Control Flow in GCC Generated Compiler

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Walking the Maze of a Large Code Base

- If you use conventional editors such as `vi` or `emacs`
  - Use cscope

    ```
    cd $SOURCE
    cscope -R
    ```

  - Use ctags

    ```
    cd $SOURCE
    ctags -R
    ```

    Make sure you use `exeburant-ctags`
- Or use IDE such as `eclipse`

gcc Driver Control Flow

```
main   /* In file gcc.c */
   validate_all_switches
   lookup_compiler
   do_spec
      do_spec_2
         do_spec_1  /* Get the name of the compiler */
      execute
         pex_init
         pex_run
            pex_run_in_environment
               obj->funcs->exec_child
```


gcc Driver Control Flow

```
main   /* In file gcc.c */
   validate_all_switches
   lookup_compiler
   do_spec
      do_spec_2
         do_spec_1  /*
      execute
         pex_init
         pex_run
            pex_run_in
               obj->fu
```

Observations

- All compilers are invoked by this driver
- Assembler is also invoked by this driver
- Linker is invoked in the end by default

cc1 Top Level Control Flow

```
main                    /* In file main.c */
|   toplev_main    /* In file toplev.c */
|   |   decode_options
|   |   do_compile
|   |   |   compile_file
|   |   |       lang_hooks.parse_file => c_common_parse_file
|   |   |       lang_hooks.decls.final_write_globals =>
|   |   |                                   c_write_global_declarations
|   |   |     targetm.asm_out.file_end
|   |   finalize
|   |
|
```


cc1 Top Level Control Flow

```
main                    /* In file main.c */
  toplev_main           /* In file toplev.c */
    decode_options
    do_compile
      compile_file
        lang_hooks                                  le
        lang_hooks
                                                    eclarations
        targetm.asm
    finalize
```

Observations

- The entire compilation is driven by functions specified in language hooks
- Not a good design!

cc1 Control Flow: Parsing for C

```
lang_hooks.parse_file => c_common_parse_file
   c_parse_file
      c_parser_translation_unit
         c_parser_external_declaration
            c_parser_declaration_or_fndef
               c_parser_declspecs /* parse declarations */
               c_parser_compound_statement
               finish_function    /* finish parsing */
                  c_genericize
                  cgraph_finalize_function
                  /* finalize AST of a function */
```


