MESURE ET ANALYSE DE PERFORMANCE D'ENCODAGE VIDÉO TEMPS RÉEL

avec Dash et Plotly

Kevin Pouget, Red Hat SPICE Senior Software Engineer

2020-02-18 — Python User Group @ La Turbine, Grenoble

ABOUT ME

Kevin Pouget

- 2011-2017: PhD & Post-doc (Grenoble)
  - Improve interactive debugging for multicore programming

- 2017-2019: Virtualization engineer (Grenoble)
  - OpenCL inside virtual machines
  - Qemu/KVM checkpoint restart
  - ...

- June 2019...: Senior Software Engineer (remote)

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  - Improve interactive debugging for multicore programming
    - Python to extend GDB and inspect C code

- 2017-2019: Virtualization engineer (Grenoble)
  - OpenCL inside virtual machines
    - Python for C code generation, benchmarking & performance analyses
  - Qemu/KVM checkpoint restart
    - Python for benchmarking & performance analyses
  - …

- June 2019…: Senior Software Engineer (remote)

⇒ Python for driving C low-level apps and collection/analyze of execution data

…in addition to multi-process low-level C programming… !

AGENDA

SPICE Remote Display

Recording Infrastructure

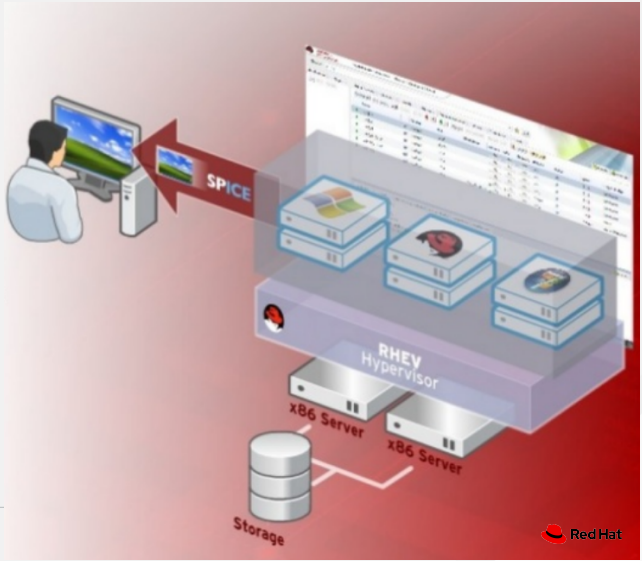
Performance Benchmarking & Visualization

SPICE REMOTE DISPLAY

SPICE REMOTE DISPLAY

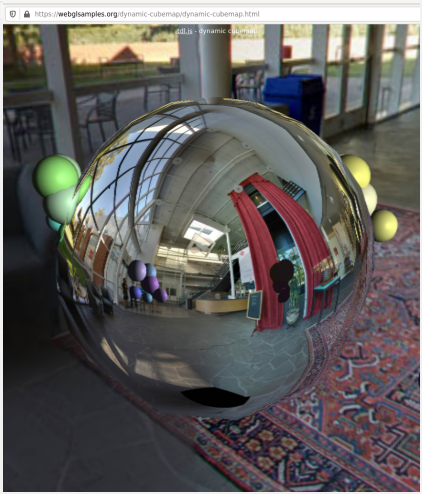
Simple Protocol for Independent Computing Environments

- GUI in remote client
  - ⋆ client/VM copy-and-paste
  - ⋆ file drag-and-drop
  - ⋆ multi-monitor support
  - ⋆ window-to-screen resolution
  - ⋆ CD-ROM/ISO sharing
  - ⋆ seamless VM host migration
  - ⋆ SSL, smartcard authentication, ...
- Server library inside Qemu-KVM
  - ⋆ OS-independent screen capture
    - hypervisor level
  - ⋆ MJPEG video encoding



SPICE REMOTE DISPLAY

3D, vGPU and Video Streaming



3D inside the VM?

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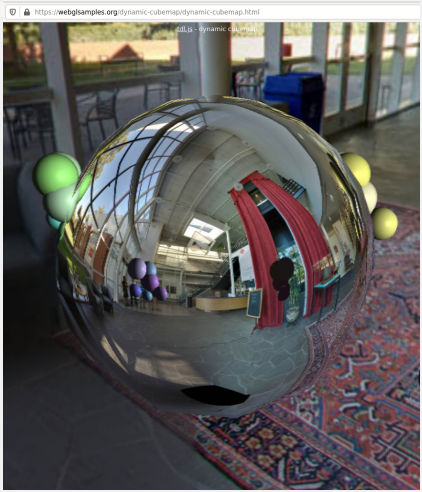

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GPU passthrough?

- disconnect from the host, give it to the VM

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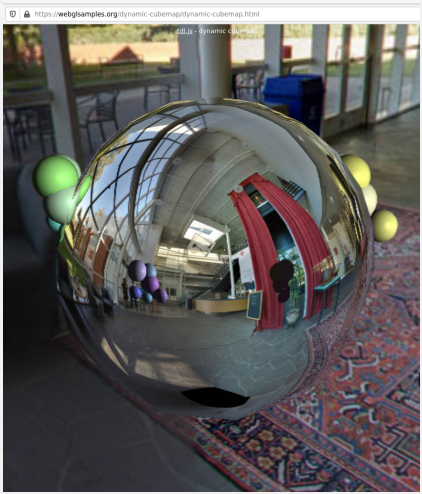

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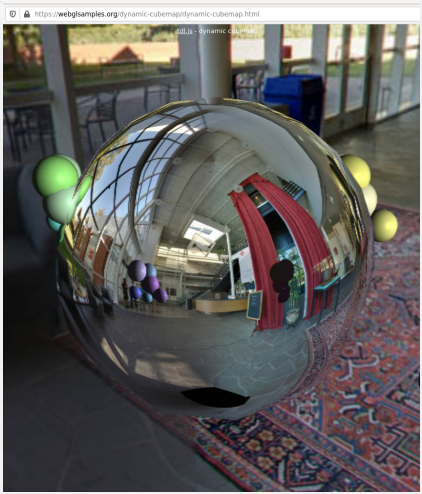

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  - under investigation for SPICE

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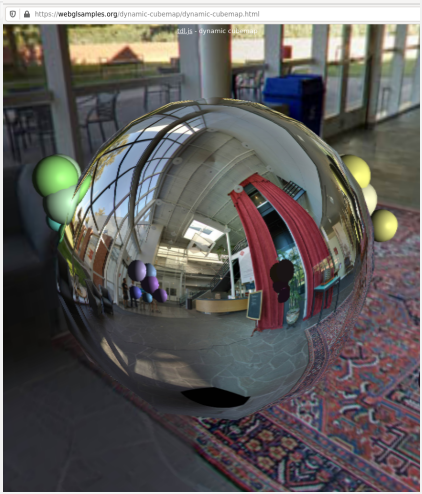

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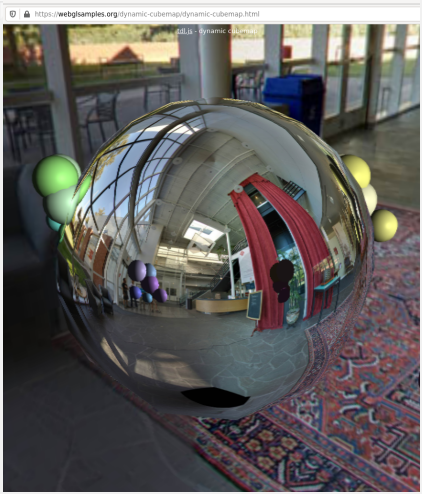

