optview2

View and improve optimizations

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What if the compiler could tell us…

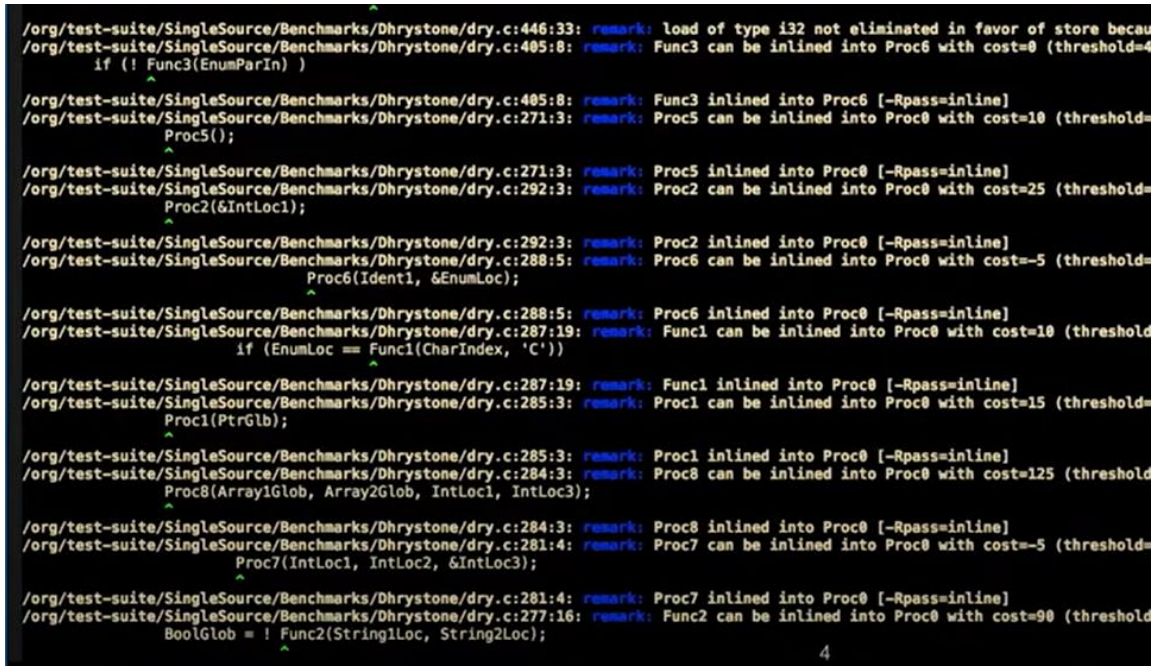
- I couldn’t inline that function
  …because I had only its declaration.
- I’m re-evaluating these loop boundaries on every iteration
  …because I couldn’t prove they stay fixed.
- I’m doing tons of memory accesses that might be redundant
  …because in theory two unrelated variables might refer to the same memory location. You modified one, so I had to reload the other from memory.

Raw optimization data *is* exposed

- Clang/gcc: `-Rpass`

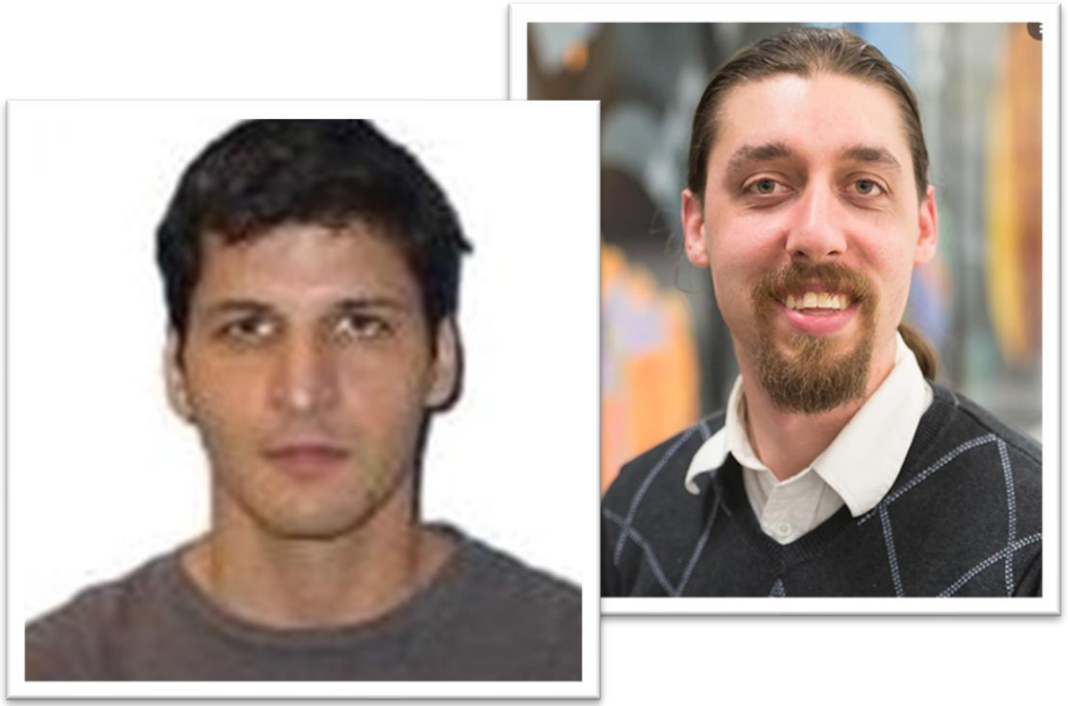
```
code.cc:4:25: remark: foo inlined into bar [-Rpass=inline]
```

- Intel: `-qopt-report=[0..5]`
- Microsoft (very partial):
  `/Qpar-report, /Qvec-report`



Presentation Matters.

