REAL-TIME GEOMETRY CACHES

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MOTIVATION

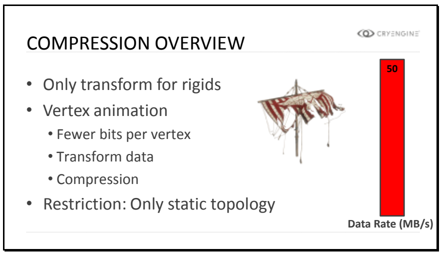
- Wanted next-gen visuals for Ryse
- Lots of VFX set pieces
- Art pipeline bottleneck (required baking to joints)
- Needed simpler way to get animations into engine
- Solution: Import Alembic

Animations like cloth, water simulations, fur
Alembic: No engine specific markup. One click to import and run. Outsourcing much easier

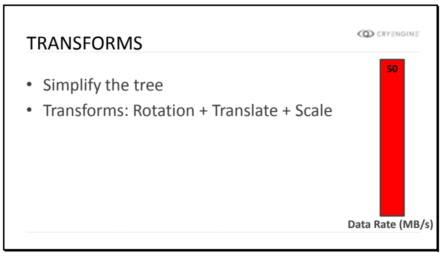
CHALLENGE

- Massive data rate?
- Naïve approach: 56 bytes per vertex (14 floats)
  - Position, UV, Normal, Tangent, Binormal, (Color)
- Sail: 30000 vertices, 30 FPS ≈ 50MB/s
- Ryse budget: 10MB/s

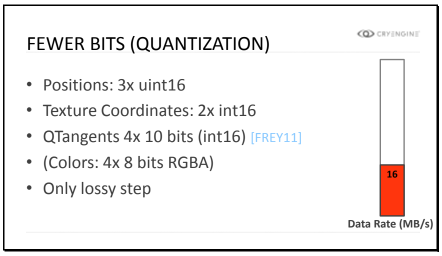
More than Alembic actually, need full tangent frames
10 MB/s is for the whole scene, not only one cache



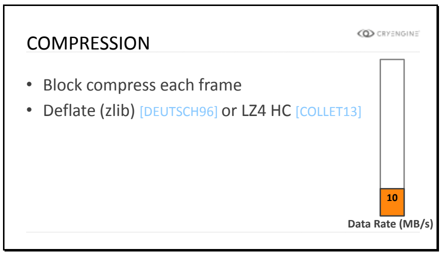
Obviously we don‘t store per frame data for rigid / non-deforming meshes
Data rate is bar is always for the sail
Transform data to help compression
Data rate meter for specific sail asset with 30.000 vertices. Data rate meter will indicate progress
on data rate reduction during the methods presented in the talk.



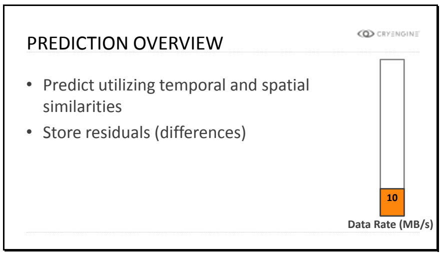
Bake down static hierarchies
Bake down animated child of animated parent
No support for shear
Transforms: 40 instead of 48 bytes. Compared to vertex animations we can neglect this. We didn‘t optimize it a lot.



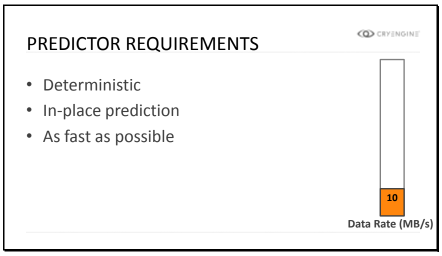
Positions defined in bbox space. mm accuracy for 64m mesh. Quantizer will use less bits if possible, artist can specify the mm precision he needs.
Texture coordinates get mapped to [-1024, 1024] which leaves enough fractional digits
Tangent frames mean only orthonormal tangent frames. Doesn‘t matter in practice for us. We use 16 bit shorts for 10 bit values because compressor works on bytes



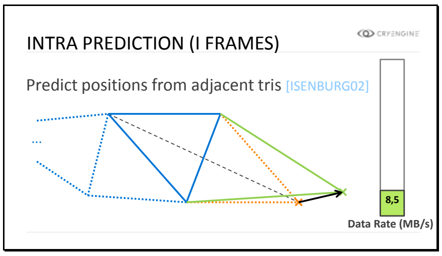
Deflate is slow but pretty good compression
LZ4 HC is usally 20% worse compression, but 10x faster decode. Almost like memcpy.
Still 10MB/s for one asset, we need to do better



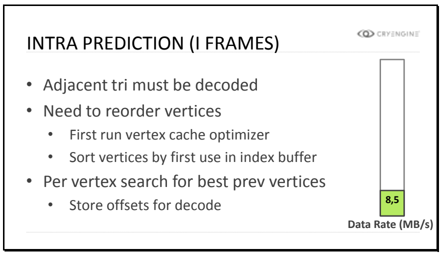
Of course need to do same prediction at runtime than at compile time, otherwise don‘t get same result
Residual symbols cluster around zero, because prediction tends to be close. The more of the same symbols, the better the compression.