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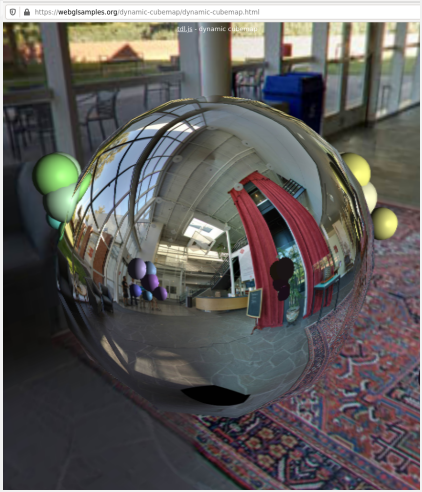

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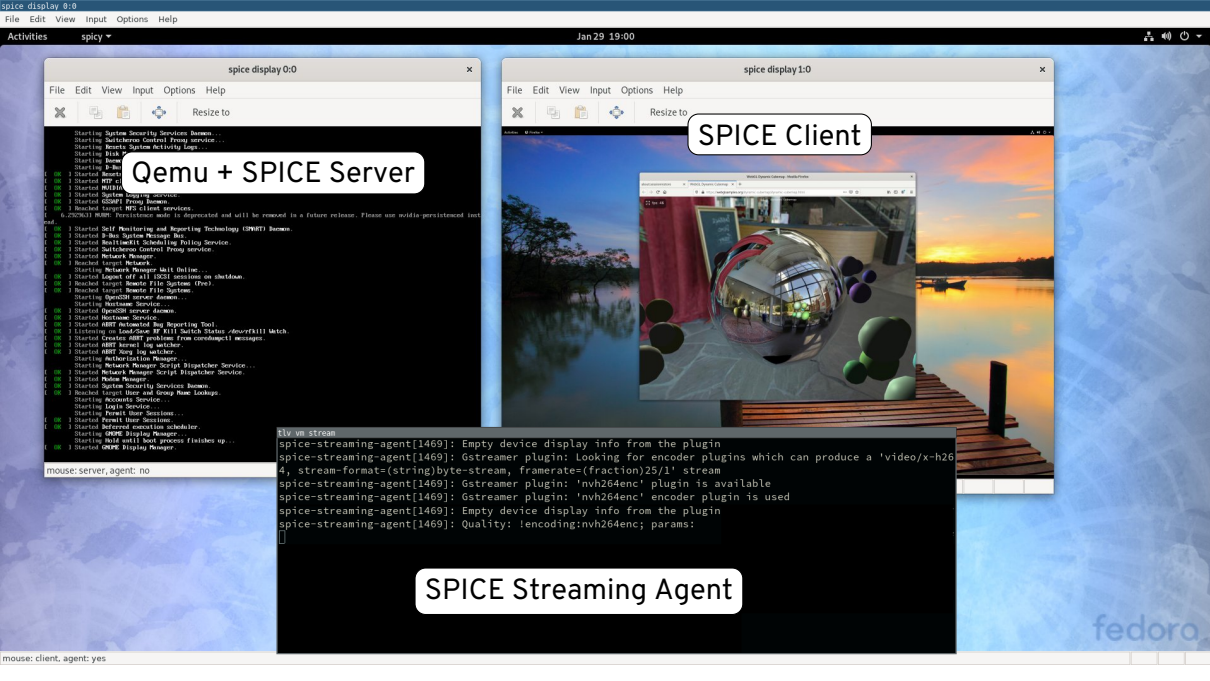
Video encoding in the guest vGPU:

1. capture the framebuffer (*ie*, do a screenshot)
2. give it to the vGPU for encoding
3. send it (1) outside of the VM and (2) to the client


spice display 0:0
File Edit View Input Options Help
Activities
spicy
Jan 29 19:00
spice display 0:0
File Edit View Input Options Help
Resize to
Qemu + SPICE Server
mouse: server, agent: no
spice display 1:0
File Edit View Input Options Help
Resize to
SPICE Client
flv vm_stream
spice-streaming-agent[1469]: Empty device display info from the plugin
spice-streaming-agent[1469]: Gstreamer plugin: Looking for encoder plugins which can produce a 'video/x-h26
4, stream-format=(string)byte-stream, framerate=(fraction)25/1' stream
spice-streaming-agent[1469]: Gstreamer plugin: 'nvh264enc' plugin is available
spice-streaming-agent[1469]: Gstreamer plugin: 'nvh264enc' encoder plugin is used
spice-streaming-agent[1469]: Empty device display info from the plugin
spice-streaming-agent[1469]: Quality: !encoding:nvh264enc; params:
SPICE Streaming Agent
mouse: client, agent: yes
fedora

RECORDING INFRASTRUCTURE

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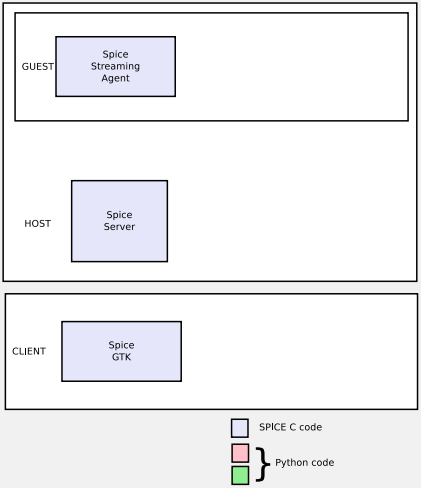

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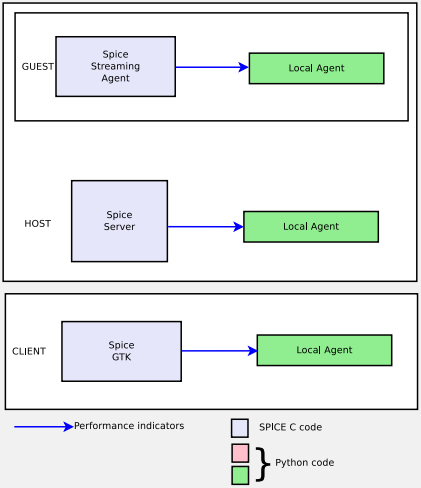
RECORDING INFRASTRUCTURE



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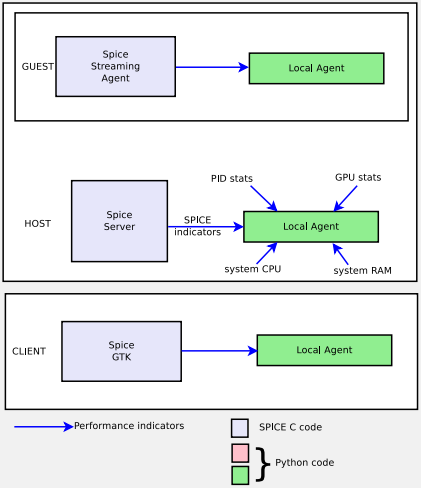
2. On each system,
   1. deploy a Python local agent

RECORDING INFRASTRUCTURE



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   2. collect various performance indicators

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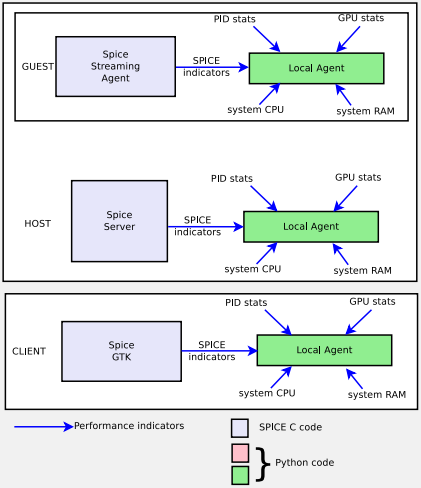

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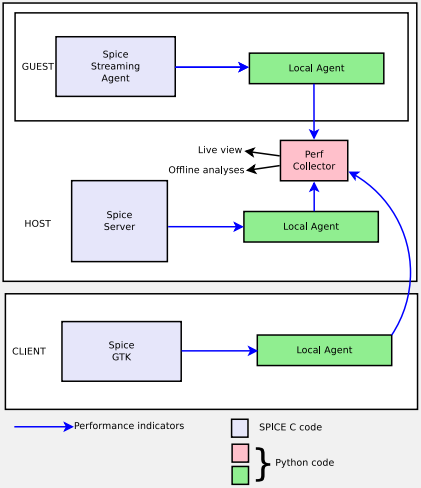