- Focus on Clang, over Linux
- **opt-viewer**, 2016 work by Adam Nemet (Apple), Hal Finkel (Argonne)



Opt-Viewer Usage

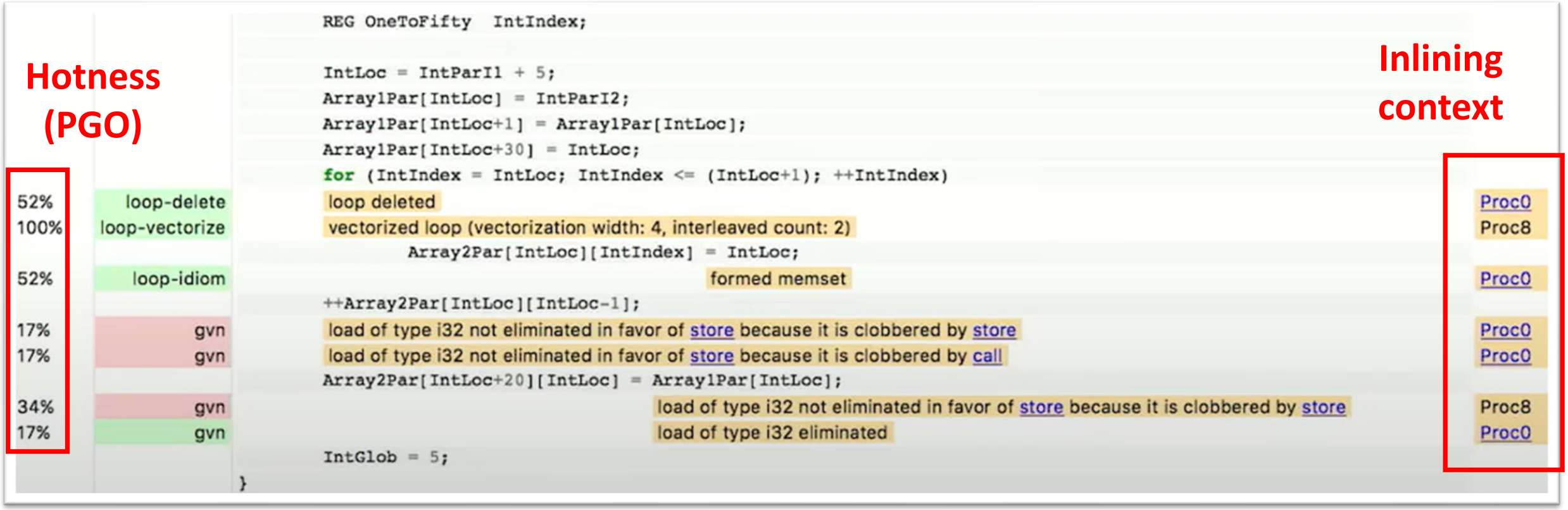
- Build with
  `-fsave-optimization-record:`
  `*.opt.yaml` files are generated, by default in the obj folder.

- Generate htmls:

```
opt-viewer.py
    --output-dir <htmls folder>
    --source-dir <repo>
    <yamls folder>
```

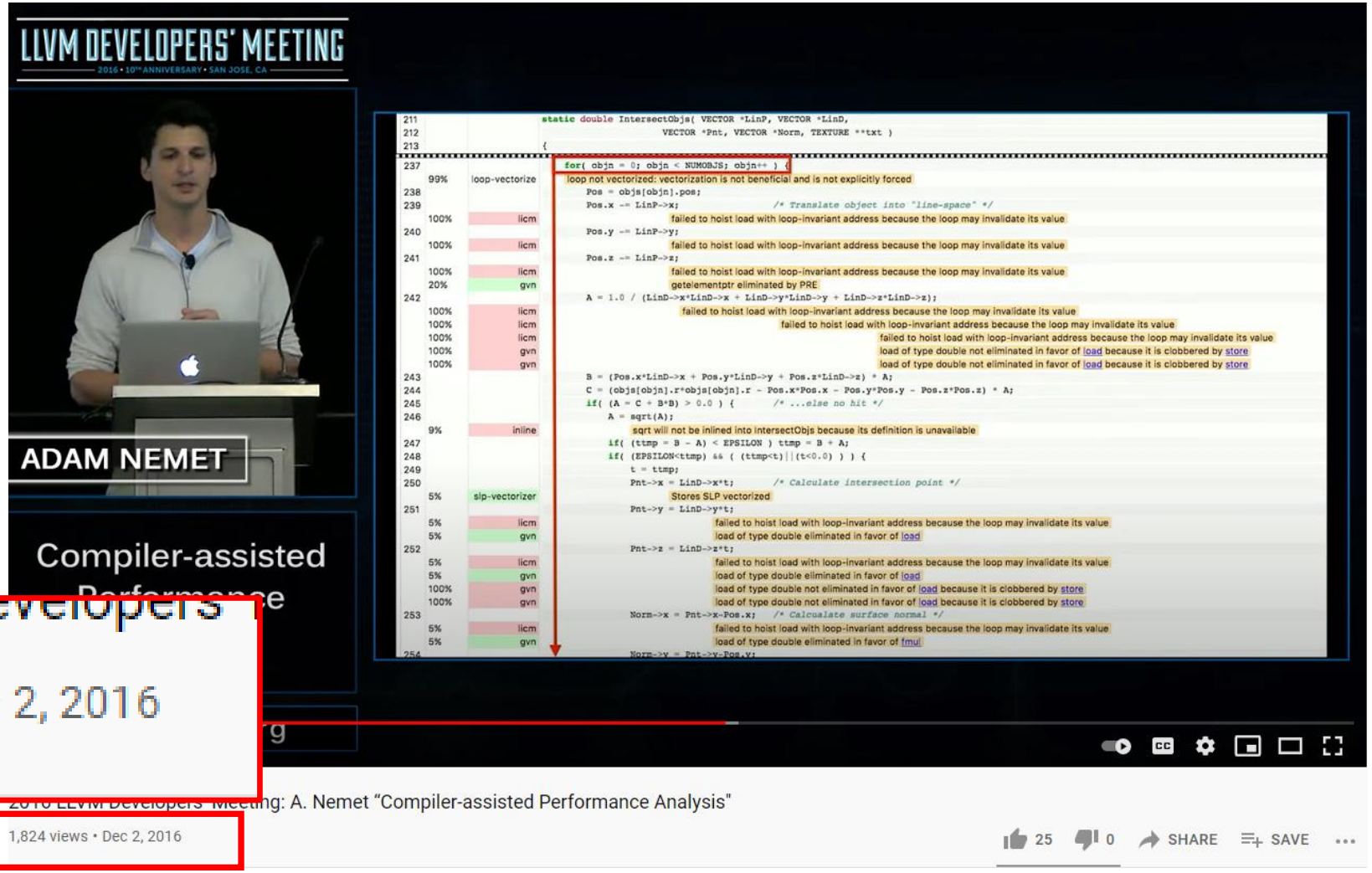
```
...
--- !Passed
Pass:            inline
Name:            Inlined
DebugLoc:        { File: '/usr/bin/../lib/gcc/
                   Line: 147, Column: 16 }
Function:        _ZNSt14pointer_traitsIPKcE10p
Args:
  - Callee:          _ZSt9addressofIKcEPT_RS1_
    DebugLoc:        { File: '/usr/bin/../lib/
                       Line: 139, Column: 0 }
  - String:          ' inlined into '
  - Caller:          _ZNSt14pointer_traitsIPKc
    DebugLoc:        { File: '/usr/bin/../lib/
                       Line: 147, Column: 0 }
  - String:          ' with '
  - String:          '(cost='
```

