OSDC OPEN SCIENCE DATA CLOUD

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Motivation

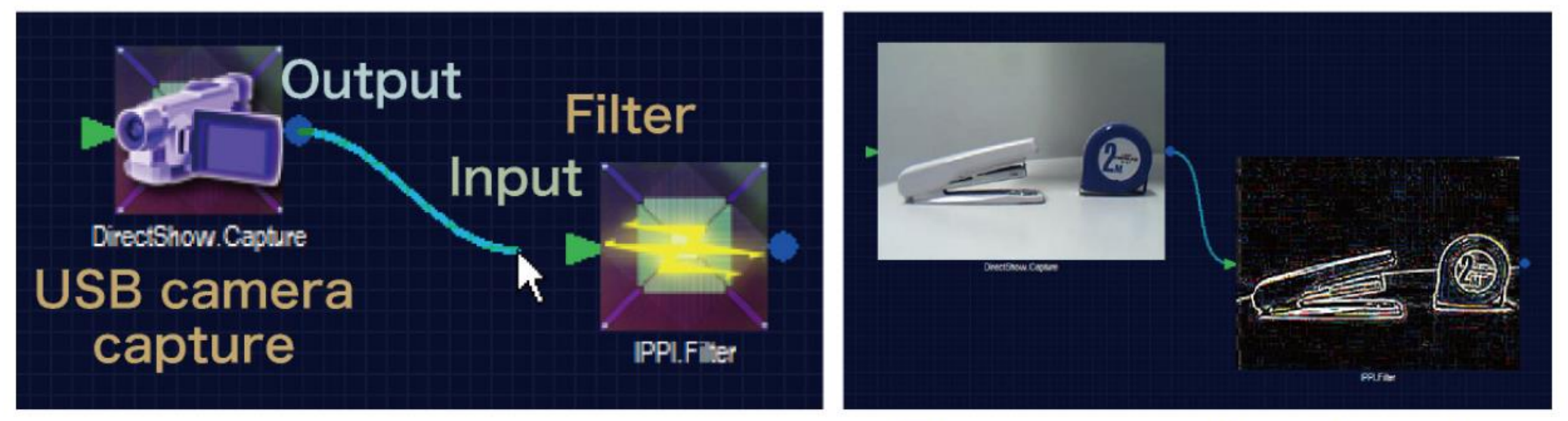
- Utilize Storm to automate allocation of nodes when distributing workflow applications across a computer cluster
- Minimize modification of the original workflow application to simplify parallelization
- Leverage Storm's inherent scalability to allow the workflow application to scale automatically with the underlying cluster

Background

Workflow Application: Lavatube

Lavatube is a visual programming framework used for computer vision research:

- Provides a graphical interface through which users piece together complex video and image processing workflows
- Provides a large library of editing functions which can be combined to perform complex operations, such as anomalous behavior detection systems
- Maximizes its use of multi-core systems with a design optimized for parallel processing