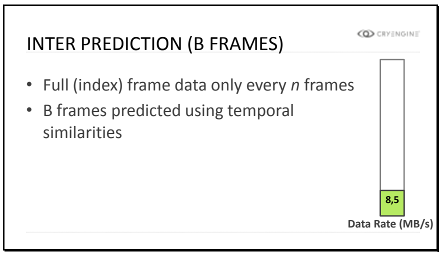
Always needs to predict exactly the same way (obvious)
No extra memory allocations on decode
Needs to decode in real time



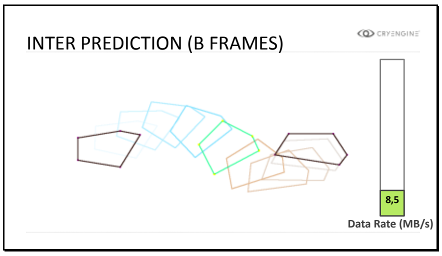
Parallelogram prediction. Extend adjacent triangles to parallelograms.
Blue: Last triangle(s) Orange: Parallelogram prediction Black arrow: Residual to store
Can do this in place: for each vertex predict, read, add, write
Also used for UVs
QTangents just use average of last two vertices, because parallelogram rule makes no sense for them
Savings depend on asset



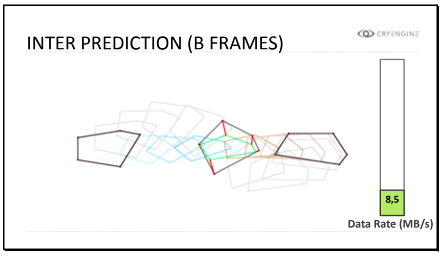
Optimizer tends to order indices so mesh gets rendered in strips
Offset only needs to be stored in file header, because we only support non-changing topology



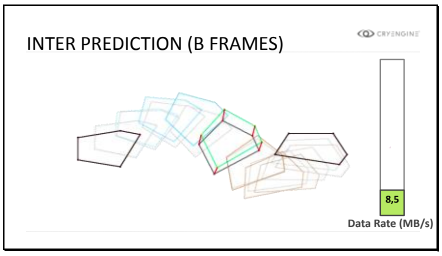
For us optimal index frame distance was about 10



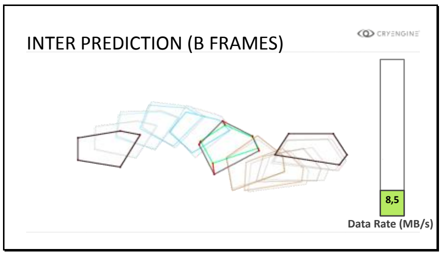
Original motion



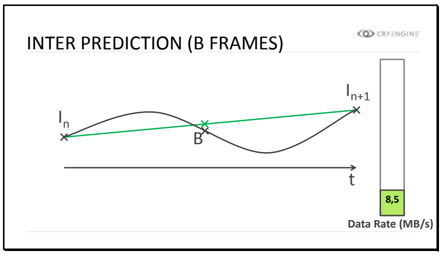
Interpolated prediction



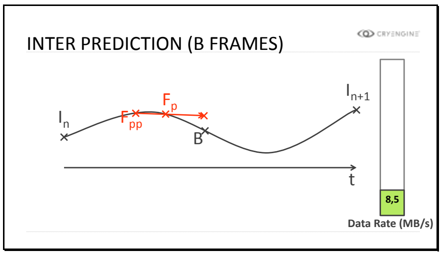
Motion prediction



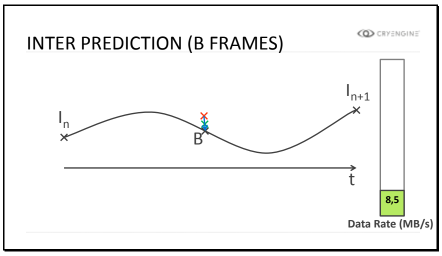
Combination of motion and interpolation prediction



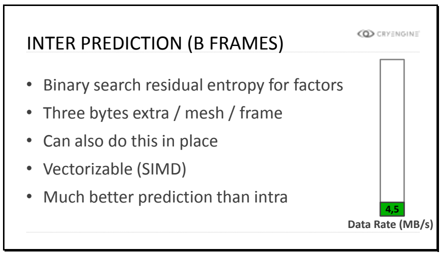
Select interpolation factor for interpolation



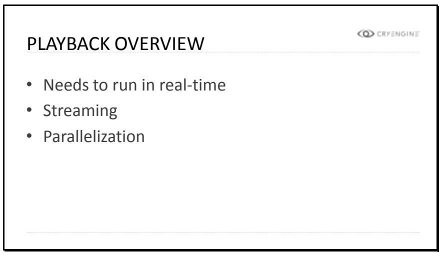
Select acceleration factor for motion



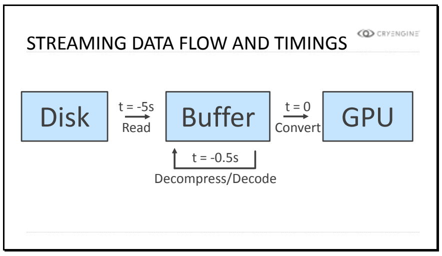
Select extrapolation factor for combination
The three factors used are the same for all vertices in mesh, so individual predictions will usually be worse than here.