cc1 Control Flow: Parsing for C

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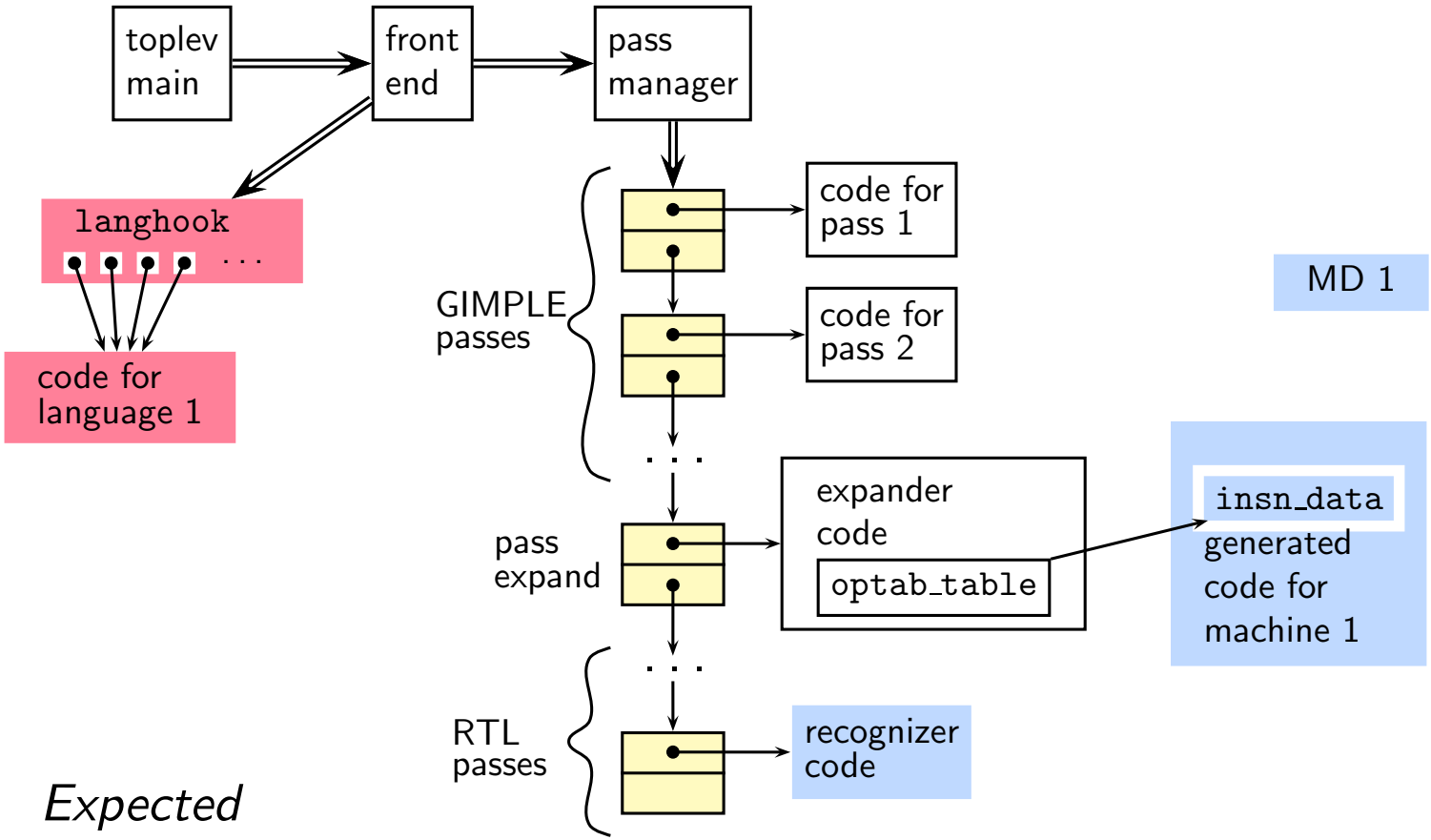
            c_parser_declaration_or_fndef
               c_pars                                    ns */
               c_pars
               finish                                    /
                  c_g
                  cgr
                  /*
```

Observations

- GCC has moved to a recursive descent parser from version 4.1.0
- Earlier parser was generated using Bison specification

Expected Vs. Actual Schematic of the Front End



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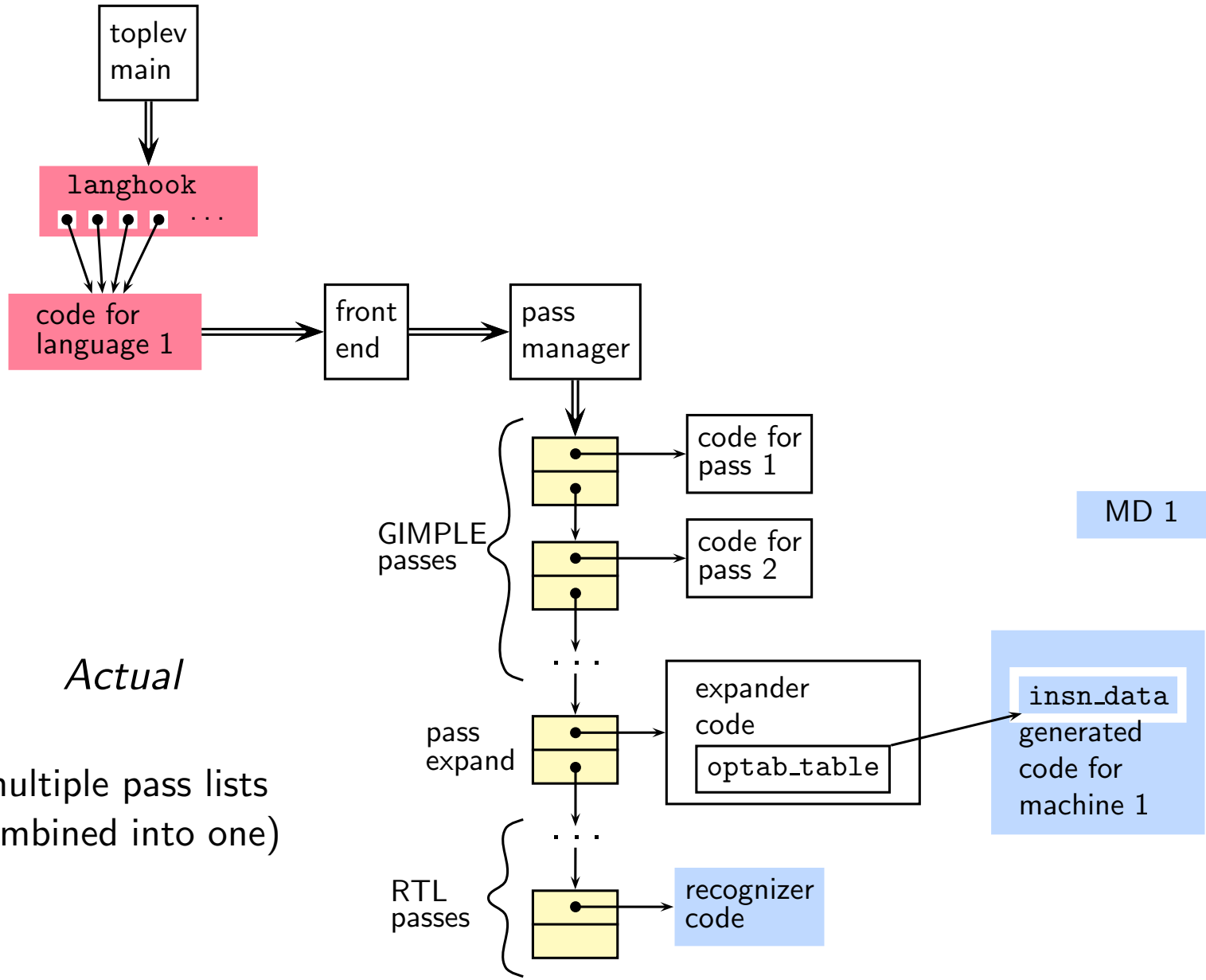

cc1 Control Flow: Lowering Passes for C

```
lang_hooks.decls.final_write_globals =>
                                        c_write_global_declarations
    cgraph_finalize_compilation_unit
       cgraph_analyze_functions      /* Create GIMPLE */
          cgraph_analyze_function
             gimplify_function_tree
                gimplify_body
                   gimplify_stmt
                      gimplify_expr
             cgraph_lower_function    /* Intraprocedural */
                tree_lowering_passes
                   execute_pass_list (all_lowering_passes)
```


cc1 Control Flow: Lowering Passes for C

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cc1 Control Flow: Lowering Passes for C

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          cgraph_analyze_function
             gimplify
                gimpl
                   gi

             cgraph_l                                  ural */
                tree_
                   ex                                  asses)
```

Observations

- Lowering passes are language independent
- Yet they are being called from a function in language hooks
- Not a good design!