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2. On each system,
   1. deploy a Python local agent
   2. collect various performance indicators
   3. … in each of the agents
3. Collect all the indicators
   - for live & interactive view
   - for offline processing

tlv qemu

```
qemu-system-x86_64: warning: Spice: Agent Inter
         Starting CUPS Scheduler...
[  OK  ] Reached target Remote File Systems (Pr
e).
[  OK  ] Reached target Remote File Systems.
         Starting Permit User Sessions...
         Starting OpenSSH server daemon...
         Starting Network Manager Wait Online...
.
[  OK  ] Started Permit User Sessions.
         Starting GNOME Display Manager...
[  OK  ] Started Deferred execution scheduler.
         Starting Hold until boot process finis
hes up...
[  OK  ] Started Command Scheduler.
[  OK  ] Started GNOME Display Manager.
         Starting Hostname Service...

Fedora 30 (Workstation Edition)
Kernel 5.3.15-200.fc30.x86_64 on an x86_64 (tty
S0)

chamechaude login:
```

tlv client

```
kevin ~
$ laptop
kevin ~
$ tlv client
CLIENT: SPICE_NOGRAB=1 /home/kevin/client
GSpice-Message: 18:25:34.798: main channel: ope

(spicy:42238): Spice-WARNING **: 18:25:41.973:
```

tlv vm stream

```
 'video/x-h264, stream-format=(string)byte-strea
m, framerate=(fraction)25/1' stream
spice-streaming-agent[1474]: Gstreamer plugin:
'nvh264enc' plugin is available
spice-streaming-agent[1474]: Gstreamer plugin:
'nvh264enc' encoder plugin is used
(spice-streaming-agent:1474): Spice-WARNING **:
 17:26:05.752: Agent Interface: client connecte
d!
spice-streaming-agent[1474]: On connect!
spice-streaming-agent[1474]: Quality: encoder:g
st.h264.nvh264enc
```

keyinputs: -c

```
running 16/16
> codec=nv.plug.h264_display=webgl-cubemap_reco
rd-time=40s_framerate=200_ratecontrol=cbr_max-b
itrate=64_gop=0_blocking=0
reset encoder parameters
set_enc: nv.plug.h264 framerate=200, nv.ratecon
trol=cbr, nv.max-bitrate=64, nv.gop=0, nv.block
ing=0
wait 2 seconds
clear graphs
clear quality
wait 2 seconds
append to quality: script: codec: nv.plug.h264
append to quality: script: record_time: 40s
append to quality: script: display: webgl_cubem
ap
append to quality: script: encoding: framerate=
200;ratecontrol=cbr;max-bitrate=64;gop=0;blocki
ng=0
request: send 'share_pipeline' to agent, client
set_enc: share_encoding
set_enc: share_resolution
wait 1 seconds
wait 40 seconds
save record into /home/kevin/spice/streaming_st
ats/results/current/webgl_cubemap/framerate=200
_ratecontrol=cbr_max-bitrate=64_gop=0_blocking=
0.rec
write result: /home/kevin/spice/streaming_stats
/results/current/matrix.csv << codec=nv.plug.h2
64_display=webgl-cubemap_record-time=40s | webg
l_cubemap | framerate=200_ratecontrol=cbr_max-b
itrate=64_gop=0_blocking=0
teardown(display)
system-exec: vm display stop https://webglsampl
es.org/dynamic-cubemap/dynamic-cubemap.html
teardown()
system-exec: xset s on +dpms
system-exec: server exec xset s on +dpms
Performed 16 experiments.
Skipped 0 experiments already recorded.
Estimated time: 12min0s
```

tlv qemu agent

```
kevin ~
$ tlv qemu agent
HOST: cd spice/streaming_stats/ && ./smart_agen

* Starting the socket for the Perf Collector on
WARNING: Intel_GPU_Top: failed to load (intel_g

* Preparing the environment ...

* Running!
Connecting to 1235
server: received 5 recorders: quality_interface
server: Agent info received: 'pid: 19240'
Quality received: 'guest' says '!encoding:nvh26
Quality received: 'guest' says 'encoder:gst.h26
New connection from 127.0.0.1:52514
```

tlv client agent

```
kevin ~
$ tlv client agent
CLIENT: cd spice/streaming_stats/ && ./smart_ag

* Starting the socket for the Perf Collector on
WARNING: Intel_GPU_Top: failed to load (intel_g
'intel_gpu_top': 'intel_gpu_top'

* Preparing the environment ...

* Running!
Connecting to 1234
client: received 5 recorders: frames_info, qual
_info
New connection from 10.35.17.23:51890238'
```

tlv vm stream agent

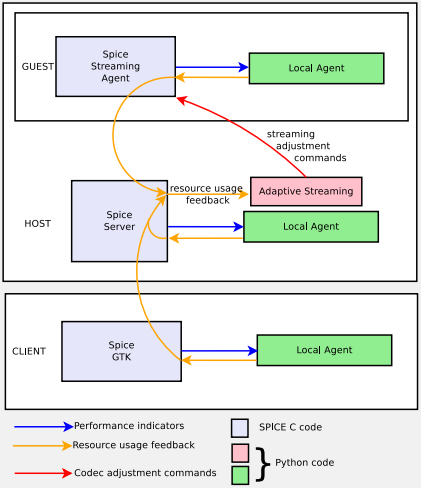
```
kevin ~
$ tlv vm stream agent
VM: cd spice/streaming_stats/ && ./smart_agent.

* Starting the socket for the Perf Collector on
WARNING: Intel_GPU_Top: failed to load (intel_g
o 2] No such file or directory: 'intel_gpu_top'
'

* Preparing the environment ...

* Running!
Connecting to 1236
guest: received 6 recorders: frame, streaming_i
New connection from 192.168.122.1:55714
```

RECORDING INFRASTRUCTURE



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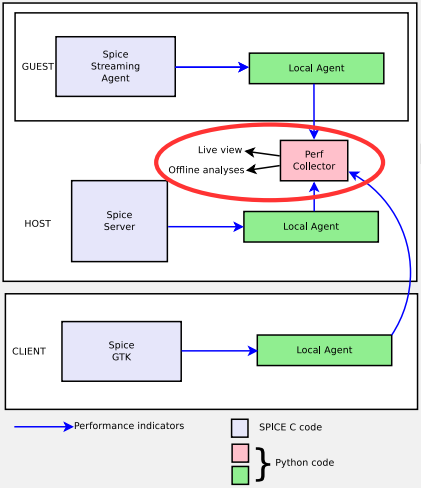
4. ⟵ future work ⟶
   - collect resource-usage feedback
   - adapt streaming quality accordingly