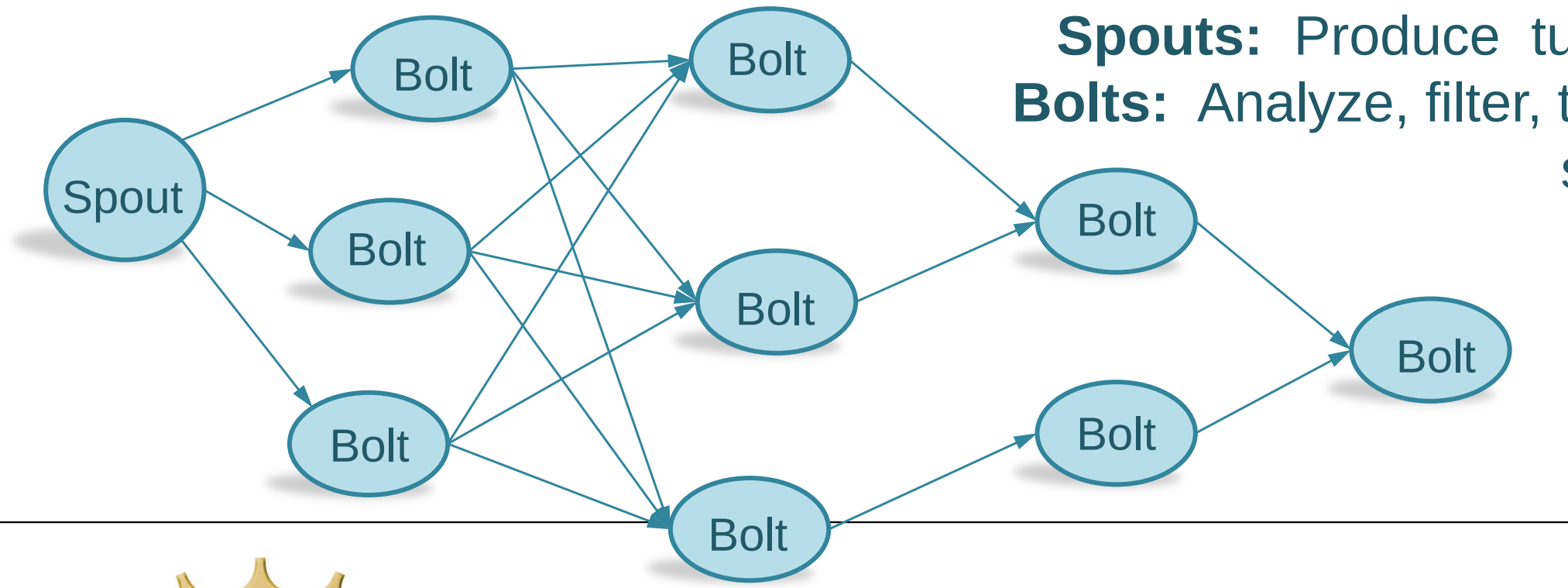


Connecting by drag & drop → The processing flow is easily constructed.

Storm

Storm is a distributed computation framework that is based on a streaming data model:

