Used against entity ID #128 to transform into entity ID #110
127	*Lead bar*	
128	Midas gold touch	When Lara is standing in same sector, turns her to gold. When entity ID #127 applied in radius of ~1/2 sector, perform transformation to entity ID #114
129	**Key 1**	
130	**Key 2**	
131	**Key 3**	
132	**Key 4**	
133	*Key 1*	
134	*Key 2*	
135	*Key 3*	
136	*Key 4*	
137	Keyhole 1	Used with entity ID #129
138	Keyhole 2	Used with entity ID #130
139	Keyhole 3	Used with entity ID #131
140	Keyhole 4	Used with entity ID #132
143	Scion piece	Special way (next to, not below) and animation for pick-up
145	Scion (shootable)	Used in LEVEL10C.PHD
146	Scion	Used in LEVEL10B.PHD
147	Scion holder	
150	*Scion piece*	
151	**Explosion**	
153	**Water ripples**	Emitted by entity ID #170 and Lara going underwater
155	**Bubbles**	Emitted by Lara underwater
158	**Blood**	
160	**Smoke**	
161	Centaur statue	
162	Natla's Mines shack	Produces no actual collision, which is done via flipmaps
163	Mutant egg (small)	Spawns different mutant types, according to own's initial activation mask
164	**Ricochet**	
165	**Sparkles**	Used for Midas golden effect
166	Gunflare	Rendered when shooting
169	Camera target	
170	Waterfall mist	Generates water ripples below

ID	Entity Name	Notes
172	Mutant bullet	Projectile, dynamically generated by mutant
173	Mutant grenade	As above
176	**Lava particles**	
177	Lava particle emitter	Produces sound and bouncing sprite bubbles
178	**Flame**	
179	Flame emitter	Generates flame sprite sequence, sets Lara on fire in radius of ~1/2 sector
180	Flowing Atlantean lava	When activated, moves until stopped by wall or slope
181	Mutant egg (big)	For Torso Boss
182	Motorboat	Produces no actual collision, which is done via flipmaps
183	Earthquake	Shakes camera and plays several rumble sound FXs
189	Lara's ponytail	Never finished and never used in game, present in LEVEL3A.PHD
190	**Font graphics**	
191	**Plant 1**	
192	**Plant 2**	
193	**Plant 3**	
194	**Plant 4**	
195	**Plant 5**	
200	**Bag 1**	
204	**Bag 2**	
212	**Rock 1**	
213	**Rock 2**	
214	**Rock 3**	
215	**Bag 3**	
216	**Debris 1**	
217	**Debris 2**	
231	**Debris 3**	
233	**Inca mummy**	
236	**Debris 4**	
237	**Debris 5**	
238	**Debris 6**	
239	**Debris 7**	

15.1.2. Tomb Raider 2

ID	Entity Name	Notes
0	Lara	Including Lara skin
1	Lara pistols animation	Same action as in TR1
2	Lara's ponytail	Hardcoded to attach to Lara's head

ID	Entity Name	Notes
3	Lara shotgun animation	Same action as in TR1
4	Lara automags animation	As above, for automags
5	Lara uzis animation	As above, for uzis
6	Lara M16 animation	As above, for M16
7	Lara grenade gun animation	As above, for grenade gun
8	Lara harpoon gun animation	As above, for harpoon gun
9	Lara flare animation	As above, for flare
10	Lara snowmobile animation	Used with snowmobile vehicles
11	Lara boat animation	Used with boat vehicles
12	Lara misc animations	Various additional anims used across the game (Talion gong anim, custom die anims)
13	Red snowmobile	Vehicle; goes faster than black one, but can't shoot
14	Boat	Vehicle
15	Doberman	
16	Masked goon 1	
17	Masked goon 2	Borrows animations from entity ID #16
18	Masked goon 3	As above
19	Knifethrower	
20	Shotgun goon	
21	Rat	
22	Dragon (front)	
23	Dragon (back)	Attaches to entity ID #22 at runtime
24	Gondola	Shatterable by boat vehicle
25	Shark	
26	Yellow moray eel	
27	Black moray eel	
28	Barracuda	
29	Scuba diver	
30	Gunman 1	
31	Gunman 2	
32	Stick-wielding goon 1	
33	Stick-wielding goon 2	Can't climb
34	Flamethrower goon	
36	Spider	
37	Giant spider	
38	Crow	
39	Tiger / Snow leopard	
40	Marco Bartoli	Not real NPC, laying still in Dragon's Lair

