

Data Management for Video Analytics



Brandon Haynes, Maureen Daum, Amrita Mazumdar,
Magdalena Balazinska, Luis Ceze, & Alvin Cheung



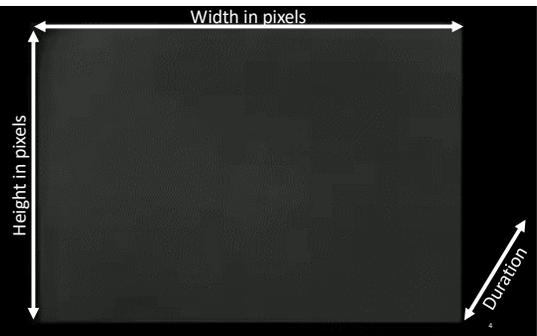
1

Video data is **everywhere**.

2

Existing systems treat video data like it's the
20TH CENTURY

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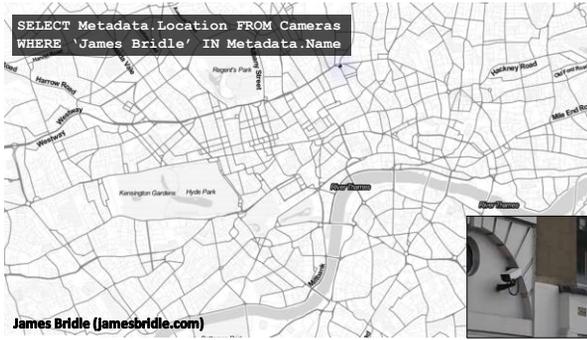
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Many recent video applications
require jointly **querying multiple cameras**,
reasoning about **position and orientation**, or
querying **complex metadata**.

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Modern Data Management for Video Analytics



LightDB
A Database System for
Virtual & Augmented Reality
Video Applications



Visual Road
A Video Data Management
Benchmark



Metastore
Efficient querying of rich
video content
(Maureen Daum)



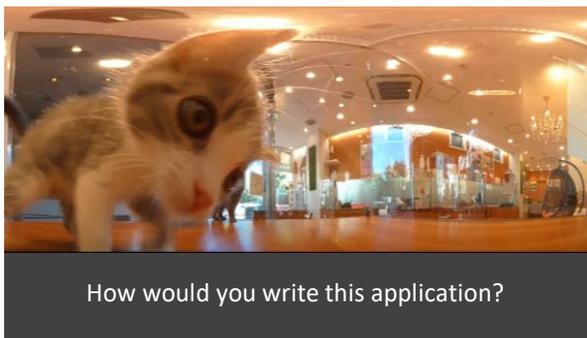
**Video
File System**
Optimized storage and
retrieval of video data

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LightDB

A Database System for
Virtual & Augmented Reality
Video Applications

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20TH CENTURY Imperative Code

```

LightDB Query
source = Scan("kittens")
detection = source.Map(detect)
result = Union(source, detection)
result.Save("output.mp4")
                    
```

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LightDB Query:

```

source = Scan("kittens")
detection = source.Map(detect)
result = Union(source, detection)
result.Save("output.mp4")
    
```

13

```

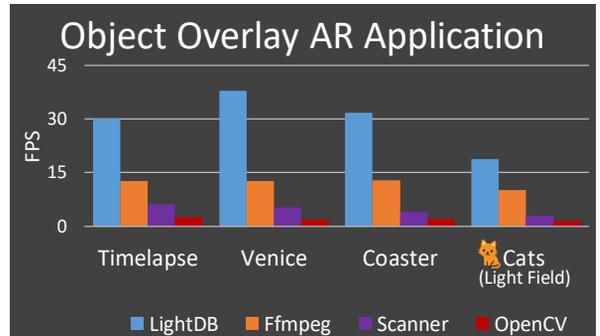
source = Scan("kittens")
detection = source.Map(detect)
result = Union(source, detection)
result.Save("output.mp4")
    
```

Logical Plan

14

Physical Plan

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Key Features:

- Data management system for VR & AR video applications
- Unified data model for panoramic (360°) and light field video
- Declarative queries with automatic optimization