Organization of Passes

Order	Task	IR	Level	Pass data structure
1	Lowering	GIMPLE	Intra	`gimple_opt_pass`
2	Optimizations	GIMPLE	Inter	`simple_ipa_opt_pass`
3	Optimizations	GIMPLE	Inter	`ipa_opt_pass_d`
4	Optimizations	GIMPLE	Intra	`gimple_opt_pass`
5	RTL Generation	GIMPLE	Intra	`rtl_opt_pass`
6	Optimization	RTL	Intra	`rtl_opt_pass`

cc1 Control Flow: Optimization and Code Generation Passes

```
cgraph_analyze_function          /* Create GIMPLE */
...                              /* previous slide */
cgraph_optimize
   ipa_passes
      execute_ipa_pass_list(all_small_ipa_passes)  /*!in_lto_p*/
      execute_ipa_summary_passes(all_regular_ipa_passes)
      execute_ipa_summary_passes(all_lto_gen_passes)
      ipa_write_summaries
   execute_ipa_pass_list(all_late_ipa_passes)
   cgraph_expand_all_functions
       cgraph_expand_function
       /* Intraprocedural passes on GIMPLE,  */
       /* expansion pass, and passes on RTL. */
            tree_rest_of_compilation
               execute_pass_list (all_passes)
```

cc1 Control Flow: Optimization and Code Generation Passes

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cgraph_analyze_function          /* Create GIMPLE */
...                              /* previous slide */
cgraph_optimize
  ipa_passes
    execute_ipa_pass_list(all_small_ipa_passes)  /*!in_lto_p*/
    execute_ipa_summary_passes(all_regular_ipa_passes)
    execute_ipa_summary_passes(all_lto_gen_passes)
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cc1 Control Flow: Optimization and Code Generation Passes