ID	Entity Name	Notes
41	Xian Guard w/spear	
42	Xian Guard w/spear statue	Transforms to entity #41 on activation
43	Xian Guard w/sword	
44	Xian Guard w/sword statue	Transforms to entity #43 on activation
45	Yeti	
46	Bird monster (guards Talion)	
47	Eagle	
48	Mercenary 1	
49	Mercenary 2	Black ski mask, gray jacket
50	Mercenary 3	Black ski mask, brown jacket
51	Black snowmobile	Vehicle; goes slower than red one, but can shoot
52	Mercenary snowmobile driver	
53	Monk with long stick	
54	Monk with knife-end stick	
55	Falling block	
57	Loose boards	Same action as entity ID #55
58	Swinging sandbag / Spiky ball	
59	Teeth spikes / Glass shards	
60	Rolling ball	
61	Disc	Acts same way as dart in TR1
62	Discgun	Acts same way as dart emitter in TR1
63	Drawbridge	
64	Slamming door	
65	Elevator	Trigger should be in sector to be standable
66	Minisub	
67	Pushable block 1	Same action as in TR1
68	Pushable block 2	As above
69	Pushable block 3	As above
70	Pushable block 4	As above
71	Lava bowl	
72	Breakable window 1	Must be shot to break
73	Breakable window 2	Must be jumped through to break
76	Airplane propeller	
77	Power saw	
78	Overhead pulley hook	
79	Falling ceiling / Sandbag	
80	Rolling spindle	

ID	Entity Name	Notes
81	Wall-mounted knife blade	
82	Statue with knife blade	
83	Multiple boulders / snowballs	
84	Detachable icicles	
85	Spiky wall	
86	Bounce pad	Bounces Lara up
87	Spiky ceiling	
88	Tibetan bell	Activates when shot
91	Snowmobile belt	Two meshes are swapped at runtime according to current snowmobile state
92	Wheel knob	
93	Small wall switch	
94	Underwater propeller	
95	Air fan	
96	Swinging box / spiky ball	
97	Cutscene actor 1	
98	Cutscene actor 2	
99	Cutscene actor 3	
100	**UI frame**	Used to create UI elements
101	Rolling storage drums	
102	Zipline handle	When used, slides until there's an obstacle ~1.5 sectors ahead; position is reset on every triggering
103	Push-button switch	
104	Wall switch	
105	Underwater switch	
106	Door 1	Same action as in TR1
107	Door 2	As above
108	Door 3	As above
109	Door 4	As above
110	Door 5	As above
111	Lifting door 1	Same action as in TR1
112	Lifting door 2	As above
113	Lifting door 3	As above
114	Trapdoor 1	Same action as in TR1
115	Trapdoor 2	As above
116	Trapdoor 3	As above
117	Bridge flat	Same action as in TR1
118	Bridge tilt 1	Same action as in TR1

ID	Entity Name	Notes
119	Bridge tilt 2	Same action as in TR1
120	*Secret 1*	Jade dragon
121	*Secret 2*	Silver dragon
122	*Lara's home photo*	
123	Cutscene actor 4	
124	Cutscene actor 5	
125	Cutscene actor 6	
126	Cutscene actor 7	
127	Cutscene actor 8	
128	Cutscene actor 9	
129	Cutscene actor 10	
130	Cutscene actor 11	
133	*Secret 3*	Gold dragon
134	*Map*	
135	**Pistols**	
136	**Shotgun**	
137	**Automags**	
138	**Uzi**	
139	**Harpoon gun**	
140	**M16**	
141	**Grenade gun**	
142	**Pistol ammo**	No actual effect on inventory
143	**Shotgun ammo**	
144	**Auto-pistol ammo**	
145	**Uzi ammo**	
146	**Harpoon gun ammo**	
147	**M16 ammo**	
148	**Grenadegun ammo**	
149	**Small medipack**	
150	**Large medipack**	
151	**Flares**	
152	Flare	Spawns when Lara throws flare away, re-pickupable
153	*Sunglasses*	
154	*CD player*	
155	*Direction keys*	
157	*Pistols*	
158	*Shotgun*	