Key Contributions:

- ~ 1/10 lines of code
- Up to 4x performance for real-world workloads
- Reduced client bandwidth & power requirements

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lightdb.uwdb.io

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Modern Data Management for Video Analytics

- LightDB**: A Database System for Virtual & Augmented Reality Video Applications
- Visual Road**: A Video Data Management Benchmark
- Metastore**: Efficient querying of rich video content (Maureen Daum)
- Video File System**: Optimized storage and retrieval of video data

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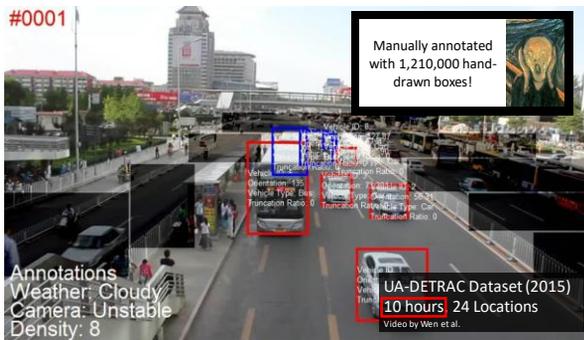
The **performance** of video systems is evaluated like it's still the **20TH CENTURY**

19

Distinct videos **performance tested** by system

Video System	# Distinct Videos
LightDB (2018)	4
Chameleon (2018)	5
Blazelt (2018)	6
NoScope (2017)	7
Focus (2018)	14
DeepLens (2019)	~16
Scanner (2018)	>100 (only 14 joined)

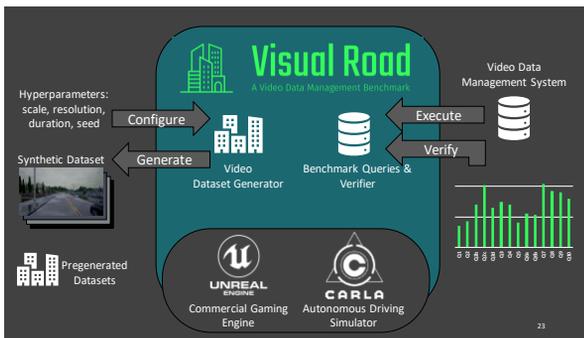
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Type	Benchmarks	Test Data
Video	(Visual Road)	Ad-Hoc Synthetic
OLTP	(TPC-H)	Synthetic
OLAP	(SSB, DWEB)	Synthetic
Streaming	(Linear Road, DTDW)	Synthetic
NoSQL	(YCSB)	Synthetic
Graph	(LDBC)	Synthetic
Privacy	(SDV)	Synthetic

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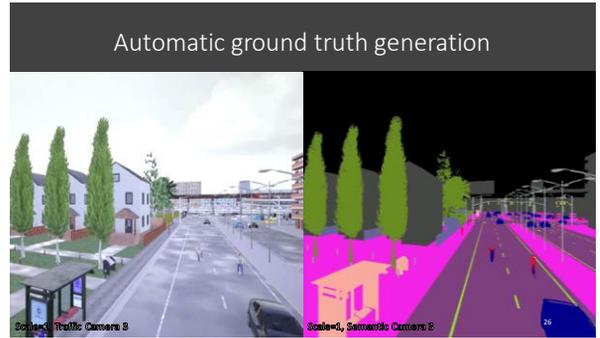
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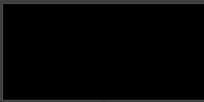
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Query 7: Object Detection

Input Input videos $\{V_1, \dots, V_n\}$
 Object detection function $A(V, O)$
 Object classes $O = \{o_1, \dots, o_m\}$

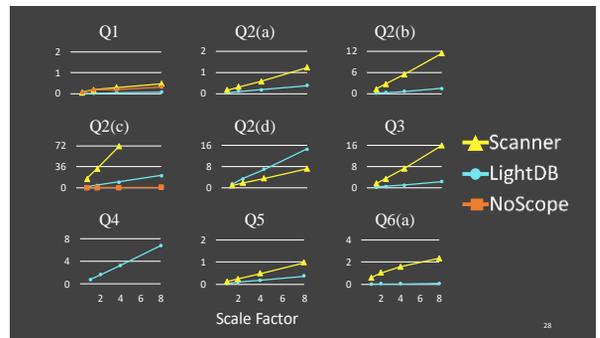
Output Videos $\{V_1^{o_1}, \dots, V_n^{o_m}\}$ where
 $V_j^{o_i} = Q_{o_i}(Q_{sa}(V_j, Q_{tc}(V_j, A, \{o_i\})))$