opt-viewer.py Sample Output



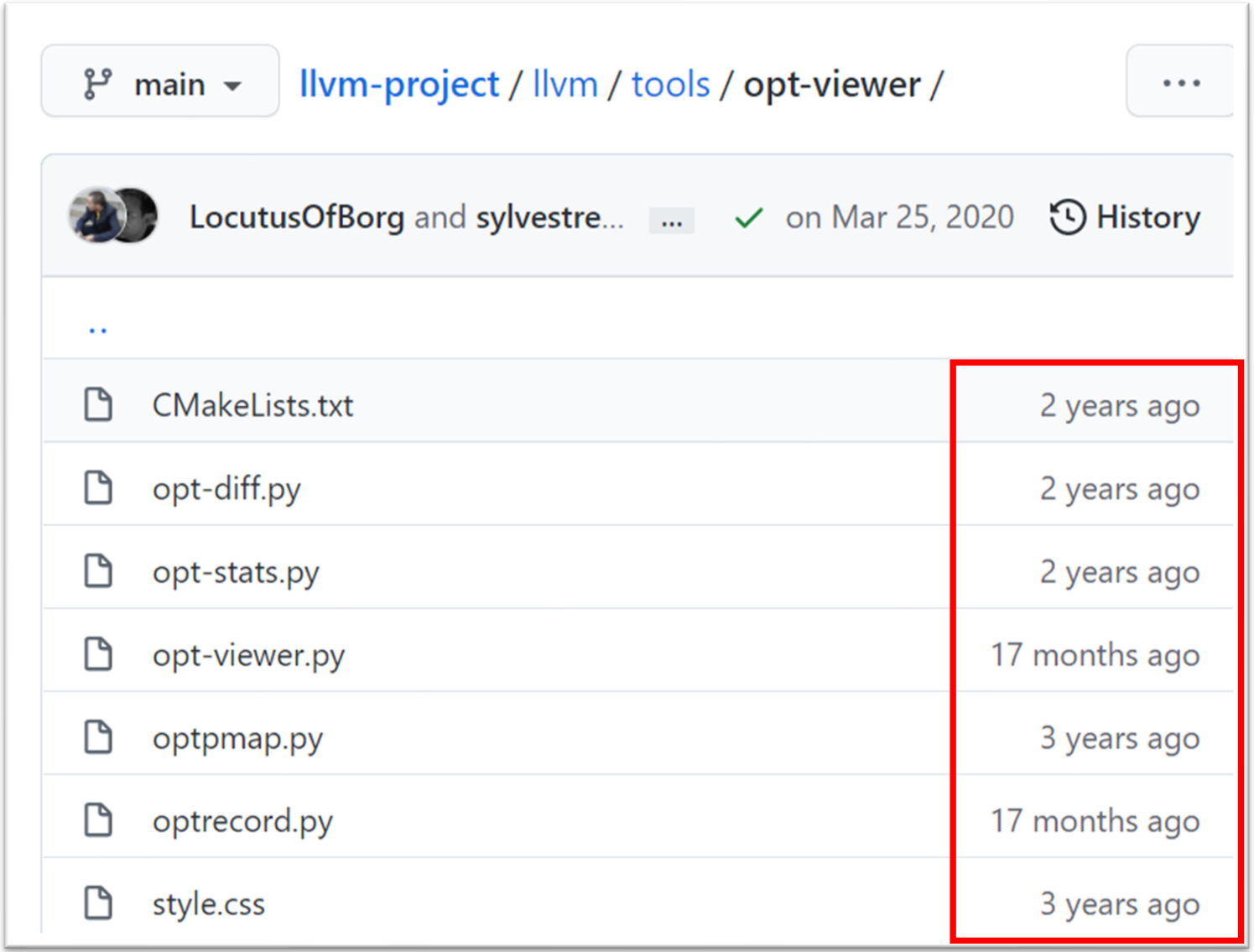
Great work, still not much traction

https://www.youtube.com/watch?v=qq0q1hfzidg



1,824 views • Dec 2, 2016

Great work, still not much traction



Why?

- Heavy
  - High I/O
  - High memory
  - >1G htmls
- Designed for compiler writers
  - Mostly non actionable to developers

Introducing optview2

- https://github.com/OfekShilon/optview2

Target Developers, Not Compiler Authors

- Denoise:
  - Collect only optimization *failures*
  - Ignore system headers
  - Display a single entry per type/source loc (in index)
  - …
  - ~1.5M lines ==> 22K lines
- Don’t mention ‘passes’
- Make the index sortable, resizable & pageable
- Abridged function names
- …

```
ssh://ofek@n56:22/home/ofek/src/optview2/venv/bin
 /python3 -u /tmp/pycharm_project_678/opt-viewer
 .py --jobs 25 --output-dir
 /data/userdata/optview2_html/istra --source-dir
 /home/ofek/repoOptView
 /data/userdata/ofek/repoOptView/obj
For faster parsing, you may want to install
 libYAML for PyYAML
Reading YAML files...
    2413 of 2413
Rendering index page...
  501821 optimization-failure remarks
  31023 unique source locations
  22236 after filtering irrelevant
Rendering HTML files...
    2000 of 2000
Ran for  0:46:10.436379
```