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...                              /* previous slide */
cgraph_optimize
   ipa_passes
      execute_ipa_pas                                  !in_lto_p*/
      execute_ipa_sum                                  ses)
      execute_ipa_sum
      ipa_write_summa
   execute_ipa_pass_l
   cgraph_expand_all_
       cgraph_expand_
       /* Intraproced
       /* expansion p
            tree_rest
               execut
```

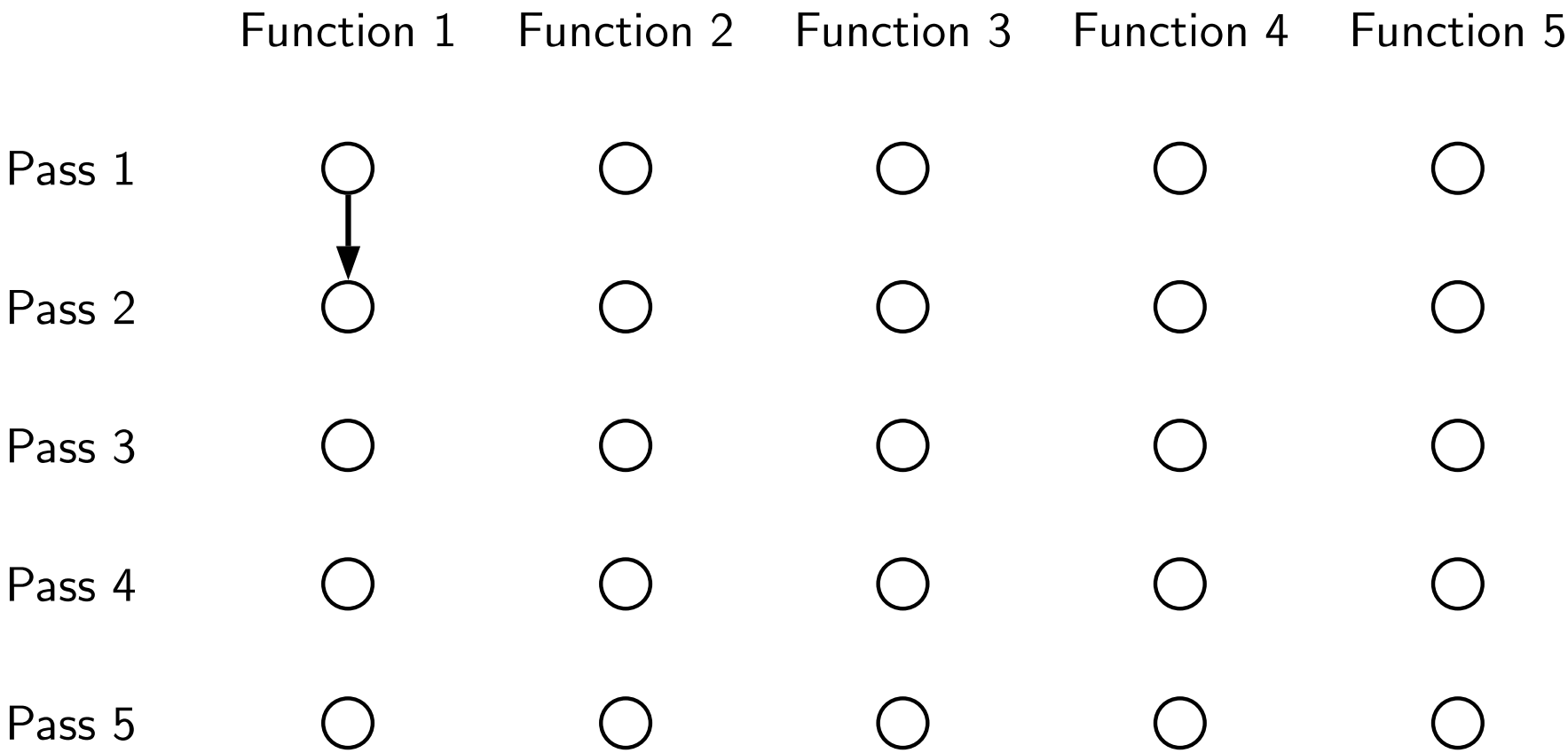
Observations

- Optimization and code generation passes are language independent
- Yet they are being called from a function in language hooks
- Not a good design!