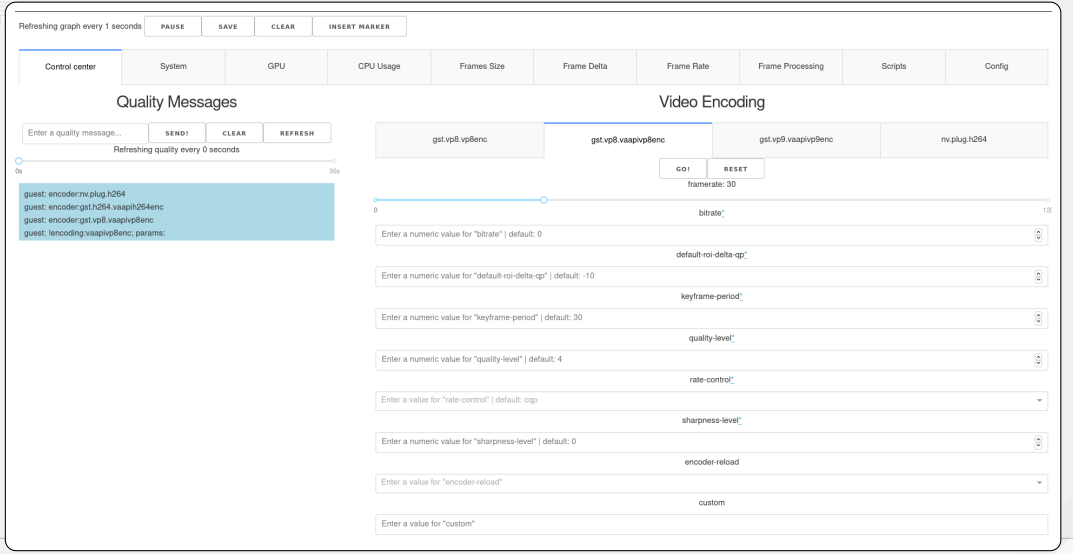
RECORDING INFRASTRUCTURE



Next: benchmarking and visualization tool

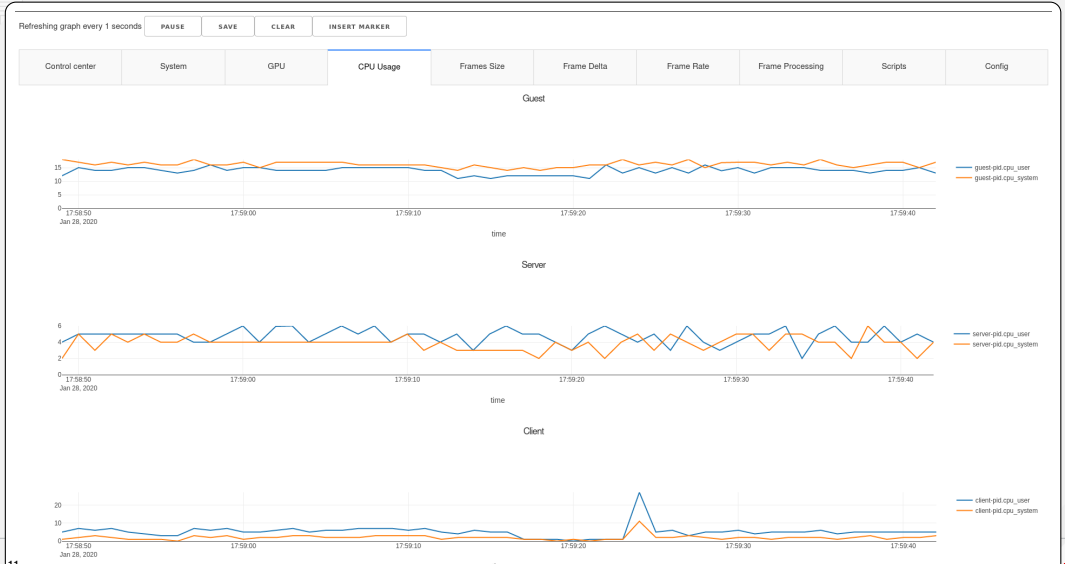
PERFORMANCE BENCHMARKING & VISUALIZATION

LIVE CONTROL AND VISUALIZATION



Red Hat

LIVE CONTROL AND VISUALIZATION



Red Hat

LIVE CONTROL AND VISUALIZATION

Red Hat

SCRIPTING AND MATRIX BENCHMARKING

Live view and manual control is nice, but ...

SCRIPTING AND MATRIX BENCHMARKING

We want to understand the impact ...

- of encoding parameters
  - `bitrate` $\Rightarrow 0.5, 1, 10, 100$ MB/s
  - `framerate` $\Rightarrow 20, 40, 60$ FPS
  - `resolution` $\Rightarrow 1K, 2K, 4K$
  - `keyframe-period` $\Rightarrow$ *auto*, $10, 60,$ *none*

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$$4 \times 3 \times 4 \times 3 = 144$$

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- over multiple resources
  - CPU/GPU on the host/guest/client, frame sizes, framerate, ...

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- with different VM use-cases
  - office work, 3D processing, still desktop, ...

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- with different resources usage
  - VM CPU busy, client GPU busy, slow network, ...

$... \times 3 = 1296$ expe!

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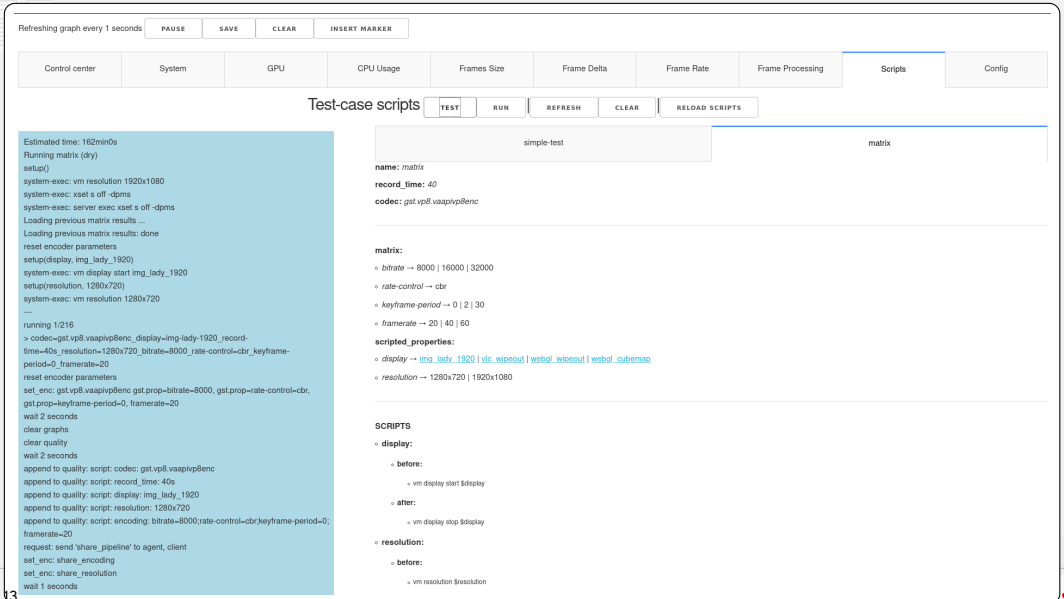
Script all of it! And make it reproducible!

SPICE RECORDING INFRASTRUCTURE



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SPICE RECORDING INFRASTRUCTURE

Scripting and Matrix Benchmarking

```
record_time: 40s
codec: gst.vp8.vaapivp8enc
matrix:
  framerate: 20, 40, 60
  gst.prop=bitrate: 8000, 16000, 32000
  gst.prop=keyframe-period: 0, 2, 30

scripted_properties:
  display:
    img_lady_1920:
    vlc_wipeout:
    webgl_wipeout: https://phoboslab.org/wipeout/
    webgl_cubemap: https://webglsamples.org/dynamic-cubemap/dynam
  resolution: 1280x720, 1920x1080
```

SPICE RECORDING INFRASTRUCTURE

Scripting and Matrix Benchmarking

```
scripts:
  setup:
    - vm resolution 1920x1080; server xset s off -dpms
  teardown:
    - xset s on +dpms; server xset s on +dpms
  resolution:
    before:
      - vm exec xrandr --output DP-2 --mode $resolution
    after:
      - vm exec xrandr --output DP-2 --mode 1920x1200
  display:
    before:
      - vm display start $display
    after:
      - vm display stop $display
```

SPICE RECORDING INFRASTRUCTURE

Scripting and Matrix Benchmarking

... and let it run during the coffee break!