ID	Entity Name	Notes
159	*Automags*	
160	*Uzi*	
161	*Harpoon gun*	
162	*M16*	
163	*Grenade gun*	
164	*Pistol ammo*	
165	*Shotgun ammo*	
166	*Automag ammo*	
167	*Uzi ammo*	
168	*Harpoon gun ammo*	
169	*M16 ammo*	
170	*Grenadegun ammo*	
171	*Small medipack*	
172	*Large medipack*	
173	*Flares*	
174	**Puzzle 1**	
175	**Puzzle 2**	
176	**Puzzle 3**	
177	**Puzzle 4**	
178	*Puzzle 1*	
179	*Puzzle 2*	
180	*Puzzle 3*	
181	*Puzzle 4*	
182	Puzzle hole 1	Swaps to entity ID #186 when entity ID #178 is used
183	Puzzle hole 2	Swaps to entity ID #187 when entity ID #179 is used
184	Puzzle hole 3	Swaps to entity ID #188 when entity ID #180 is used
185	Puzzle hole 4	Swaps to entity ID #189 when entity ID #181 is used
186	Puzzle done 1	
187	Puzzle done 2	
188	Puzzle done 3	
189	Puzzle done 4	
190	**Secret 1**	
191	**Secret 2**	
192	**Secret 3**	
193	**Key 1**	
194	**Key 2**	
195	**Key 3**	

ID	Entity Name	Notes
196	**Key 4**	
197	*Key 1*	
198	*Key 2*	
199	*Key 3*	
200	*Key 4*	
201	Keyhole 1	Used with entity ID #193
202	Keyhole 2	Used with entity ID #194
203	Keyhole 3	Used with entity ID #195
204	Keyhole 4	Used with entity ID #196
205	**Quest item 1**	
206	**Quest item 2**	Talion
207	*Quest item 1*	
208	*Quest item 2*	
209	Dragon explosion effect 1	
210	Dragon explosion effect 2	
211	Dragon explosion effect 3	
212	Alarm	Plays looped sound ID #332
213	Dripping water	Randomly plays sound ID #329
214	T-Rex	
215	Singing birds	Randomly plays sound ID #316
216	Bartoli's Hideout clock	
217	Placeholder	Purpose unknown
218	Dragon bones (front)	Transformed from entity ID #22 when dragon dies
219	Dragon bones (back)	Transformed from entity ID #23 when dragon dies
220	**Extra fire**	Used in Ice Palace
222	Aquatic Mine (Venice)	
223	Menu background	
224	**Gray disk**	Purpose unknown
225	Gong stick	Contains animation for gong stick itself, Lara anim is placed in ID #12
226	Gong	Acts same way as ID #202, i.e. entity ID #194 can be used
227	Detonator box	
228	Helicopter (Diving Area)	Flies upwards and away
229	**Explosion**	Same action as in TR1
230	**Water ripples**	As above
231	**Bubbles**	As above
233	**Blood**	As above
235	**Flare sparkles**	Used on activated flare, animation is done via randomized rotation

ID	Entity Name	Notes
236	**Glow**	Overlay for M16 gunflare mesh
238	**Ricochet**	Same action as in TR1
240	Gunflare	Same action as in TR1, except M16
241	M16 gunflare	Used when shooting M16 only
243	Camera target	Same action as in TR1
244	Waterfall mist	As above
245	Harpoon	
247	Placeholder	Purpose unknown
248	Grenade (single)	Projectile, generated when shooting grenadegun
249	Harpoon (flying)	Projectile, generated when shooting harpoon gun
250	**Lava particles**	Same action as in TR1
251	Lava / air particle emitter	As above
252	**Flame**	As above
253	Flame emitter	As above
254	Skybox	Rendered when any room with *outside* flag set is visible
255	**Font graphics**	
256	Monk	
257	Door bell	Plays sound ID #334 once
258	Alarm bell	Plays looped sound ID #335
259	Helicopter	Travels around 30 sectors, then deactivates itself
260	Winston	
262	Lara cutscene placement	Used in last level to engage shower cutscene
263	Shotgun animation	Used in end game cutscene (shower)
264	Dragon explosion emitter	Activates when Lara at a close range, produces animation sequence using entity models ID #209-211, then spawns entity ID #22 at the end

15.1.3. Tomb Raider 3

ID	Entity Name	Notes
0	Lara	Animations only, skin is now placed in ID #315
1	Lara pistol animation	Same action as in TR2
2	Lara's ponytail	As above
3	Lara shotgun animation	As above
4	Lara Desert Eagle animation	One-handed gun animation
5	Lara Uzi animation	Same action as in TR2
6	Lara MP5 animation	As above
7	Lara rocket launcher animation	
8	Lara grenade gun animation	Same action as in TR2
9	Lara harpoon gun animation	As above