Traffic Camera V_j : 

Result for query instance i : 

(4 x Scale query instances) 27

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Visual Road

A Video Data Management Benchmark
visualroad.uwdb.io

Key Features:

- Video data management benchmark
- Synthetic dataset generation
- Unlimited scale, resolution, duration, and overlap
- Extensible suite of computer vision, VR, and microbenchmarks
- Applicable to both general and specialized video DBMSs



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Metastore
Efficient querying of rich video content
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Video File System
Optimized storage and retrieval of video data

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LightDB
lightdb.uwdb.io

Key Features:

- DBMS for VR & AR video applications
- Unified data model
- Declarative queries
- Automatic optimization





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A Video Data Management Benchmark
visualroad.uwdb.io

Key Features:

- Video data management benchmark
- Synthetic dataset generation
- Unlimited scale, resolution, duration
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Towards Efficient Querying of Rich Video Content

Maureen Daum




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Motivation

- We want to enable rich, content-based queries over video data
- Existing systems optimize running object detection over videos
 - As a result, they focus on simple queries only
- We want to use this metadata to enable more complex queries

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Metadata

- Object labels
- Weather conditions
- Descriptions
- License plate numbers
- Aggregates



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```
SELECT pixels FROM video WHERE dog
```



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Overlay the dog pixels from video 1 onto the background in video 2



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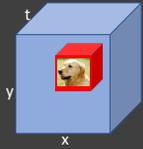
Select sequences of frames that contain increasing numbers of cats



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Metadata Model



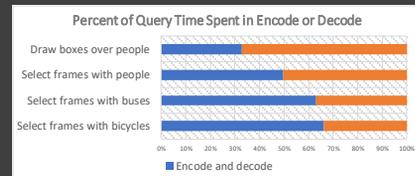
Label	Volume
Dog	$[t_0, t_1], [x_0, x_1], [y_0, y_1]$

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Executing Queries

- Videos are stored in a compressed format
- Encoding and decoding are expensive operators



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SELECT frames FROM video WHERE dog



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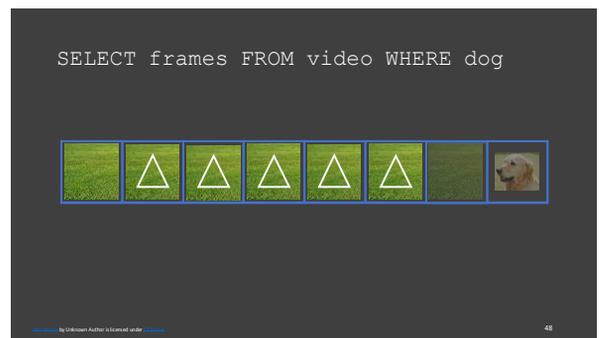
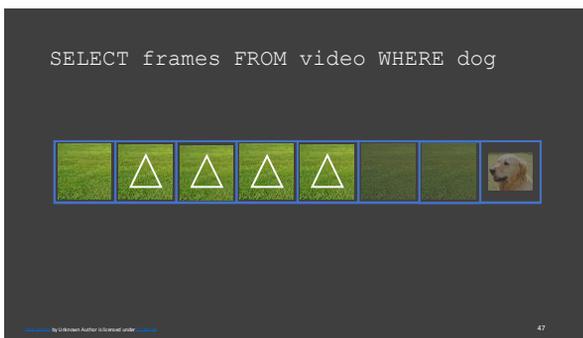
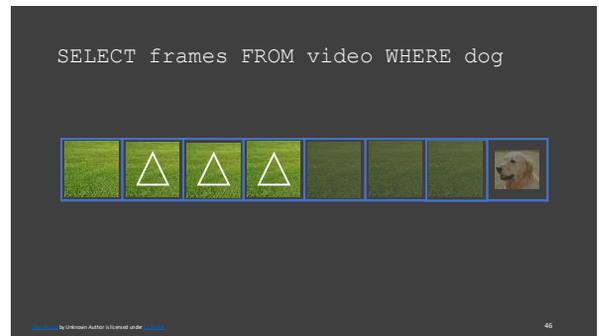
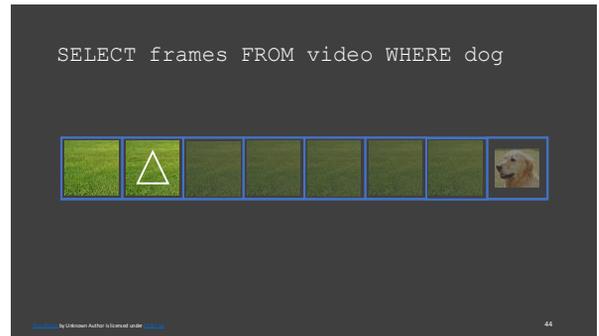
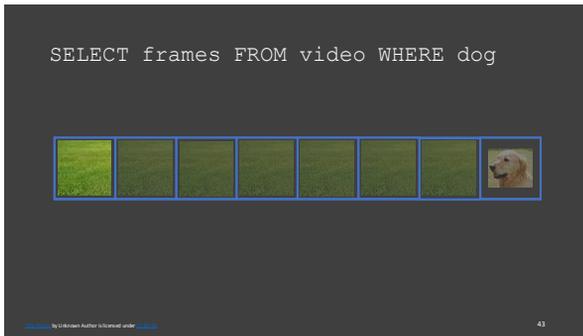
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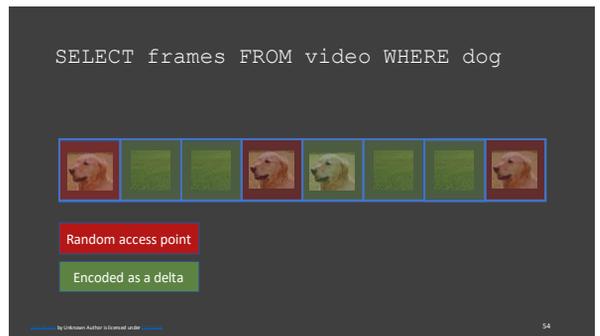
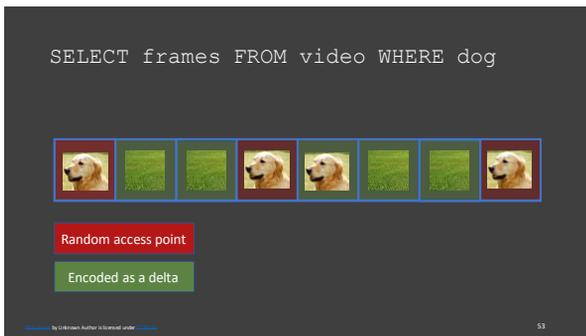
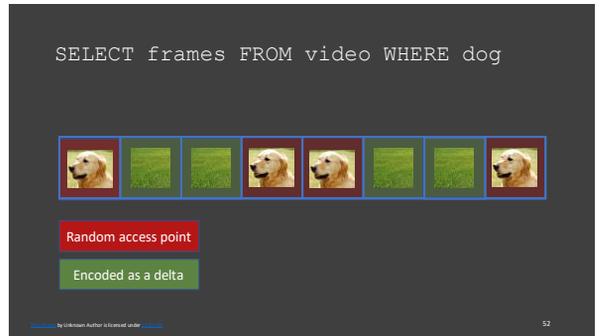
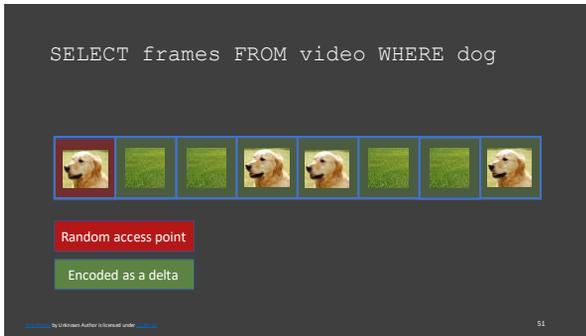
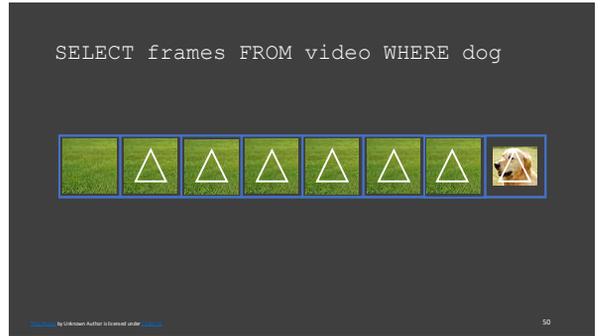
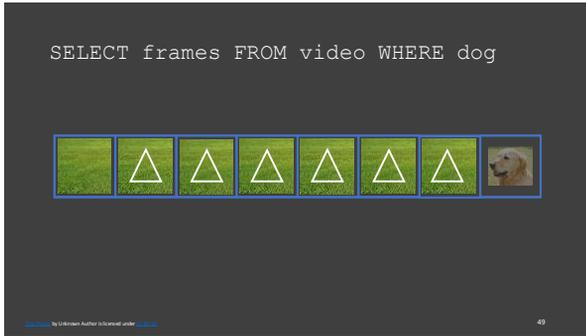
SELECT frames FROM video WHERE dog



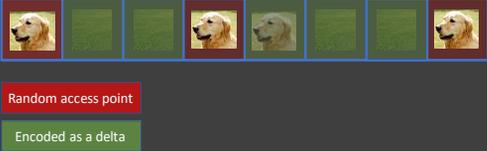
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SELECT frames FROM video WHERE dog



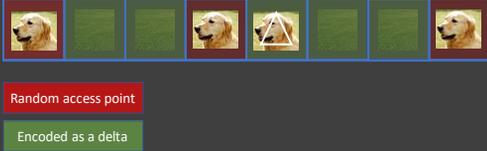
Random access point

Encoded as a delta