Demos - OpenCV

File | C:/optview2/html/opencv/index.html

Show 100 entries

Location	Description	Function	Message
/home/ofek/src/opencv-clean/modules/ml/test/test_mltests.cp	MissedDetails	__cxx_global_array_dtor.44	loop not vectorized
/home/ofek/src/opencv-clean/modules/ml/test/test_mltests.cp	MissedDetails	__cxx_global_array_dtor.51	loop not vectorized
3rdparty/ade/ade-0.1.1f/sources/ade/include/ade/commun	MissedDetails	std::_Function_handler::finalize()::Connector>::_M_inv	loop not vectorized
3rdparty/ade/ade-0.1.1f/sources/ade/include/ade/commun	TooCostly	ade::CallbackConnector<>::finalize	std::function<void ()>::operator=<ade::CallbackConnector<>::finalize()::Connector> n ade::CallbackConnector<>::finalize because too costly to inline (cost=310, threshold
3rdparty/ade/ade-0.1.1f/sources/ade/include/ade/commun	TooCostly	ade::CallbackConnector<>::finalize	std::function<void ()>::operator=<ade::CallbackConnector<>::finalize()::{lambda()#1} ade::CallbackConnector<>::finalize because too costly to inline (cost=280, threshold
3rdparty/ade/ade-0.1.1f/sources/ade/include/ade/commun	TooCostly	ade::CallbackConnector<>::finalize	std::function<void ()>::operator=<ade::CallbackConnector<>::finalize()::{lambda()#2} ade::CallbackConnector<>::finalize because too costly to inline (cost=280, threshold
3rdparty/ade/ade-0.1.1f/sources/ade/include/ade/commun	MissedDetails	std::_Function_handler::finalize():: {lambda()#3}>::_M_invoke	loop not vectorized
3rdparty/ade/ade-0.1.1f/sources/ade/include/ade/commun	TooCostly	ade::CallbackConnector<>::finalize	std::function<void ()>::operator=<ade::CallbackConnector<>::finalize()::{lambda()#3} ade::CallbackConnector<>::finalize because too costly to inline (cost=280, threshold
3rdparty/ade/ade-0.1.1f/sources/ade/include/ade/commun	TooCostly	ade::CallbackConnector<>::finalize	std::function<void ()>::operator=<ade::CallbackConnector<>::finalize()::{lambda()#4} ade::CallbackConnector<>::finalize because too costly to inline (cost=280, threshold
3rdparty/ade/ade-0.1.1f/sources/ade/include/ade/commun	NoDefinition	ade::ICommChannel::BufferDesc::BufferDesc	ade::MemoryDescriptorRef::MemoryDescriptorRef will not be inlined into ade::ICommChannel::BufferDesc::BufferDesc because its definition is unavailable
3rdparty/ade/ade-0.1.1f/sources/ade/include/ade/execut	TooCostly	ade::ExecutionEngine::addPass	ade::ExecutionEngine::addPass<ade::passes::CheckCycles, char const*> not inlined int ade::ExecutionEngine::addPass<ade::passes::CheckCycles> because too costly to inline threshold=625)
3rdparty/ade/ade-0.1.1f/sources/ade/include/ade/execut	TooCostly	ade::ExecutionEngine::addPass, cv::gapi::GNetPackage))(ade::passes::PassContext&, cv::gapi::GNetPackage const&)>, char const*>	ade::PassManager<ade::passes::PassContext>::addPass<ade::ExecutionEngine::PassWrappe (*(std::_Placeholder<1>, cv::gapi::GNetPackage))(ade::passes::PassContext&, cv::gapi const&)> > > not inlined into ade::ExecutionEngine::addPass<std::_Bind<void (*(std:: cv::gapi::GNetPackage))(ade::passes::PassContext&, cv::gapi::GNetPackage const&)>, c because too costly to inline (cost=250, threshold=250)

Demo 1: inlining

```
template<typename _Tp> inline SeqIterator<_Tp>& SeqIterator<_Tp>::operator ++()
{
    CV_NEXT_SEQ_ELEM(sizeof(_Tp), *this);
inline  • cvChangeSeqBlock will not be inlined into cv::SeqIterator<CvSeq*>::operator++ because its definition is unavailable
```

- `cvChangeSeqBlock will not be inlined into cv::SeqIterator<CvSeq*>::operator++ because its definition is unavailable`
- Dirty fix:
  - Move cvChangeSeqBlock from datastructs.cpp to types_c.h
  - Copy some marcros - CV_SEQ_ELEM, CV_WRITE_SEQ_ELEM_VAR CV_WRITE_SEQ_ELEM
  - Remove declaration from core_c.h
- Less relevant if you’re building with LTO

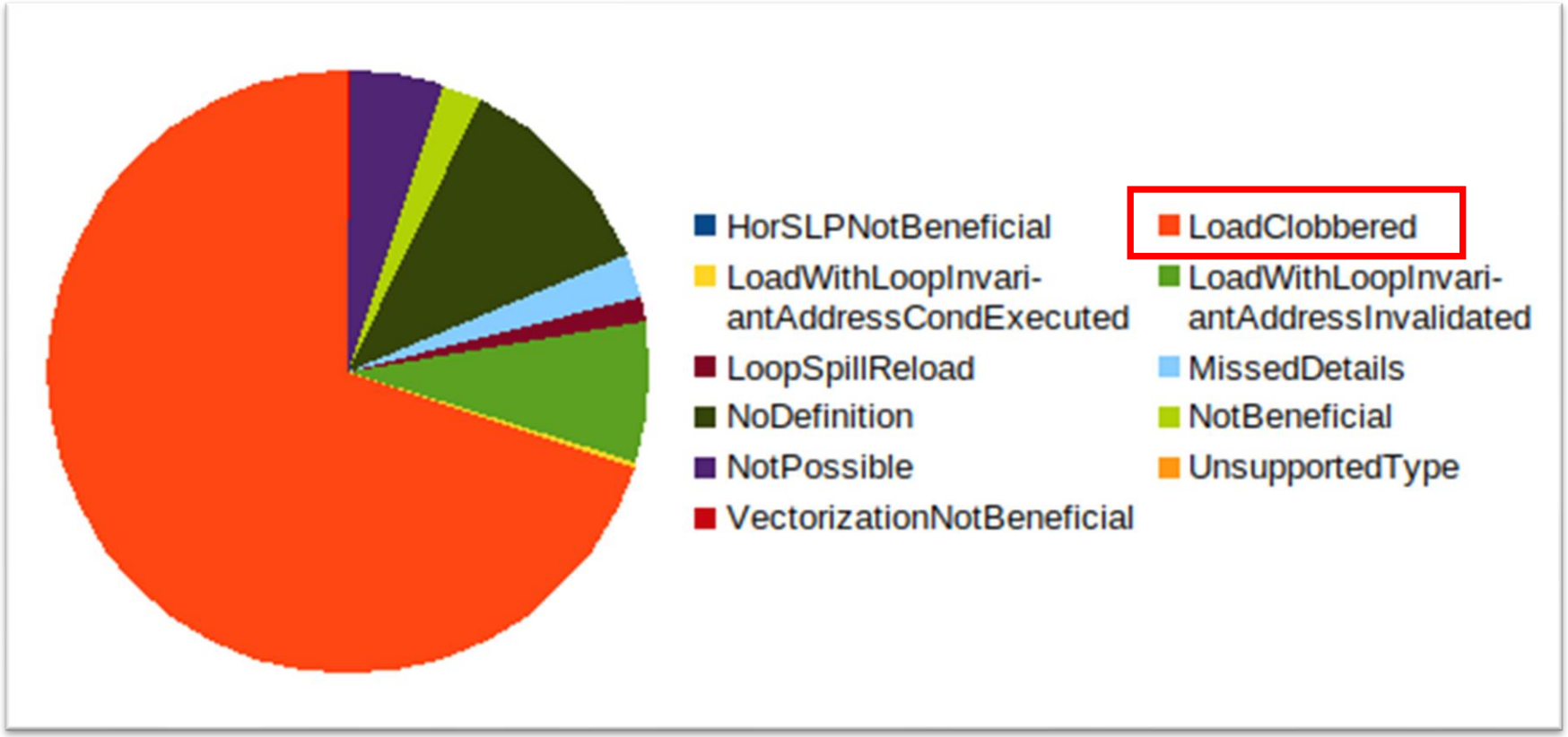
Demo 2:

```
for (int i = 0; i < histSize; ++i)
    tileHist[i] += redistBatch;
      • load of type i32 not eliminated because it is clobbered by store
```