ID	Entity Name	Notes
10	Lara flare animation	As above
11	Lara UPV animation	Animations for UPV vehicle
12	UPV	Vehicle
14	Kayak	As above
15	Inflatable boat	As above
16	Quadbike	As above
17	Mine cart	As above
18	Big gun	Mannable gun (Lara can operate it)
19	Hydro propeller (?)	
20	Tribesman with spiked axe	
21	Tribesman with poison-dart gun	
22	Dog	
23	Rat	
24	Kill All Triggers	Deactivates all triggered entities, sometimes buggy
25	Killer whale	
26	Scuba diver	
27	Crow	
28	Tiger	
29	Vulture	
30	Assault-course target	
31	Crawler mutant in closet	
32	Crocodile (in water)	
34	Compsognathus	
35	Lizard man	
36	Puna	
37	Mercenary	
38	Raptor hung by rope	Used as fish bait in Crash Site (CRASH.TR2)
39	RX-Tech guy in red jacket	
40	RX-Tech guy with gun	Dressed like flamethrower guy (ID #50)
41	Dog (Antarctica)	
42	Crawler mutant	
44	Tinnos wasp	
45	Tinnos monster	
46	Brute mutant (with claw)	
47	Tinnos wasp respawn point	When activated, constantly generates specific number of wasps
48	Raptor respawn point	Hardcoded to respawn number of raptors previously unkilled in level
49	Willard spider	

ID	Entity Name	Notes
50	RX-Tech flamethrower guy	
51	London mercenary	
53	Punk	"Damned" stick-wielding goon
56	London guard	
57	Sophia Lee	
58	Cleaner robot	Also called "Thames Wharf machine"
60	MP with stick	
61	MP with gun	
62	Prisoner	
63	MP with sighted gun and night sight	
64	Gun turret	
65	Dam guard	
66	Tripwire	
67	Electrified wire	
68	Killer tripwire	
69	Cobra / Rattlesnake	
70	Shiva	
71	Monkey	
73	Tony Firehands	
74	AI Guard	
75	AI Ambush	
76	AI Patrol 1	
77	AI Modify	
78	AI Follow	
79	AI Patrol 2	
80	AI Path	Used by Willard spider boss to circle around meteorite cavern
81	AI Check	Used by Willard spider boss to check if Lara is in artifact chamber and shoot if she's in
82	Unknown	
83	Falling block	
86	Swinging thing	
87	Teeth spikes / Barbed wire	
88	Rolling ball / Barrel	
89	Giant boulder	Appears in Temple of Puna
90	Disc	Mesh is a leftover from TR2 discgun, engine uses wireframe darts instead
91	Dart shooter	
94	Skeleton trap / Slamming door	

ID	Entity Name	Notes
97	Pushable block 1	
98	Pushable block 2	
101	Destroyable boarded-up window	
102	Destroyable boarded-up window / wall	
106	Area 51 swinger	
107	Falling ceiling	
108	Rolling spindle	
110	Subway train	
111	Wall knife blade / Knife disk	
113	Detachable stalactites	
114	Spiky wall	Same action as in TR2
116	Spiky vertical wall / Tunnel borer	
117	Valve wheel / Pulley	
118	Small wall switch	
119	Damaging animating 1	Underwater propeller / Diver sitting on block / Underwater rotating knives / Meteorite, causes damage on collision
120	Damaging animating 2	Fan, causes damage on collision
121	Damaging animating 3	Heavy stamper / Grinding drum / Underwater rotating knives, causes damage on collision
122	Shiva statue	Original petrified state, never activates
123	Monkey medipack meshswap	Monkey head gets replaced by this when it picks up medipack
124	Monkey key meshswap	Monkey head gets replaced by this when it picks up key
125	**UI frame**	Used to create UI elements
127	Zipline handle	Same action as in TR2
128	Push-button switch	
129	Wall switch	
130	Underwater switch	
131	Door 1	
132	Door 2	
133	Door 3	
134	Door 4	
135	Door 5	
136	Door 6	
137	Door 7	
138	Door 8	
139	Trapdoor 1	
140	Trapdoor 2	
141	Trapdoor 3	

ID	Entity Name	Notes
142	Bridge flat	
143	Bridge tilt 1	
144	Bridge tilt 2	
145	Passport (opening up)	
146	Stopwatch	
147	Lara's Home photo	
148	Cutscene actor 1	
149	Cutscene actor 2	
150	Cutscene actor 3	
151	Cutscene actor 4	
152	Cutscene actor 5	
153	Cutscene actor 6	
154	Cutscene actor 7	
155	Cutscene actor 8	
156	Cutscene actor 9	
158	Passport (closed)	
159	Map	
160	Pistols	
161	Shotgun	
162	Desert Eagle	
163	Uzis	
164	Harpoon gun	
165	MP5	
166	Rocket launcher	
167	Grenade launcher	
168	Pistol ammo	
169	Shotgun ammo	
170	Desert Eagle ammo	
171	Uzi ammo	
172	Harpoons	
173	MP5 ammo	
174	Rockets	
175	Grenades	
176	Small medipack	
177	Large medipack	
178	Flares	
179	Flare	Spawns when Lara throws flare away, re-pickupable