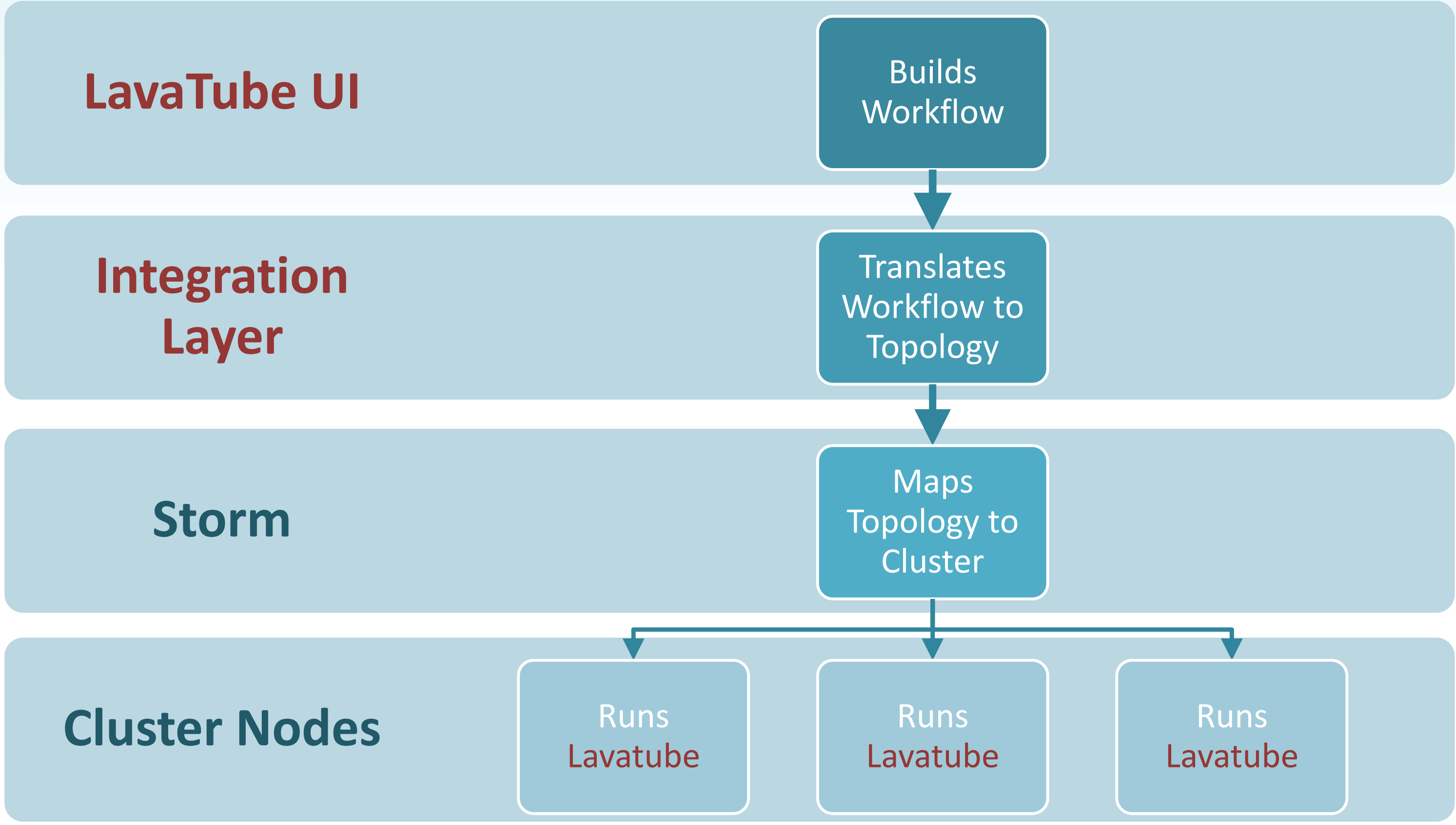
- Spreads complex topologies across a computer cluster, making it possible to run the topologies on torrents of data that would drown a single computer
- Uses efficient message passing to allow it to push as much as 1,000,000 messages per second per node
- Does this in a robust manner, with the ability to automatically detect and recover from failed nodes, assign new nodes, and redistribute tasks dynamically



Storm Topologies:
Spouts: Produce tuples of data
Bolts: Analyze, filter, transform, and store that data

Distributed Processing of Workflow Applications Using the Storm Framework

Mapping the Application's Workflow onto Storm



Lavatube UI:

- Users create workflows using HTML5 based GUI
- XML doc is generated which is passed to next layer

Integration layer:

- Parses the XML and separates it into multiple sub-workflows
- Analyzes the workflow's structure and uses it to build a Storm topology

Storm:

- Initializes the cluster, assigning sections of the workflow to various nodes
- Manages the messages passed between nodes

Nodes:

- Each runs its own instance of Lavatube locally, initialized using the sub-workflow XML doc received during Storm initialization
- Image frames arrive via Storm, are processed by the local sub-workflow, and then are sent out to consuming sub-workflows via Storm