- What if redistBatch references an element of tileHist?
  - ***Aliasing***
  - Forces reloading redistBatch on every loop iteration
  - Compilers are remarkably bad at alias analysis.

Aliasing – the silent killer

- Distribution of 22K remarks in a C++ project:



Detour

Aliasing II: What can we do?

- LTO ? ✗
- __restrict__ ✓
  - Non standard, tells the compiler *an argument* doesn't alias with anything else
- __attribute__((pure)), __attribute__((const)) ✗
  - Non standard, tell the compiler *a function* doesn't write/read global state.
  - Potentially resolve 'clobbered by call' opt failures,
  - No successes seen in the wild yet.
- Strict-Aliasing ✓
  - The only C++ standard compliant way.

Detour

Aliasing III: Types and Strict-Aliasing

- "Strict aliasing is **an assumption made by the compiler**, that objects of different types will never refer to the same memory location (i.e. alias each other.)"

  Mike Acton https://cellperformance.beyond3d.com/articles/2006/06/understanding-strict-aliasing.html

- Allowed optimization. on by default for -O2 +
- char* is an exception – always allowed to alias with any type.
- Can be disabled with –fno-strict-aliasing (pessimization!)
- In the example above – all vars are int.

Detour

Aliasing IV: Forcing type difference

- `typedef / using ?` ✗
- Inherit int? ✗
  - "I considered …to allow derivation from built-in classes … However, I restrained myself. … the C conversion rules are so chaotic that pretending that int, short, etc., are well-behaved ordinary classes is not going to work. They are either C compatible, or they obey the relatively well-behaved C++ rules for classes, but not both."
    Bjarne Stroustrup, The Design and Evolution of C++, §15.11.3.
- Strong-Typedefs ✓
  - Discussion typically motivated by type safety, not optimization
  - boost/serialization/strong_typedef.hpp comes close.

Aliasing IV: BOOST starting point

https://www.boost.org/doc/libs/1_67_0/boost/serialization/strong_typedef.hpp

```
#define BOOST_STRONG_TYPEDEF(T, D)                                          \
struct D : boost::totally_ordered1< D, boost::totally_ordered2< D, T> > \
{                                                                           \
    T t;                                                                    \
    explicit D(const T& t_)  : t(t_) {}                                     \
    D() : t() {}                                                            \
    D(const D & t_)  : t(t_.t) {}                                           \
    D& operator=(const D& rhs)  {t = rhs.t; return *this;}                  \
    D& operator=(const T& rhs)  {t = rhs; return *this;}                    \
    operator const T&() const {return t;}                                   \
    operator T&() {return t;}                                               \
    bool operator==(const D& rhs) const {return t == rhs.t;}                \
    bool operator<(const D& rhs) const {return t < rhs.t;}                  \
};
```

Detour

Aliasing IV: New Types From *Primitive*

```
#define CUSTOM_STRONG_TYPEDEF(T, D)                                  \
struct D                                                             \
{                                                                    \
    T t;                                                             \
    D(const T t_) : t(t_) {};                                        \
    D(){};                                                           \
    D(const D & t_) : t(t_.t){}                                      \
    D & operator=(const D & rhs) { t = rhs.t; return *this;}         \
    D & operator=(const T & rhs) { t = rhs; return *this;}           \
    operator const T & () const {return t; }                        \
    operator T & () { return t; }                                    \
};
```

Aliasing V: Impact

Detour

```
cv::AutoBuffer<int> _tileHist(histSize);
int* tileHist = _tileHist.data();
std::fill(tileHist, tileHist + histSize, 0);
```

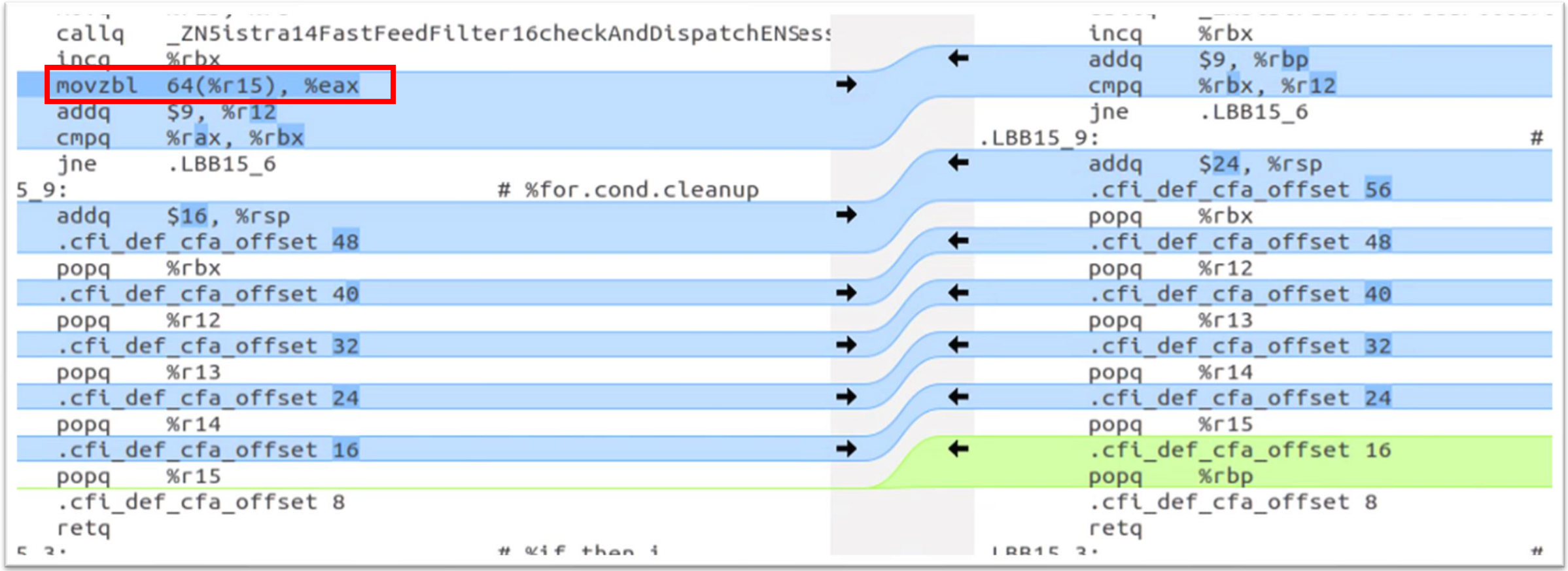
```
CUSTOM_STRONG_TYPEDEF(int, tHistDat)
cv::AutoBuffer<tHistDat> _tileHist(histSize);
tHistDat* tileHist = _tileHist.data();
std::fill(tileHist, tileHist + histSize, 0);
```

```
// redistribute clipped pixels
int redistBatch = clipped / histSize;
int residual = clipped - redistBatch * histSize;

for (int i = 0; i <
    tileHist[i] +=
      • load of typ
      • load of typ
      • load of typ
      • load of typ
      • failed to m
```

```
// redistribute clipped pixels
int redistBatch = clipped / histSize;
int residual = clipped - redistBatch * histSize;

for (int i = 0; i < histSize; ++i)
    tileHist[i] += redistBatch;
      • failed to move load with loop-invariant address because the loop may invalidate its val
```