MATRIX VISUALIZER

Overview: multiple plots for overview view of CPU usage (Guest/Server/Client))

Parameters:

experiment:
[all]

codec:
[all]

display:
[all]

record-time:
40s

bitrate:
[all]

rate-control:
cbr

keyframe-period:
[all]

framerate:
200

stats:
× Guest CPU × Server CPU × Client CPU

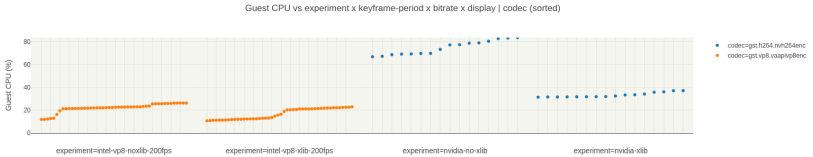
Configuration:

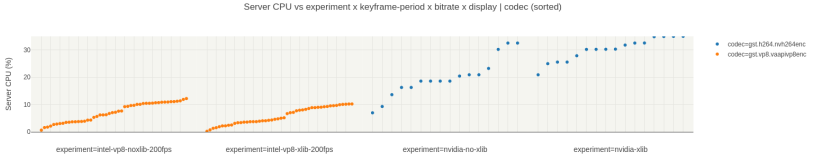
Config settings

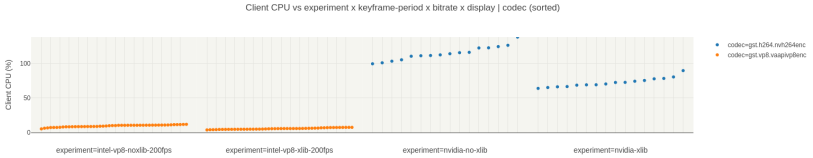
record-time rate-control framerate codec display bitrate keyframe-period experiment

Permalink

Download







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MATRIX VISUALIZER

Overview: multiple plots for overview view of CPU usage (Guest/Server/Client))

Parameters:

experiment:
[all]

codec:
[all]

display:
[all]

record-time:
40s

bitrate:
[all]

rate-control:
cbr

keyframe-period:
[all]

framerate:
200

stats:
× Guest CPU × Server CPU × Client CPU

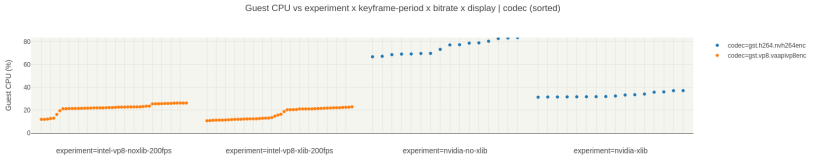
Configuration:

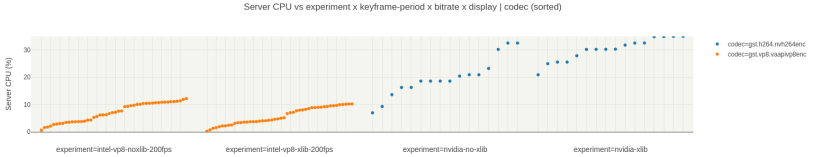
Config settings

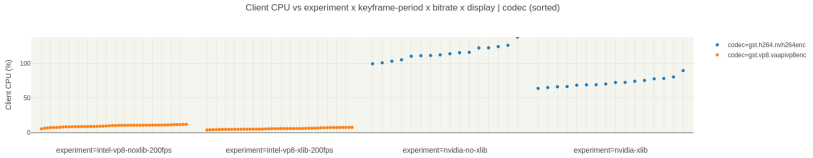
record-time rate-control framerate codec display bitrate keyframe-period experiment

Permalink

Download







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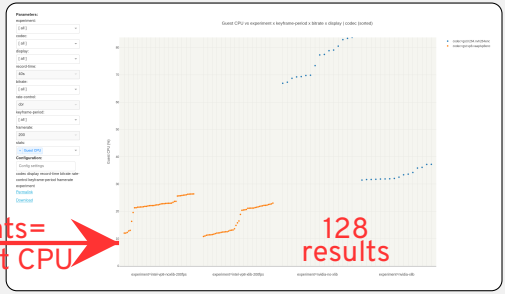
MATRIX VISUALIZER

Overview: Guest CPU usage with 4+ variable parameters



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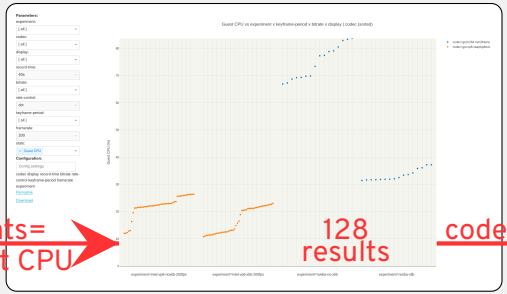
MATRIX VISUALIZER

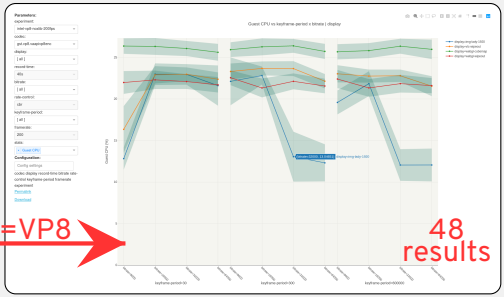
Overview: Guest CPU usage with 3 variable parameters (`display, bitrate, keyframe-period`)



stats=
guest CPU

128
results

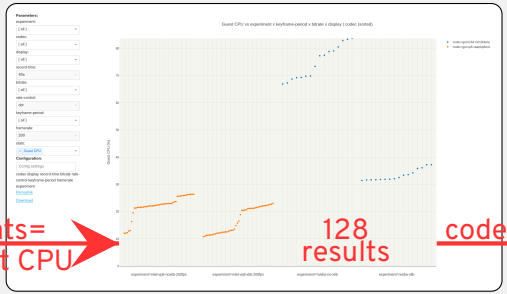
codec=VP8



48
results

MATRIX VISUALIZER

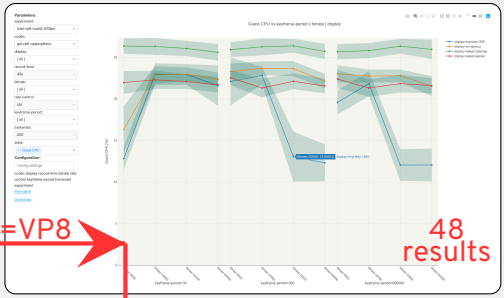
Overview: Guest CPU usage with 2 variable parameters (`display, bitrate`)