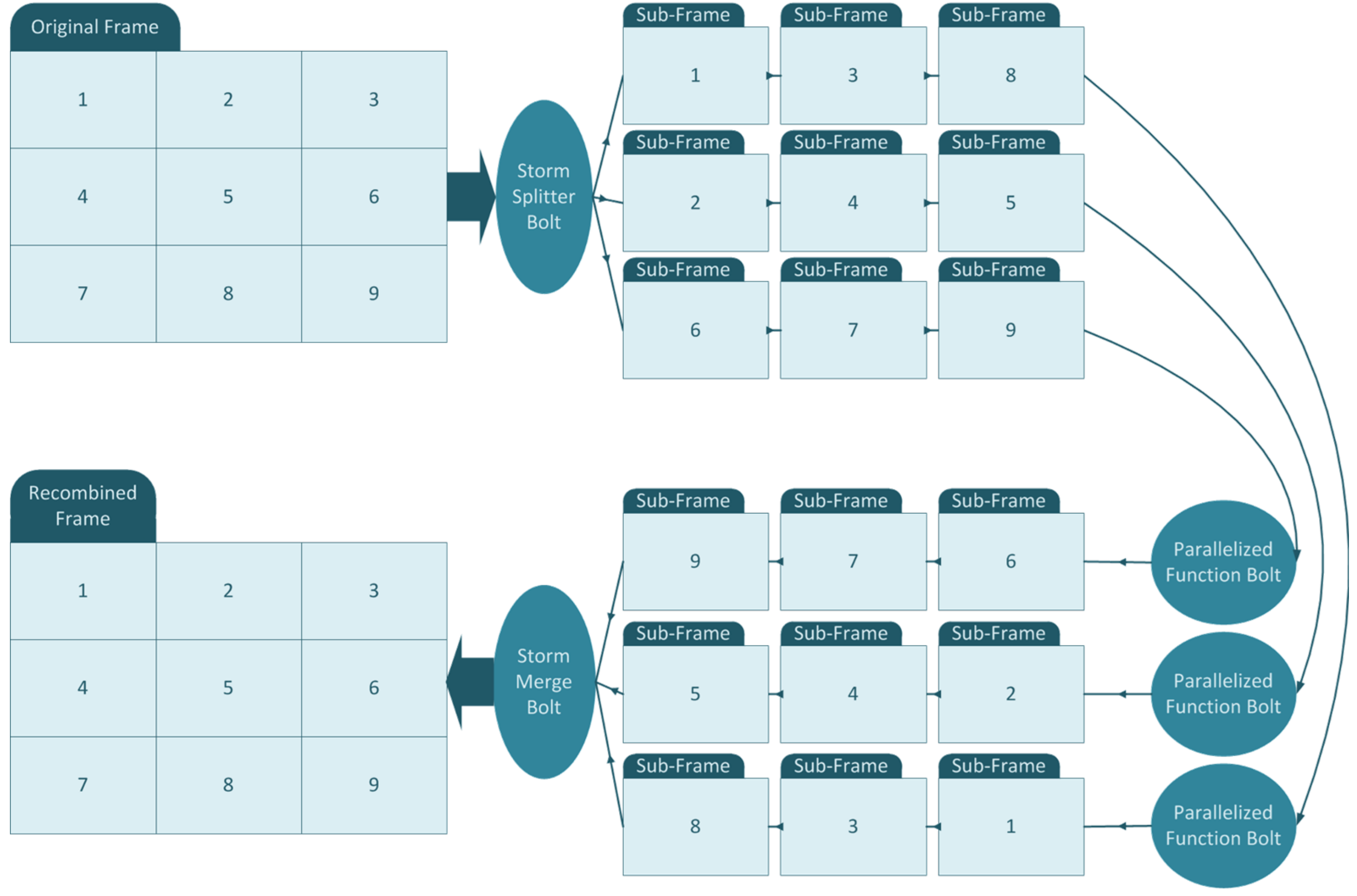
Two Dimensions of Parallel Processing

1) Task Parallelism is inherent to Storm's distribution of sub-workflows across the cluster
2) Data Parallelism involves duplicating sub-workflows and processing subsets of the video stream on the separate duplicated nodes

Frames are distributed to the duplicated nodes using a modular division based batching method:

- Resolves issues with synchronizing the frames of merging video streams that arrive as input to parallelized components
- Maintains a partial ordering in the frames, reducing the burden on components which later need the frames to be in order