Aliasing V: Impact

Detour



Impact

```
class CV_EXPORTS Mat
{
…
    //! pointer to the data
    uchar* data;
    tDat   data;
```

Detour

```
struct tDat
{
    uchar* t;
    tDat(uchar* const & t_) : t(t_) {};
    tDat(){};
    tDat(const tDat & t_) : t(t_.t){}
    tDat(tDat & t_) : t(t_.t){}
    tDat & operator=(tDat & rhs) { t = rhs.t; return *this;}
    tDat & operator=(uchar* rhs) { t = rhs; return *this;}
    operator uchar*  () const { return t; }
    operator const uchar* () { return t;}
    bool operator==(uchar* rhs) const {return t == rhs;}
    bool operator==(const uchar* rhs) const {return t == rhs;}
    bool operator==(tDat& rhs) const {return t == rhs.t;}
    bool operator==(const tDat& rhs) const {return t == rhs.t;}
    bool operator==(nullptr_t) const { return t == nullptr;}
    bool operator!=(uchar* rhs) const {return t != rhs;}
    bool operator!=(tDat& rhs) const {return t != rhs.t;}
    bool operator!=(const tDat& rhs) const {return t != rhs.t;}
    uchar* operator+(long i) const { return t + i; }
    uchar* operator+=(long i) { t += i; return t;}
    uchar* operator-=(long i) { t -= i; return t;}
    uchar& operator[](long i) { return t[i];}
    uchar operator[](long i) const { return t[i];}
    template<typename T> operator T*() const { return (T*)(t); }
};
```

Detour

Impact

https://github.com/opencv/opencv/wiki/HowToUsePerfTests

```
$ cd ~/src/opencv/modules/ts/misc/
$ python3 ./run.py ~/src/opencv-clean/build/ -w ~/logs-opencv-clean
$ python3 ./run.py ~/src/opencv-opt/build/ -w ~/logs-opencv-opt
$ python3 ./summary.py ~/logs-opencv-clean/core* ~/logs-opencv-opt/core*
-u mks -m median
```

- Seems substantial.
- Will publish more detailed steps in the optview2 github page (and possibly fork opencv)

Demo 3: loop hoisting

```
//   2 - the pixel does belong to an edge
for (int i = rowStart; i <= boundaries.end; ++i)
  • failed to move load with loop-invariant address because the loop may invalidate its value
  • load of type i32 not eliminated in favor of load because it is clobbered by store
  • load of type i32 not eliminated because it is clobbered by store
```

```
        if (L2gradient)
          • failed to move load with loop-invariant address because the loop may inva
```

Demo 3: loop hoisting

```
const int end = boundaries.end;
  • load of type i32 not eliminated in favor of load because it is clobbered by store
const bool localL2gradient = L2gradient;
  • load of type i8 not eliminated because it is clobbered by invoke
  • load of type i8 not eliminated because it is clobbered by call
  • load of type i8 not eliminated because it is clobbered by call

for (int i = rowStart; i <= end; ++i)
  • 64 spills 1 folded spills 115 reloads 18 folded reloads generated in loop
{
    // Scroll the ring buffer
```

```
if (localL2gradient)
{
    int j = 0, width = src.cols * cn;
```

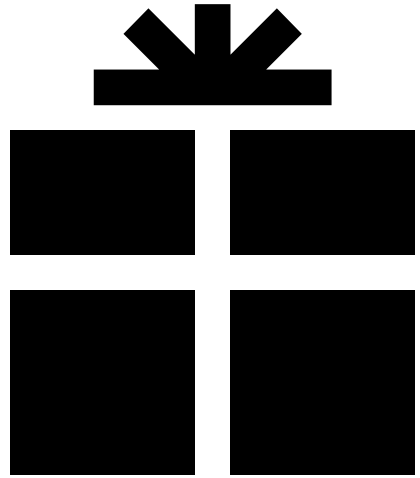
PGO integration

- “Hotness” column, can be used for sorting or filtering
- Demo

- Not necessary. If you have profiling data – use that to narrow your search.

