Simple Outer Loop Vectorization == Loop Unroll-and-Jam + SLP

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Simple OLV == Loop Unroll-And-Jam (UnJ) + SLP

- OLV can be visualized as [Nuzman & Zaks, PACT 2008]
  - Unroll the outer loop by k times
  - Jam all the k-inner loop instances of the outer loop
  - Vectorize the loops using SLP

- Ex:

```c
for (i = 0; i < N; i++)
    accum = 0;
for (j = 0; j < 5; j++)
    accum += in[i][j] * filter[j];
out[i] = sqrtf(accum)/particles;
```

```c
for (i = 0; i < N; i+= 4) {
    accum1 = accum2 = accum3 = accum4 = 0;
    for (j = 0; j < 5; j++)
        accum1 += in[i][j] * filter[j];
    for (j = 0; j < 5; j++)
        accum2 += in[i][j+1] * filter[j];
    for (j = 0; j < 5; j++)
        accum3 += in[i][j+2] * filter[j];
    for (j = 0; j < 5; j++)
        accum4 += in[i][j+3] * filter[j];
    out[i] = sqrtf(accum1)/particles;
    out[i+1] = sqrtf(accum2)/particles;
    out[i+2] = sqrtf(accum3)/particles;
    out[i+3] = sqrtf(accum4)/particles;
}
```

Better code generation of inner loop reduction
No gather in the inner loop
Loop Unroll-And-Jam

- New Pass introduced in July 2018
  - `lib/Transforms/Scalar/LoopUnrollAndJamPass.cpp`
- Two flags –`enable-unroll-and-jam` and –`allow-unroll-and-jam`
- Supports pragma `allow_unroll_and_jam(factor)`
- Called ‘after’ SLP in PassManager
Modifications in IPO/PassManager to support OLV

- Schedule UnJ Pass before the LoopVectorizer Pass
- Call a bunch of cleanup routines after that
  - Looks like we may need to call LSR as a cleanup pretty early (challenging ?)
  - LSR needed probably because UnJ implementation is not optimal
- ... ➔ UnJ ➔ cleanup ➔ LV ➔ ... ➔ SLP ➔ ...
- Need to schedule SLP also before LV ?
  - ... ➔ UnJ ➔ cleanup ➔ SLP’ ➔ ... ➔ LV ➔ ... ➔ SLP’ ➔ ...
  - Else LV may vectorize the jammed inner loop resulting in code which we don’t like ?
  - Very likely that due to costing LV will not vectorize the inner loop
    - Even if it does, we can modify SLP to SLP’ to vectorize “already-vectorized” code
One more example

- Reported in llvm-dev in 2017
  - Inner loop data dependence
  - No outer loop simdization pragma
    - Expects automatic OLV
- UnJ+SLP does OLV
  - Current LLVM stage does some OLV but not cleanly
    - mul, sub not vectorized
Open Problems

- **Costing and Feasibility**
  - Which loops to UnJ
    - Inner loops with reductions
    - Inner Loops with accesses strided on the outer loop index
    - Inner Loops with low trip count
    - Inner loops with data dependence but no dependence on the outer loops
  - What is the unroll factor (UF)?
    - Assume SLP will work in which case choose UF such that DataSize * UF = SIMD width
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