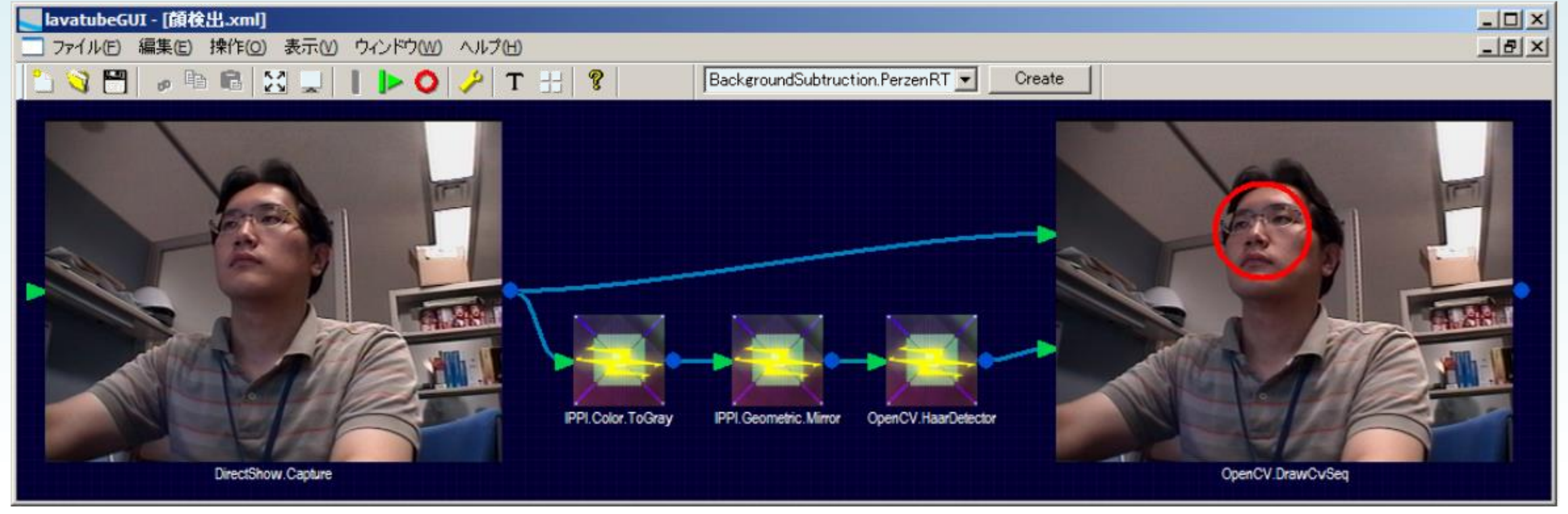
**Further data parallelism can also be achieved by splitting individual video frames into macro blocks, allowing large frames, such as with 4K Ultra HD, to be processed in parallel*