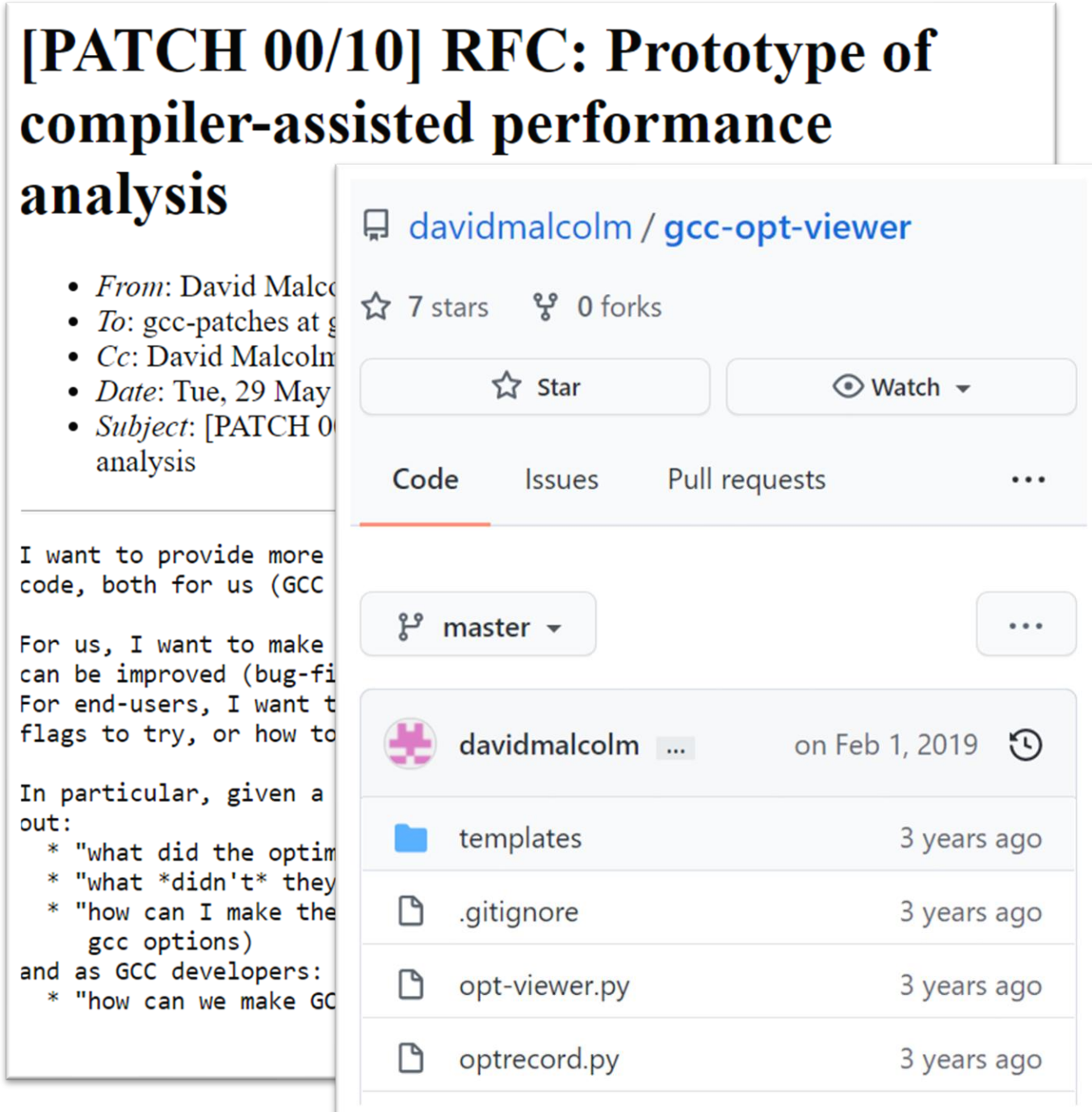
!

iuuqt ;00hpecpnu/psh0{0c5t : cX Xdp



GCC work

- https://gcc.gnu.org/legacy-ml/gcc-patches/2018-05/msg01675.html
- https://github.com/davidmalcolm/gcc-opt-viewer
- YAML -> JSON
  - Actually a better choice
    https://stackoverflow.com/questions/27743711/can-i-speedup-yaml
- Worse starting point
- Active only during 2018



[PATCH 00/10] RFC: Prototype of compiler-assisted performance analysis

- *From*: David Malc
- *To*: gcc-patches at g
- *Cc*: David Malcoln
- *Date*: Tue, 29 May
- *Subject*: [PATCH 0
  analysis

```
I want to provide more
code, both for us (GCC

For us, I want to make
can be improved (bug-fi
For end-users, I want t
flags to try, or how to

In particular, given a
out:
  * "what did the optim
  * "what *didn't* they
  * "how can I make the
     gcc options)
and as GCC developers:
  * "how can we make GC
```

davidmalcolm / gcc-opt-viewer

7 stars 0 forks

Star Watch

Code Issues Pull requests ...

master

davidmalcolm ... on Feb 1, 2019

templates	3 years ago
.gitignore	3 years ago
opt-viewer.py	3 years ago
optrecord.py	3 years ago

Conclusions applicable to other compilers?

- ?