Execution Order in Intraprocedural Passes

	Function 1	Function 2	Function 3	Function 4	Function 5
Pass 1	○	○	○	○	○
Pass 2	○	○	○	○	○
Pass 3	○	○	○	○	○
Pass 4	○	○	○	○	○
Pass 5	○	○	○	○	○

Execution Order in Intraprocedural Passes



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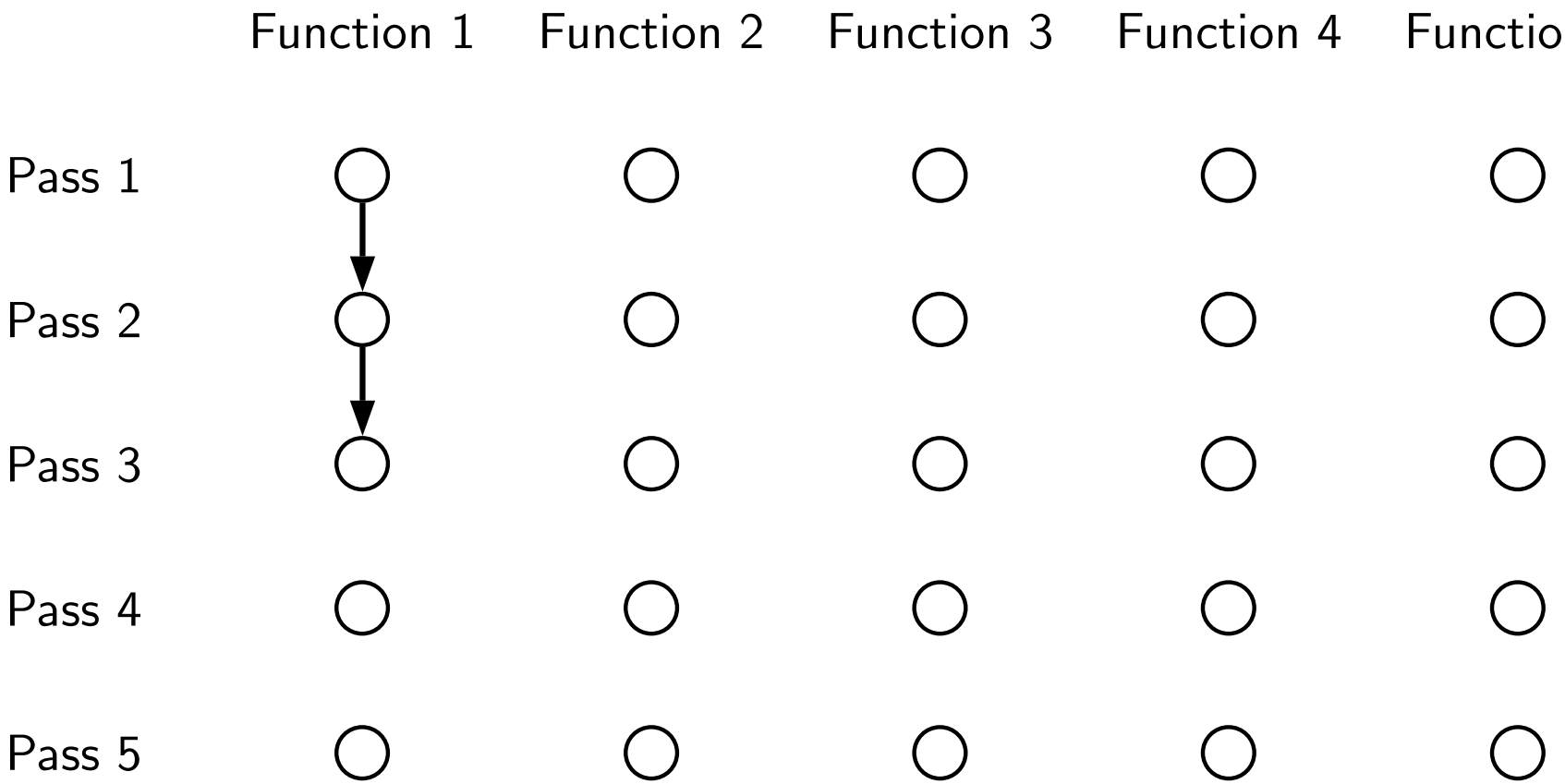