stats=
guest CPU

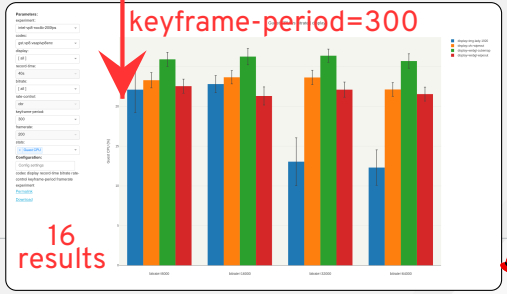
128
results

codec=VP8



48
results

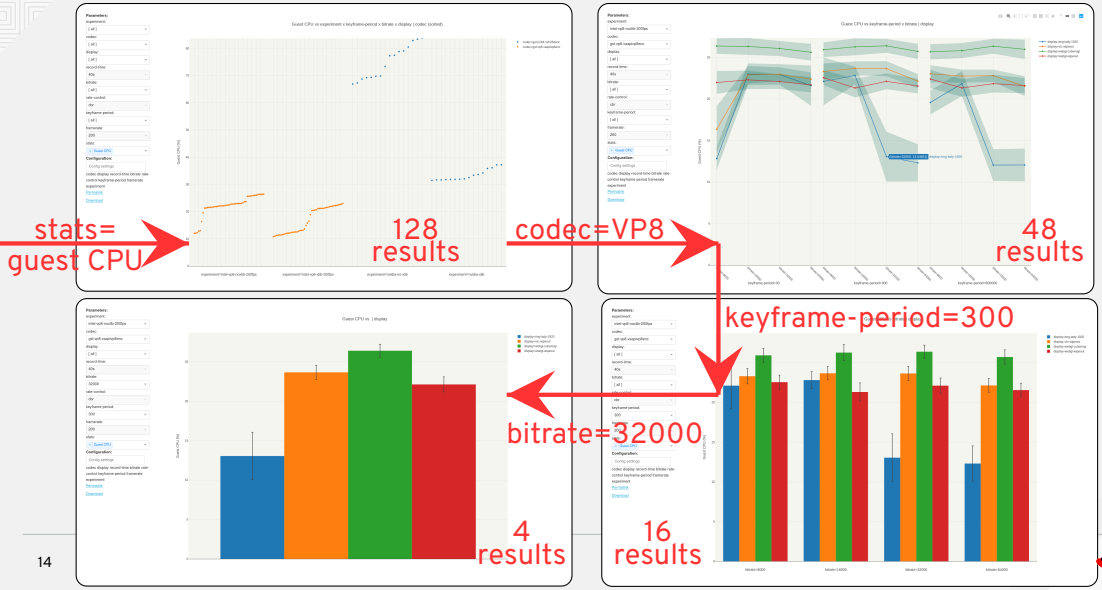
keyframe-period=300



16
results

MATRIX VISUALIZER

Overview: Guest CPU usage with 1 variable parameter (`display`)



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MATRIX VISUALIZER

Overview: linear regression (Client CPU vs Framerate)

Parameters:

experiment:
study-FPS

codec:
gst.vp8.vaapivp8enc

display:
webgl-aquarium

record-time:
40s

resolution:
[all]

bitrate:
32000

rate-control:
cbr

keyframe-period:
600000

framerate:
[all]

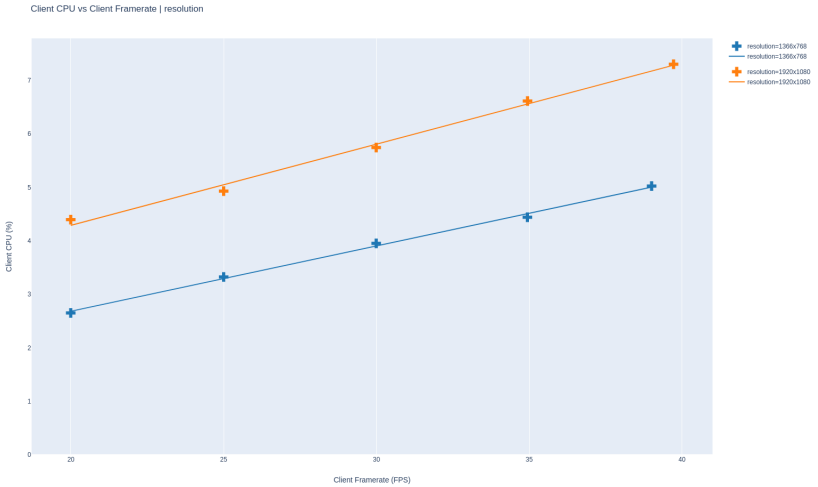
stats:
× Reg: Client CPU vs Framerate

Configuration:

Config settings

Permalink

Download



Client CPU = +0.12 * Client Framerate +0.24 | r=+0.999, p=+0.000, stderr=+0.004 | resolution=1366x768

Client CPU = +0.15 * Client Framerate +1.25 | r=+0.997, p=+0.000, stderr=+0.007 | resolution=1920x1080

MATRIX VISUALIZER

Overview: report mode (GPU vs Framerate on Guest/Client)

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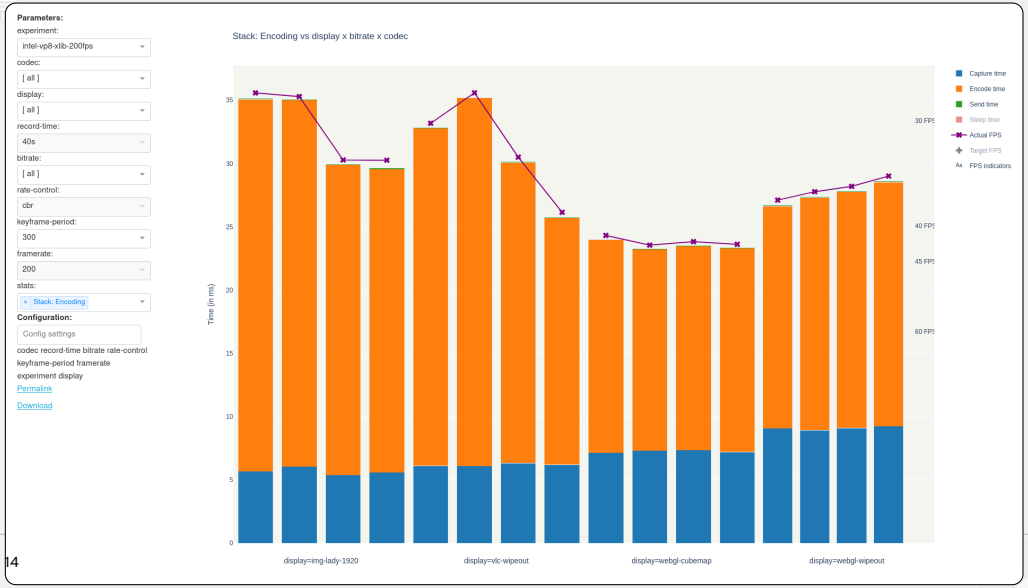
MATRIX VISUALIZER

Overview: encoding stack on the guest (current work)



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MATRIX VISUALIZER

Some interesting cases and open questions...

MATRIX VISUALIZER: INTERESTING CASES

FPS: why desktop encoding is slow?

Parameters:

experiment:
current

codec:
gst.vp8.vaapivp8enc

display:
[all]

record-time:
20s

resolution:
1920x1080

bitrate:
8000

rate-control:
cbr

keyframe-period:
9000

framerate:
[all]

stats:
× Guest Framerate

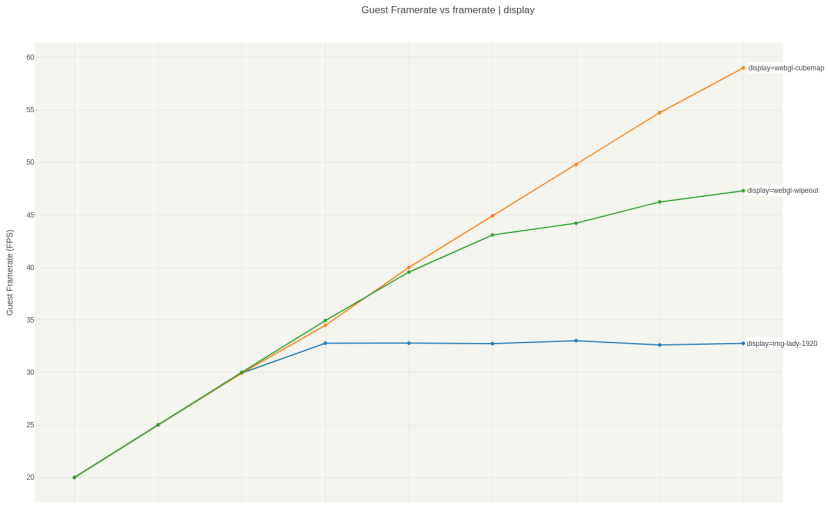
Configuration:

Config settings

experiment codec record-time
resolution bitrate rate-control
keyframe-period display framerate