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SELECT frames FROM video WHERE dog



Random access point

Encoded as a delta

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SELECT pixels FROM video WHERE dog



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SELECT pixels FROM video WHERE dog



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SELECT pixels FROM video WHERE dog



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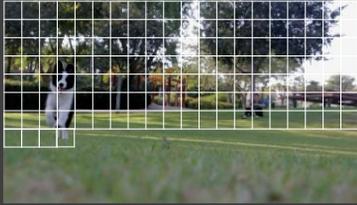
SELECT pixels FROM video WHERE dog



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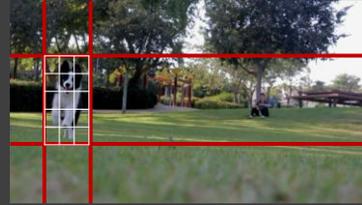
```
SELECT pixels FROM video WHERE dog
```



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```
SELECT pixels FROM video WHERE dog
```

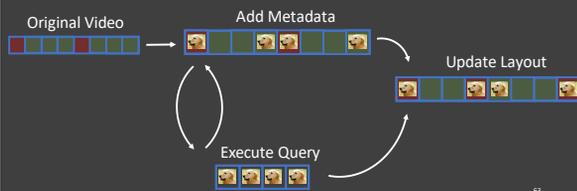


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Putting Things Together

Similar to DB cracking, incrementally partition the video and add indices



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Ongoing Work

- Measure the effectiveness of selection optimization techniques
- Investigate optimization techniques for more compute-heavy queries
- Determine how to effectively layout videos with a lot of metadata
 - Possibly store multiple versions of a video with different layouts

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Conclusion

- Deep learning opens the door to rich queries over video data
- Videos are large and slow to process
- Database techniques can accelerate such queries
 - Partitioning
 - Indexing
 - Incremental physical tuning
- Indexing must be balanced with maintaining reasonable storage sizes

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