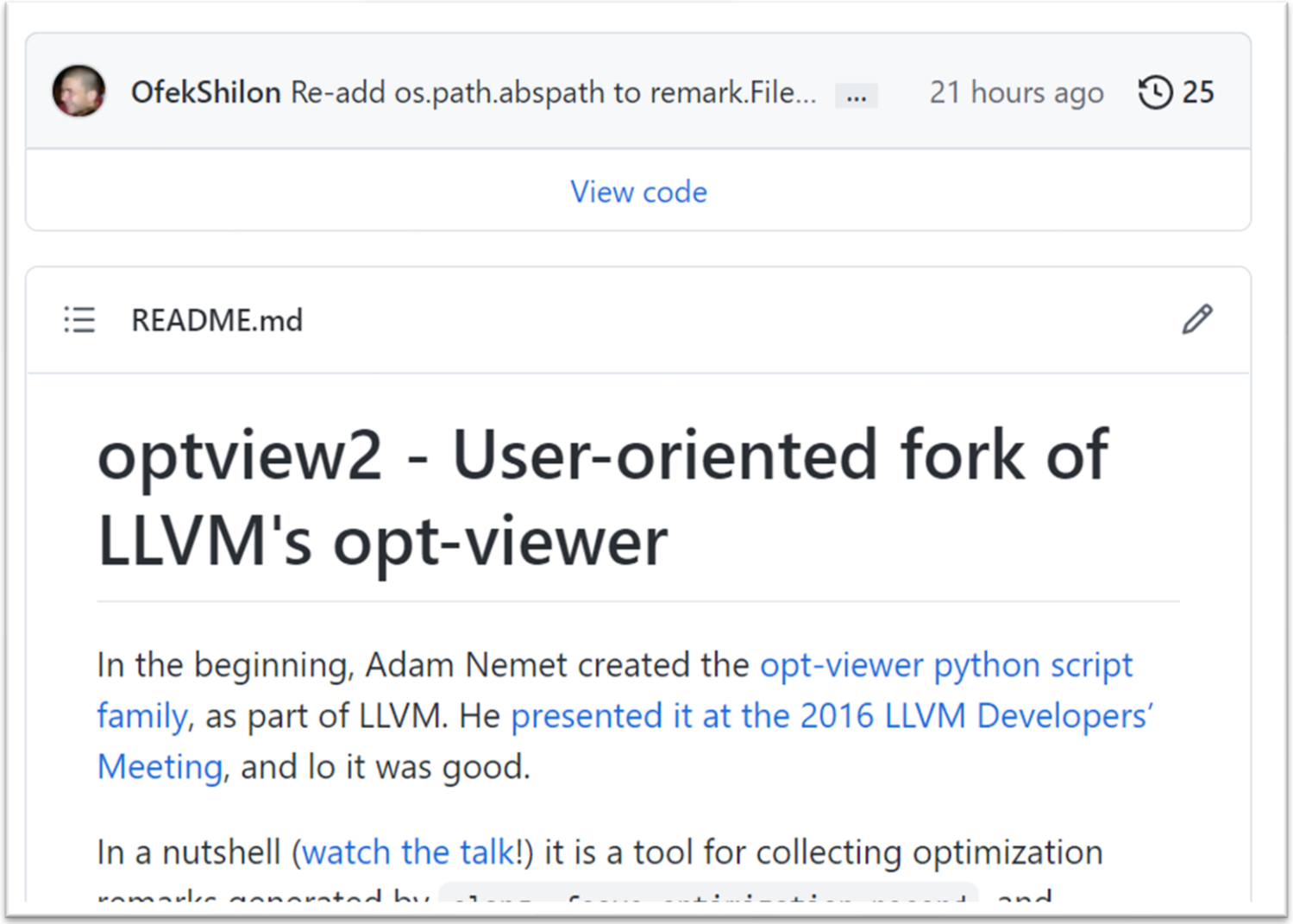
Future work

- Enhance filtering,
- Consume binary optimization remarks,
- Reduce run time & memory,
- Adapt (possibly integrate) gcc opt-viewer,
- Support code annotations,
- Script code quality improvements,
- Report LLVM bugs

  - Lots of help needed ☺
  - https://github.com/OfekShilon/optview2

https://github.com/OfekShilon/optview2

- ofekshilon@gmail.com
- Questions?



Bkp

llvm-opt-report

```
$ clang -O3 -o /tmp/v.o -c /tmp/v.c -fsave-optimization-record
$ llvm-opt-report /tmp/v.yaml > /tmp/v.lst
$ cat /tmp/v.lst
```

- https://reviews.llvm.org/D25262
- https://github.com/llvm/llvm-project/tree/main/llvm/tools/llvm-opt-report

```
< /tmp/v.c
 2           | void bar();
 3           | void foo() { bar(); }
 4           |
 5           | void Test(int *res, int *c, int *d, int *p, int n) {
 6           |   int i;
 7           |
 8           | #pragma clang loop vectorize(assume_safety)
 9      V4,2 |   for (i = 0; i < 1600; i++) {
10           |     res[i] = (p[i] == 0) ? res[i] : res[i] + d[i];
11           |   }
12           |
13  U16      |   for (i = 0; i < 16; i++) {
14           |     res[i] = (p[i] == 0) ? res[i] : res[i] + d[i];
15           |   }
16           |
17 I         |   foo();
18           |
19           |   foo(); bar(); foo();
   I         |   ^
   I         |                 ^
20           | }
```

Name of Test	core clean 20210825-025513	core opt 20210825-035217	core opt 20210825-035217 vs core clean
subtract::BinaryOpTest::(1920x1080, 16SC4)	3189.750	3163.450	1.01
subtractScalarDouble::BinaryOpTest::(640x480, 8UC1)	143.450	103.900	1.38
subtractScalarDouble::BinaryOpTest::(640x480, 8SC1)	91.400	86.600	1.06
subtractScalarDouble::BinaryOpTest::(640x480, 16SC1)	78.100	79.800	0.98
subtractScalarDouble::BinaryOpTest::(640x480, 32SC1)	60.800	55.900	1.09
subtractScalarDouble::BinaryOpTest::(640x480, 32FC1)	59.950	56.100	1.07
subtractScalarDouble::BinaryOpTest::(640x480, 16SC2)	170.000	162.700	1.04
subtractScalarDouble::BinaryOpTest::(640x480, 8UC3)	361.100	291.200	1.24
subtractScalarDouble::BinaryOpTest::(640x480, 16SC3)	262.750	249.200	1.05
subtractScalarDouble::BinaryOpTest::(640x480, 8UC4)	405.900	346.250	1.17
subtractScalarDouble::BinaryOpTest::(640x480, 16SC4)	338.100	333.800	1.01
subtractScalarDouble::BinaryOpTest::(1280x720, 8UC1)	300.050	265.100	1.13
subtractScalarDouble::BinaryOpTest::(1280x720, 8SC1)	343.700	262.100	1.31
subtractScalarDouble::BinaryOpTest::(1280x720, 16SC1)	319.800	233.100	1.37
subtractScalarDouble::BinaryOpTest::(1280x720, 32SC1)	189.000	196.800	0.96
subtractScalarDouble::BinaryOpTest::(1280x720, 32FC1)	187.000	196.300	0.95
subtractScalarDouble::BinaryOpTest::(1280x720, 16SC2)	630.350	536.000	1.18
subtractScalarDouble::BinaryOpTest::(1280x720, 8UC3)	925.650	821.550	1.13
subtractScalarDouble::BinaryOpTest::(1280x720, 16SC3)	942.100	921.600	1.02
subtractScalarDouble::BinaryOpTest::(1280x720, 8UC4)	1486.450	1063.900	1.40
subtractScalarDouble::BinaryOpTest::(1280x720, 16SC4)	1130.700	1259.200	0.90
subtractScalarDouble::BinaryOpTest::(1920x1080, 8UC1)	705.650	591.050	1.19
subtractScalarDouble::BinaryOpTest::(1920x1080, 8SC1)	713.450	609.800	1.17
subtractScalarDouble::BinaryOpTest::(1920x1080, 16SC1)	615.850	627.650	0.98
subtractScalarDouble::BinaryOpTest::(1920x1080, 32SC1)	762.300	759.900	1.00
subtractScalarDouble::BinaryOpTest::(1920x1080, 32FC1)	768.750	795.300	0.97
subtractScalarDouble::BinaryOpTest::(1920x1080, 16SC2)	1311.400	1327.700	0.99
subtractScalarDouble::BinaryOpTest::(1920x1080, 8UC3)	2252.000	2382.750	0.95
subtractScalarDouble::BinaryOpTest::(1920x1080, 16SC3)	2587.250	2258.700	1.15
subtractScalarDouble::BinaryOpTest::(1920x1080, 8UC4)	3004.700	3235.900	0.93
subtractScalarDouble::BinaryOpTest::(1920x1080, 16SC4)	3333.300	2812.950	1.18