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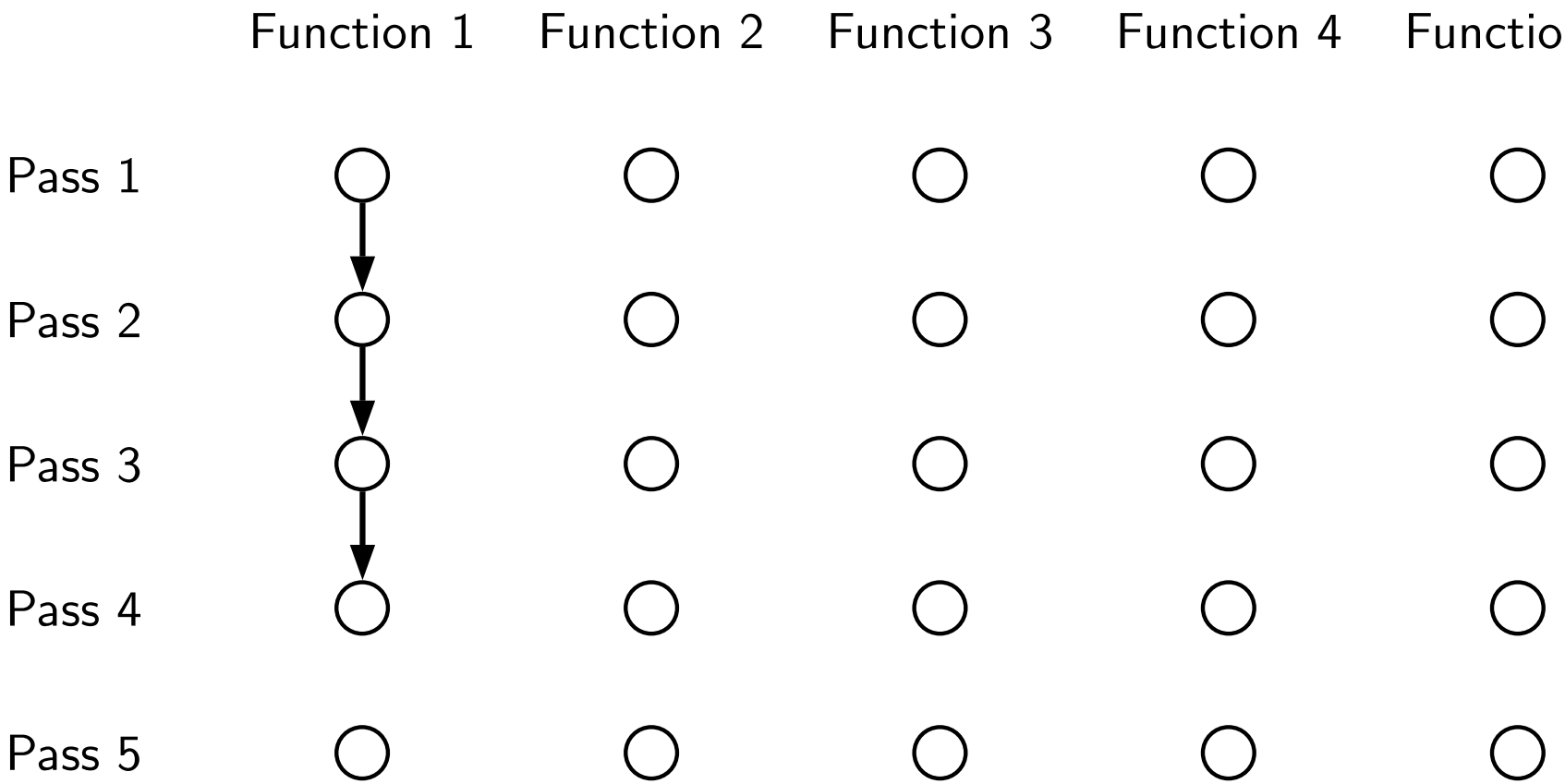

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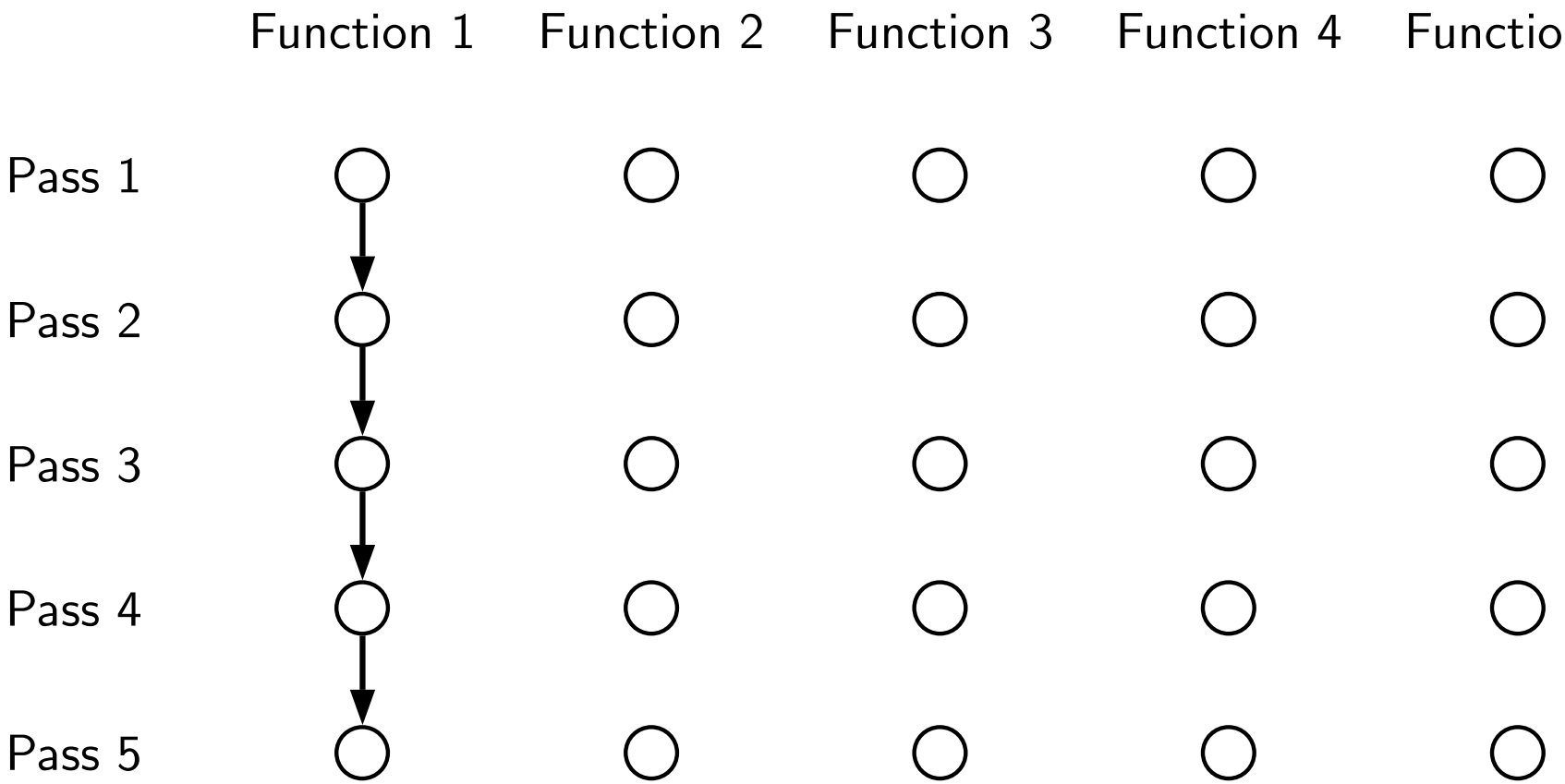

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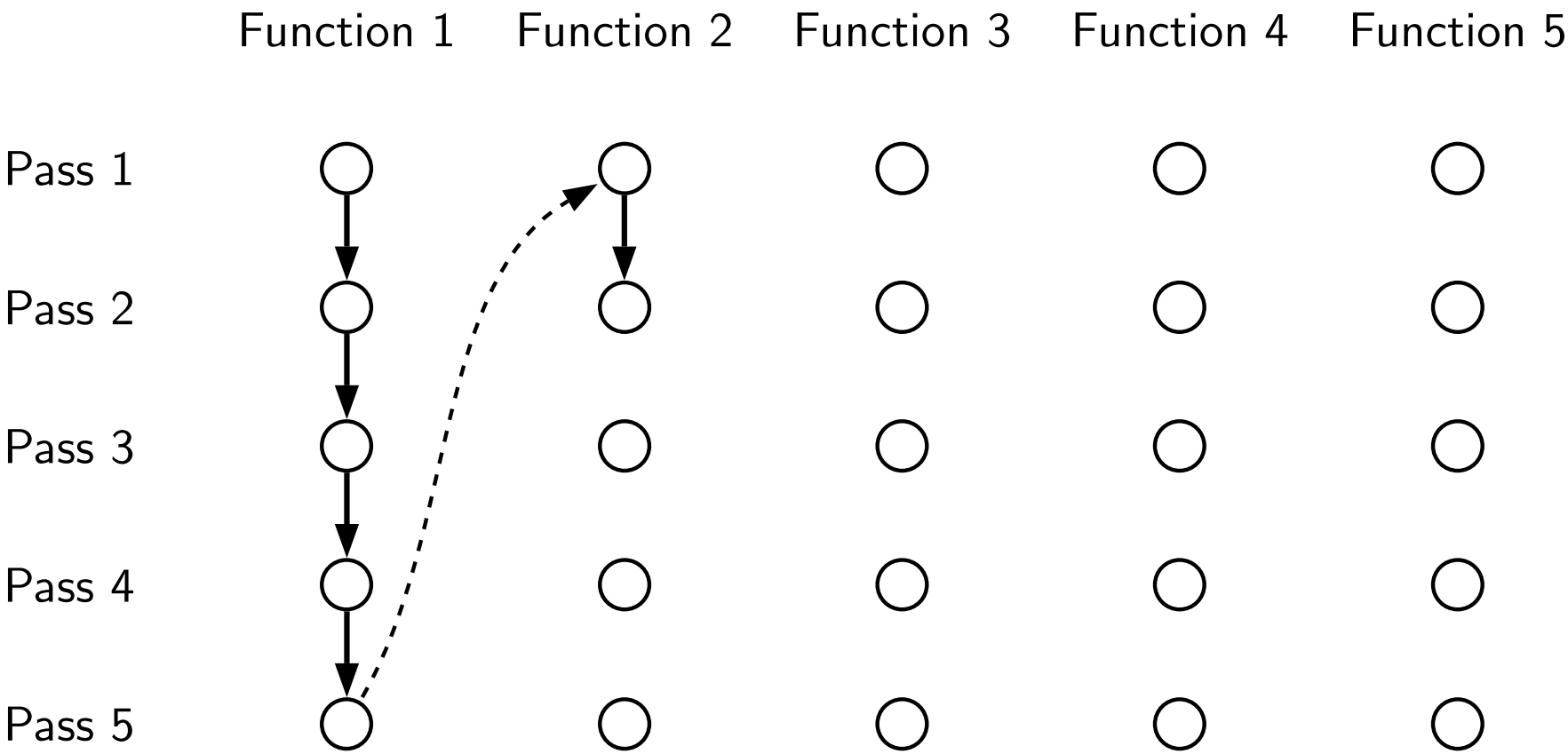

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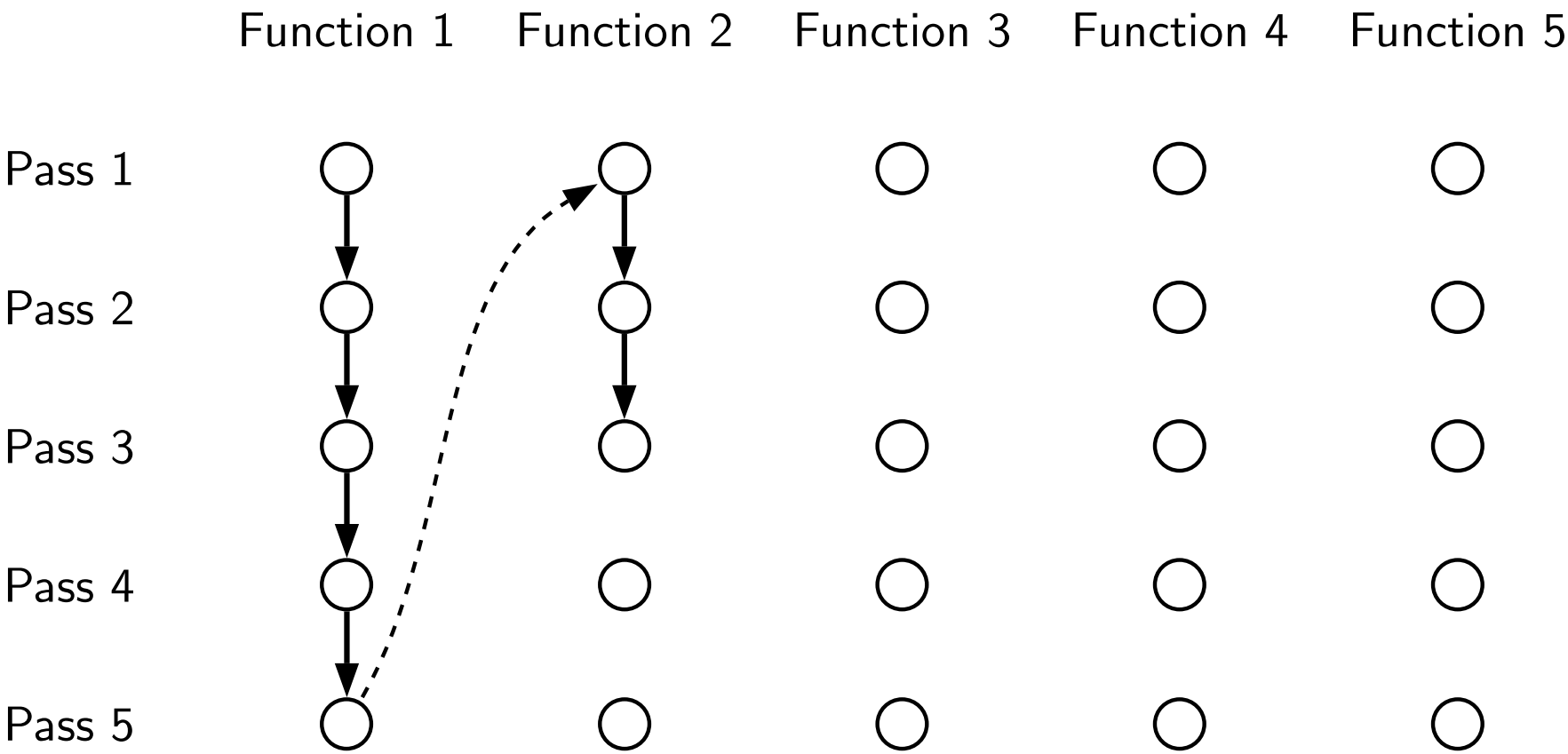