Permalink

Download



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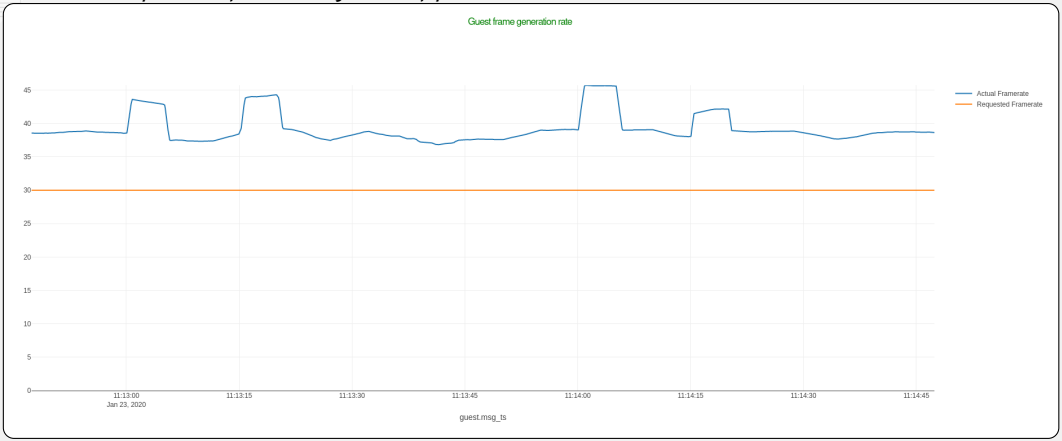
MATRIX VISUALIZER: INTERESTING CASES

FPS: why desktop encoding is bumpy?



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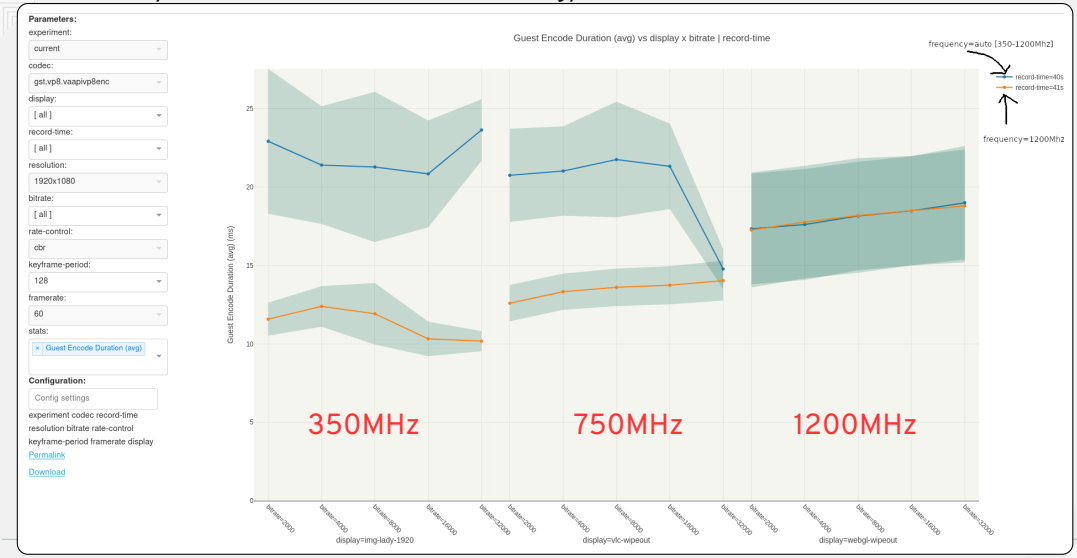
MATRIX VISUALIZER: INTERESTING CASES

FPS: why? because the GPU tries to save energy!!



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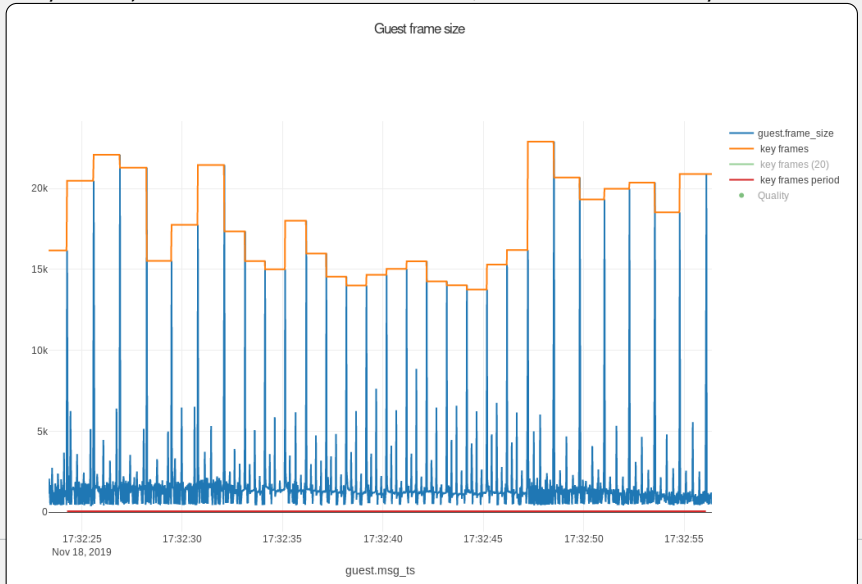
MATRIX VISUALIZER: INTERESTING CASES

keyframe-period=0 → “auto”. Thanks Intel, but what does it really mean?



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MATRIX VISUALIZER: INTERESTING CASES

keyframe-period=0 → “auto” ⇒ 1 keyframe per second!

Parameters:

experiment:
current

resolution:
[all]

codec:
gst.vp8.vaapivp8enc

record_time:
30s

webpage:
[all]

bitrate:
[all]

rate-control:
[all]

keyframe-period:
[all]

framerate:
[all]

stats:
× Keyframe Period

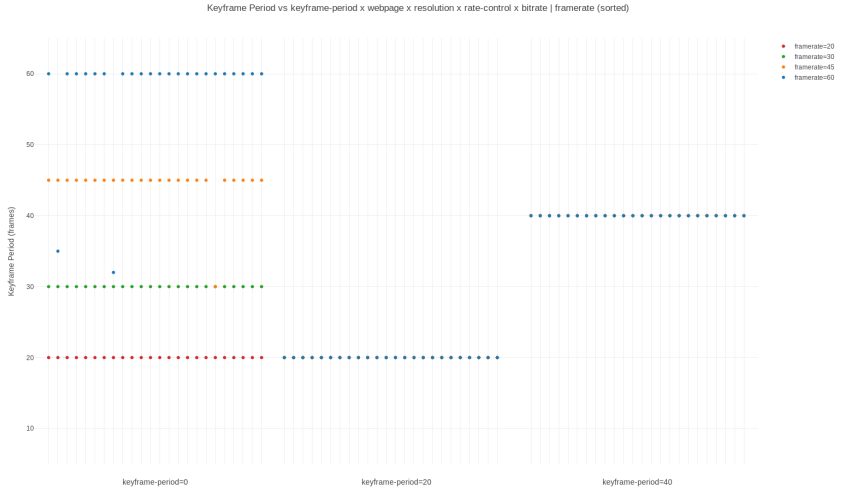
Aspect:

Show text

experiment codec record_time
framerate bitrate rate-control resolution
webpage keyframe-period

Invalids:

SHOW DELETE



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MATRIX VISUALIZER: OPEN QUESTIONS

Bandwidth vs bitrate with VLC playback: everything as expected

Parameters:

experiment:
current

codec:
gst.vp8.vaapivp8enc

display:
vlc-mix-quick

record-time:
41s

resolution:
1920x1080

bitrate:
[all]

rate-control:
cbr

keyframe-period:
128

framerate:
[all]

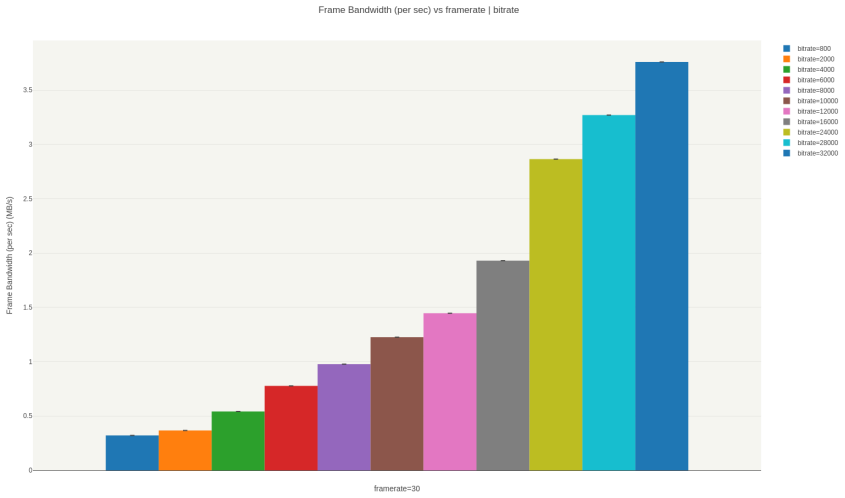
stats:
× Frame Bandwidth (per sec)

Configuration:

Config settings

Permalink

Download



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MATRIX VISUALIZER: OPEN QUESTIONS

Bandwidth vs bitrate with still desktop: beginning as expected, but what's wrong with the tail?