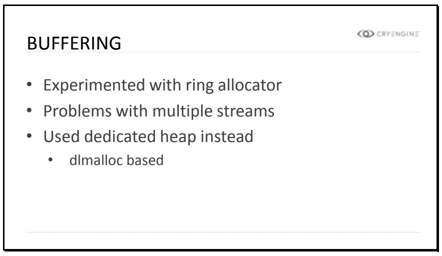
Factors get quantized to three bytes per frame for all vertices
Can use SIMD for this to predict 4 elements in parallel (some INT16 operations even on 8 elements)
Just unpack 8xINT32 -> 2x4xUINT32, mul, shift, truncate & pack again on Jaguar per interpolate/extrapolate



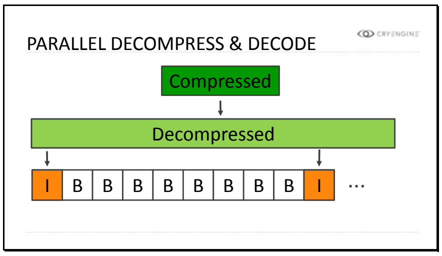
Loading time would also be a problem
Next gen CPU cores still not terribly fast



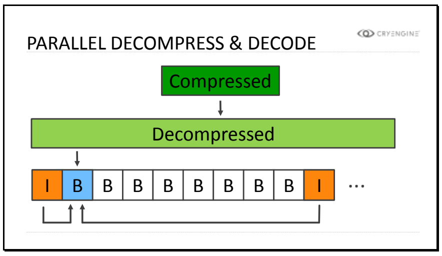
Disk reads and decompress/decode are asynchronous and non-blocking
Read combining to avoid disk seeks (>1 MB chunks)
Upload to GPU is asynchronous but render thread will wait for data
Data in buffer stays in compact disk format until decompress starts
Timings are configurable, values were choosen by experimentation



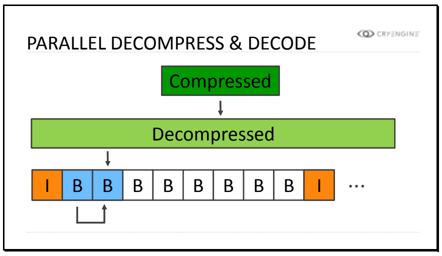
Ring buffer allocator doesn‘t work for multiple streams, because of different data rates. Would need to defragment holes. Really tried to make this work, but wasn‘t worth it in the end.
Fragmentation with normal allocator wasn‘t a big problem
128 MB for both compressed and uncompressed data



Jobs for decompression
Index frame jobs can start as soon as decompressed data is ready

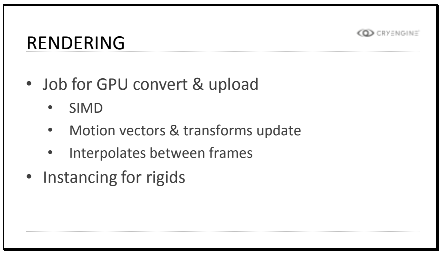


First B frame has I frames and own residuals as input (First B frame does not do acceleration prediction)



Other B frames have only last B frame and residuals as dependencies, because by induction both I frames and the last two B frames are decoded
All other B-frames depend on previous one as well
We do the synchronization for all jobs with lockless atomic counting:

- I frames get initialized to 1, first B frame after I frame to 3, all other B frames to 2
- After dependency is finished will decrease counter of dependent task and launch it when counter reaches 0



The conversion job gets launched for each job the geom cache actually gets rendered
Conversion job could possibly be avoided if GPU would directly read quantized format
The vertex shader could possibly directly support the quantized format

FUTURE DEVELOPMENT

- Support for changing topology
- Improve compression
  - Better predictors
  - Better block compression
  - Automatic skinning
- Support for physics
  - Tricky with vertex animation

All of the compression research tends to lead to require more and more computational power for little gains
Automatic skinning would be a way to do more lossy compression

SPECIAL THANKS

- Sascha Herfort, Nicolas Schulz, Bogdan Coroi, Theodor Mader, Carsten Wenzel, Chris Raine, Chris Bolte & Ivo Zoltan Frey
- The entire Ryse team and Crytek

REFERENCES

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