ID	Entity Name	Notes
180	Savegame crystal	
181	*Sunglasses*	
182	*Portable CD Player*	
183	*Direction keys*	
184	*Globe*	For indicating destinations in "Select level" dialog
185	*Pistols*	
186	*Shotgun*	
187	*Desert Eagle*	
188	*Uzis*	
189	*Harpoon gun*	
190	*MP5*	
191	*Rocket launcher*	
192	*Grenade gun*	
193	*Pistol ammo*	
194	*Shotgun ammo*	
195	*Desert Eagle ammo*	
196	*Uzi ammo*	
197	*Harpoons*	
198	*MP5 ammo*	
199	*Rockets*	
200	*Grenades*	
201	*Small medipack*	
202	*Large medipack*	
203	*Flares*	
204	*Savegame crystal*	
205	Puzzle 1	
206	Puzzle 2	
207	Puzzle 3	
208	Puzzle 4	
209	*Puzzle 1*	
210	*Puzzle 2*	
211	*Puzzle 3*	
212	*Puzzle 4*	
213	Slot 1 empty	Swaps to entity ID #217 when entity ID #209 is used
214	Slot 2 empty	Swaps to entity ID #218 when entity ID #210 is used
215	Slot 3 empty	Swaps to entity ID #219 when entity ID #211 is used
216	Slot 4 empty	Swaps to entity ID #220 when entity ID #212 is used

ID	Entity Name	Notes
217	Slot 1 full	
218	Slot 2 full	
219	Slot 3 full	
220	Slot 4 full	
224	Key 1	
225	Key 2	
226	Key 3	
227	Key 4	
228	*Key 1*	
229	*Key 2*	
230	*Key 3*	
231	*Key 4*	
232	Keyhole 1	Used with entity ID #224
233	Keyhole 2	Used with entity ID #225
234	Keyhole 3	Used with entity ID #226
235	Keyhole 4	Used with entity ID #227
236	Quest item 1	
237	Quest item 2	No effect on actual inventory
238	*Quest item 1*	
239	*Quest item 2*	No effect on actual inventory
240	Infada stone	
241	Element 115	
242	Eye of Isis	
243	Ora dagger	
244	*Infada stone*	
245	*Element 115*	
246	*Eye of Isis*	
247	*Ora dagger*	
272	Keys (sprite)	
273	Keys (sprite)	
276	Infada stone	
277	Element 115	
278	Eye of Isis	
279	Ora dagger	
282	Fire-breathing dragon statue	
285	Unknown visible 285	
287	Tyrannosaur	

ID	Entity Name	Notes
288	Raptor	
291	Laser sweeper	
292	Electrified Field	
294	**Shadow sprite**	Applied as a blob shadow with subtractive blending
295	Detonator switch box	
296	**Misc sprites**	Sprites for different purposes merged into single object
297	**Bubble**	
299	**Glow**	
300	Gunflare	
301	Gunflare (MP5)	
304	Look At item	
305	Waterfall mist	
306	Harpoon (single)	
309	Rocket (single)	
310	Harpoon (single)	
311	Grenade (single)	
312	Big missile	
313	Smoke	
314	Movable Boom	
315	Lara skin	
316	**Glow 2**	
317	Unknown visible 317	
318	Alarm light	
319	Light	
321	Light 2	
322	Pulsating Light	
324	Red Light	
325	Green Light	
326	Blue Light	
327	Light 3	
328	Light 4	
330	Fire	
331	Alternate Fire	
332	Alternate Fire 2	
333	Fire 2	
334	Smoke 2	
335	Smoke 3	

ID	Entity Name	Notes
336	Smoke 4	
337	Greenish Smoke	
338	Pirahnas	
339	Fish	
347	Bat swarm	
349	Animating 1	
350	Animating 2	
351	Animating 3	
352	Animating 4	
353	Animating 5	
354	Animating 6	
355	Skybox	
356	**Font graphics**	
357	Doorbell	Produces no actual sound
358	Unknown id 358	
360	Winston	
361	Winston in camo suit	Deactivates entity ID #360 when triggered
362	**Timer font graphics**	Used in Assault Course and racetrack
365	Earthquake	
366	Yellow shell casing	Spawned when firing pistols, uzis, MP5 or Desert Eagle
367	Red shell casing	Spawned when firing shotgun
370	Tinnos light shaft	
373	Electrical switch box	