Parameters:

experiment:
current

codec:
gst.vp8.vaapivp8enc

display:
img-lady-1920

record-time:
41s

resolution:
1920x1080

bitrate:
[all]

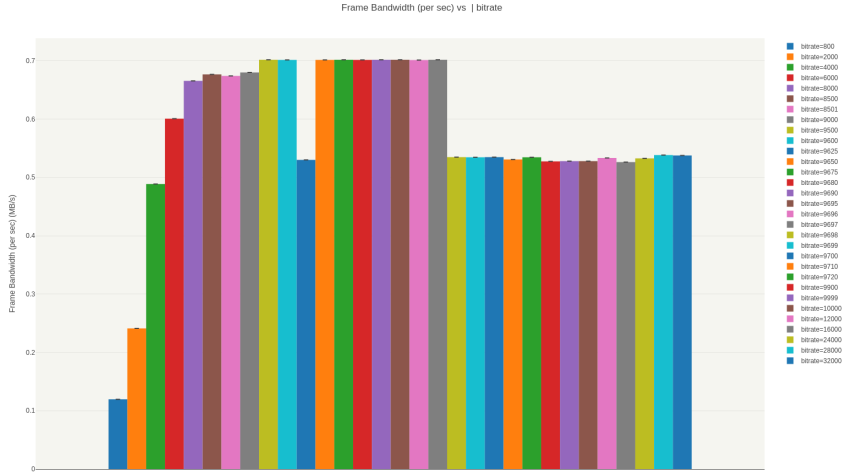
rate-control:
cbr

keyframe-period:
128

framerate:
30

stats:
Frame Bandwidth (per sec)

Saved on 2020-02-05 11:26
from this page.



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MATRIX VISUALIZER: OPEN QUESTIONS

Encoding vs keyframe-period: why keyframe encoding take more and more time?

Parameters:

experiment:
study-kfr

codec:
gst.vp8.vaapivp8enc

display:
img-lady-1920

record-time:
41s

resolution:
1920x1080

bitrate:
12000

rate-control:
cbr

keyframe-period:
[all]

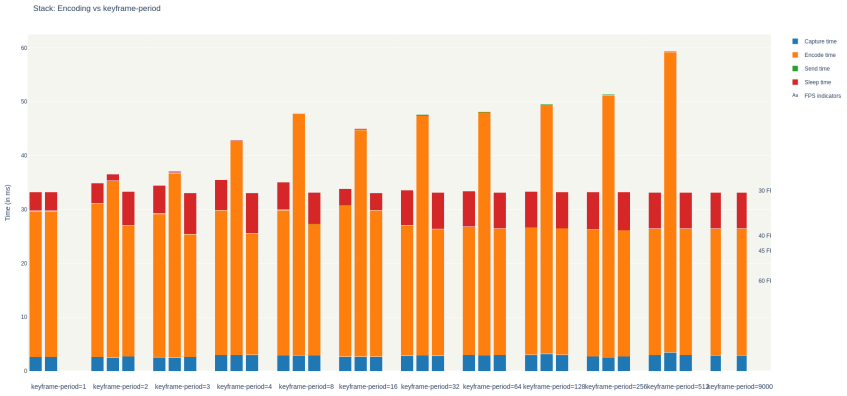
framerate:
30

stats:
× Stack: Encoding

Configuration:
stack_i_vs_p=1

Permalink

Download



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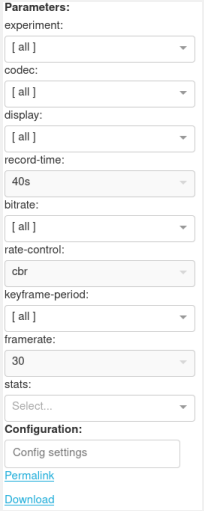
MATRIX VISUALIZER

Extra: a bit of help with the interface ...

MATRIX VISUALIZER

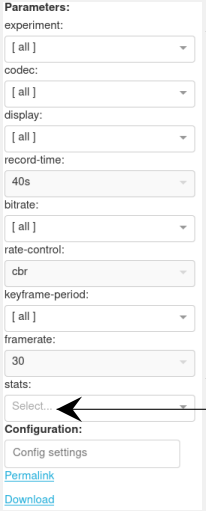
Interface in details



Set matrix parameters as needed: [all] or specific value

MATRIX VISUALIZER

Interface in details

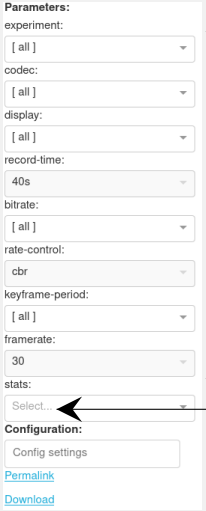


Set matrix parameters as needed: [all] or specific value

Select the stats graph you want to see (3 max)

MATRIX VISUALIZER

Interface in details

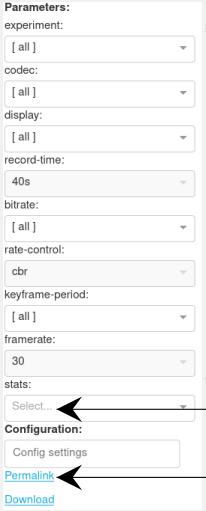


Set matrix parameters as needed: [all] or specific value
Click the label to change the property order (subplot, ..., legend)

Select the stats graph you want to see (3 max)

MATRIX VISUALIZER

Interface in details



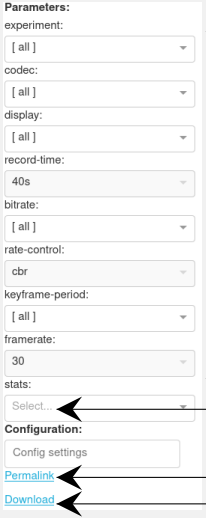
Set matrix parameters as needed: [all] or specific value
Click the label to change the property order (subplot, ..., legend)

Select the stats graph you want to see (3 max)

Only works if same tool/dataset available at reload

MATRIX VISUALIZER

Interface in details



Set matrix parameters as needed: [all] or specific value
Click the label to change the property order (subplot, ..., legend)

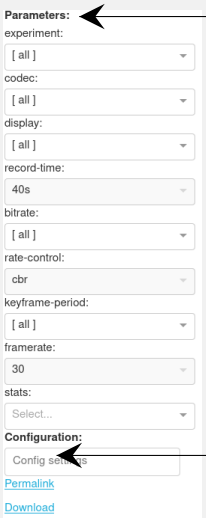
Select the stats graph you want to see (3 max)

Only works if same tool/dataset available at reload

`dill` (`pickle`) object to store/share easily

MATRIX VISUALIZER

Interface in details — mainly for dev



Click to redraw the draw without reload the page

Extra/specific settings