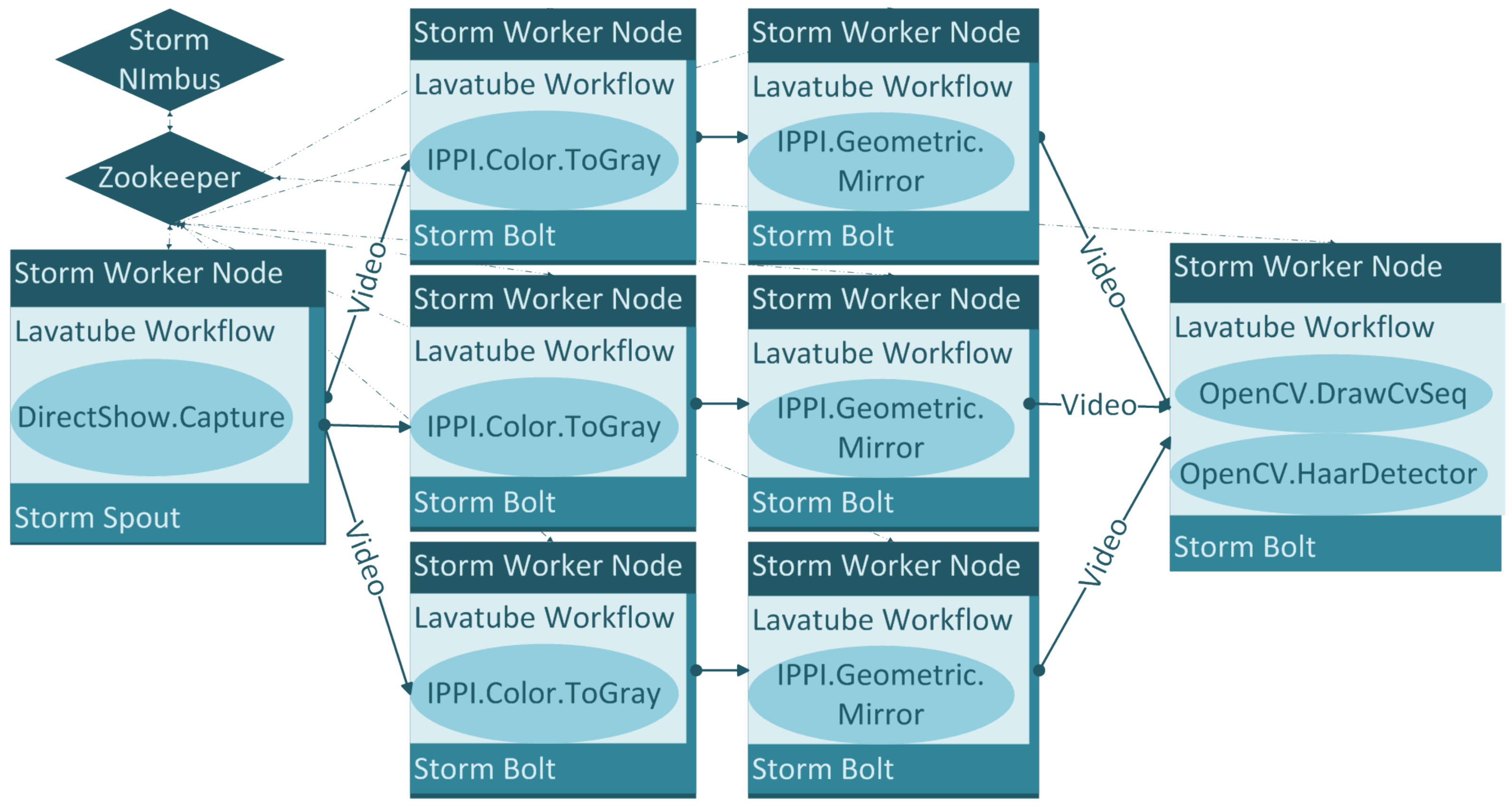
Macro Block based Data Parallelization *(even splitting and merging can be accomplished in parallel, with only frame reordering requiring a non-parallelized component)*

Example Mapping From Lavatube to Storm

Original Workflow (Lavatube Face detection algorithm):



Mapping of the above Lavatube face detection workflow to a Storm cluster:



The above example demonstrates both data and task parallelism:

- Data Parallelism: IPPI.Color.ToGray and IPPI.Geometric.Mirror functions are each duplicated on three nodes each, with each duplicate processing a subset of the original video stream
- Task Parallelism: Separate worker nodes are used to process sequential functions, such as with DirectShow.Capture being processed on a separate worker node from IPPI.Color.ToGray

Research Results

Successfully validated this model using actual video data.

- Tested on grid of five computers using 16 Storm worker processes
- Input two video files, performed multiple transformations, including parallelized merge of video streams
- Output AVI file 100% identical to non-distributed processing

Tested performance of Storm infrastructure when supporting larger volumes of video data:

- Ran input in infinite loops to observe performance bottlenecks
- Primary bottleneck found to be computationally expensive Lavatube functions, such as the geometric resize function
- Indicates capability of the combined framework to increase the processing capacity of Lavatube for such functions by using data parallelism to spread computation across multiple nodes

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