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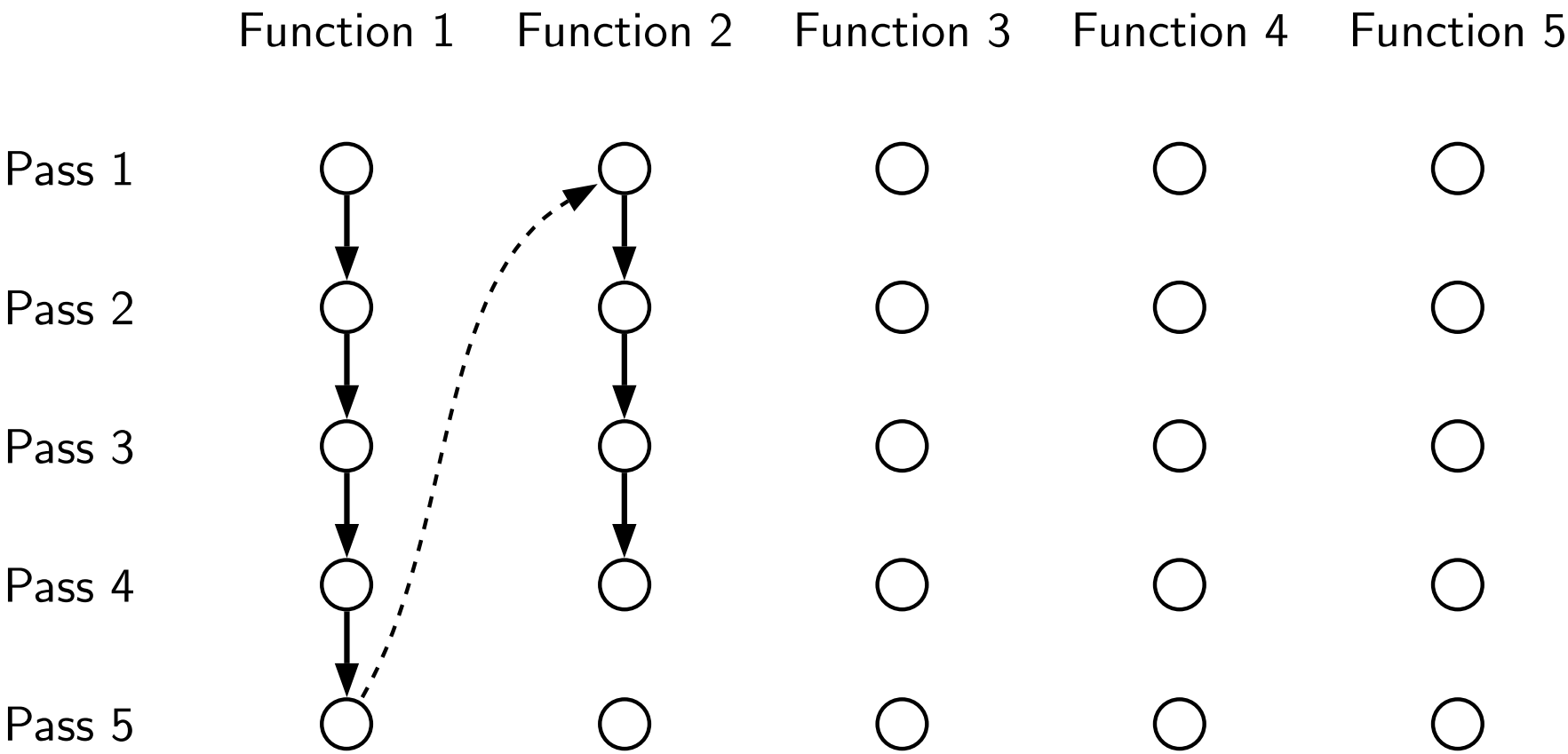

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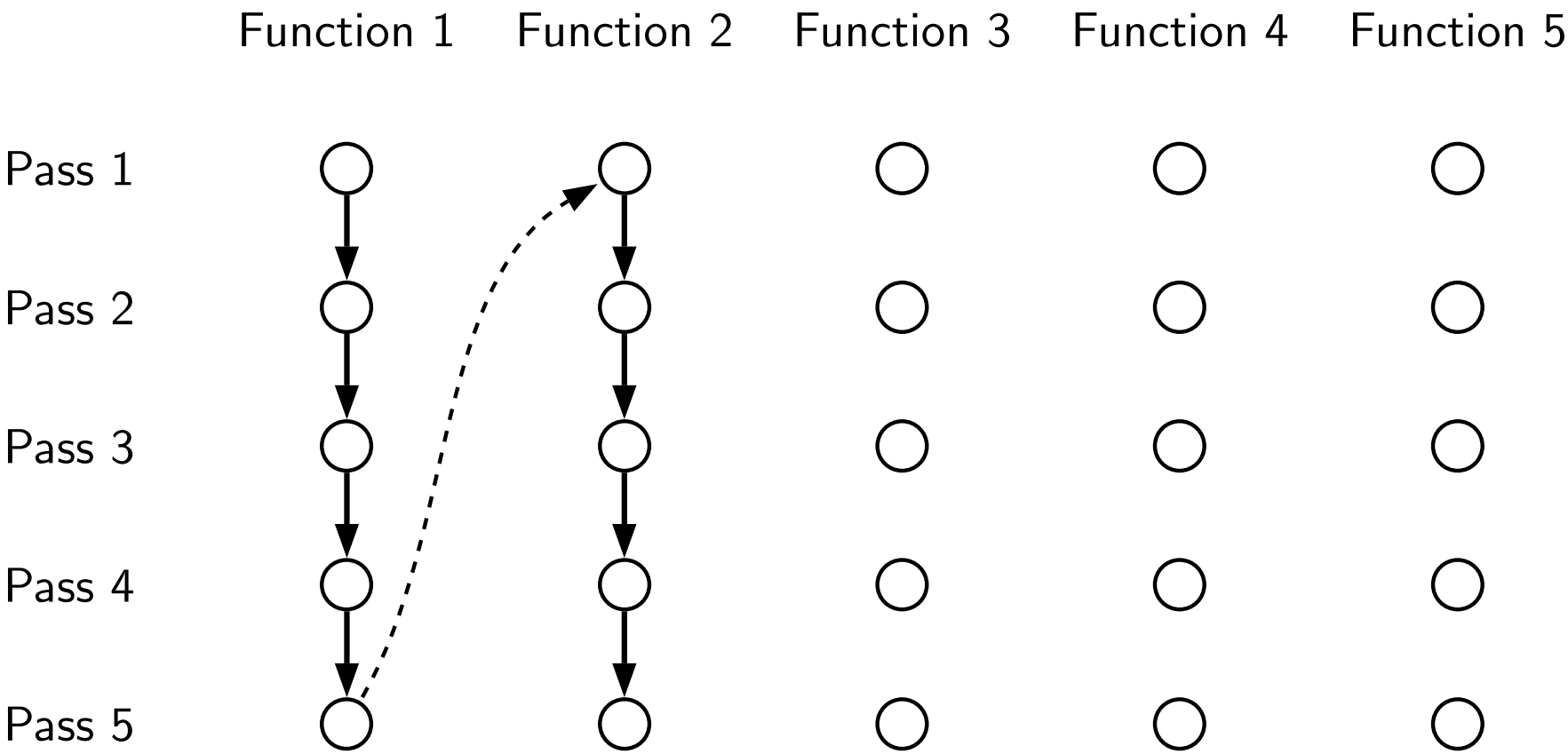

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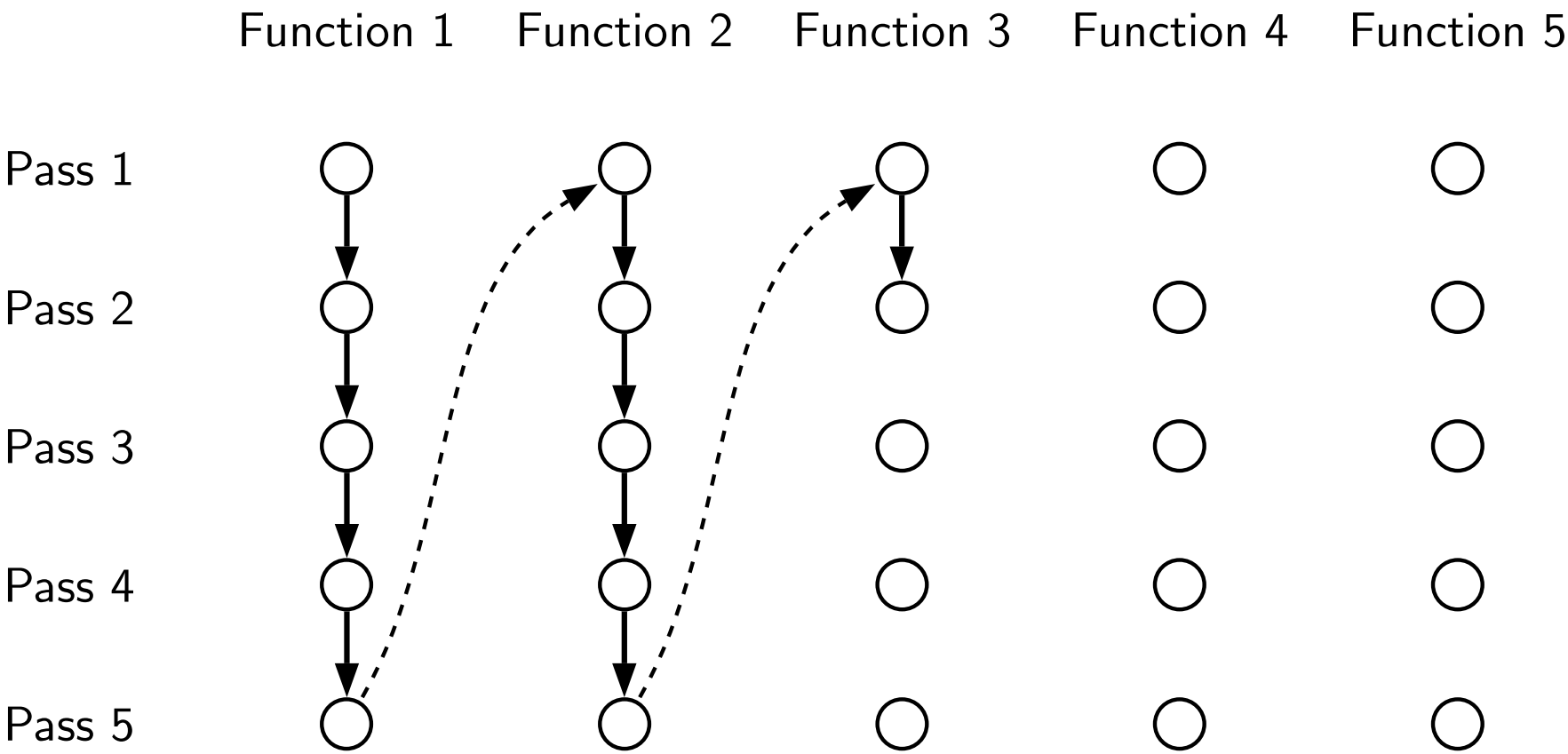

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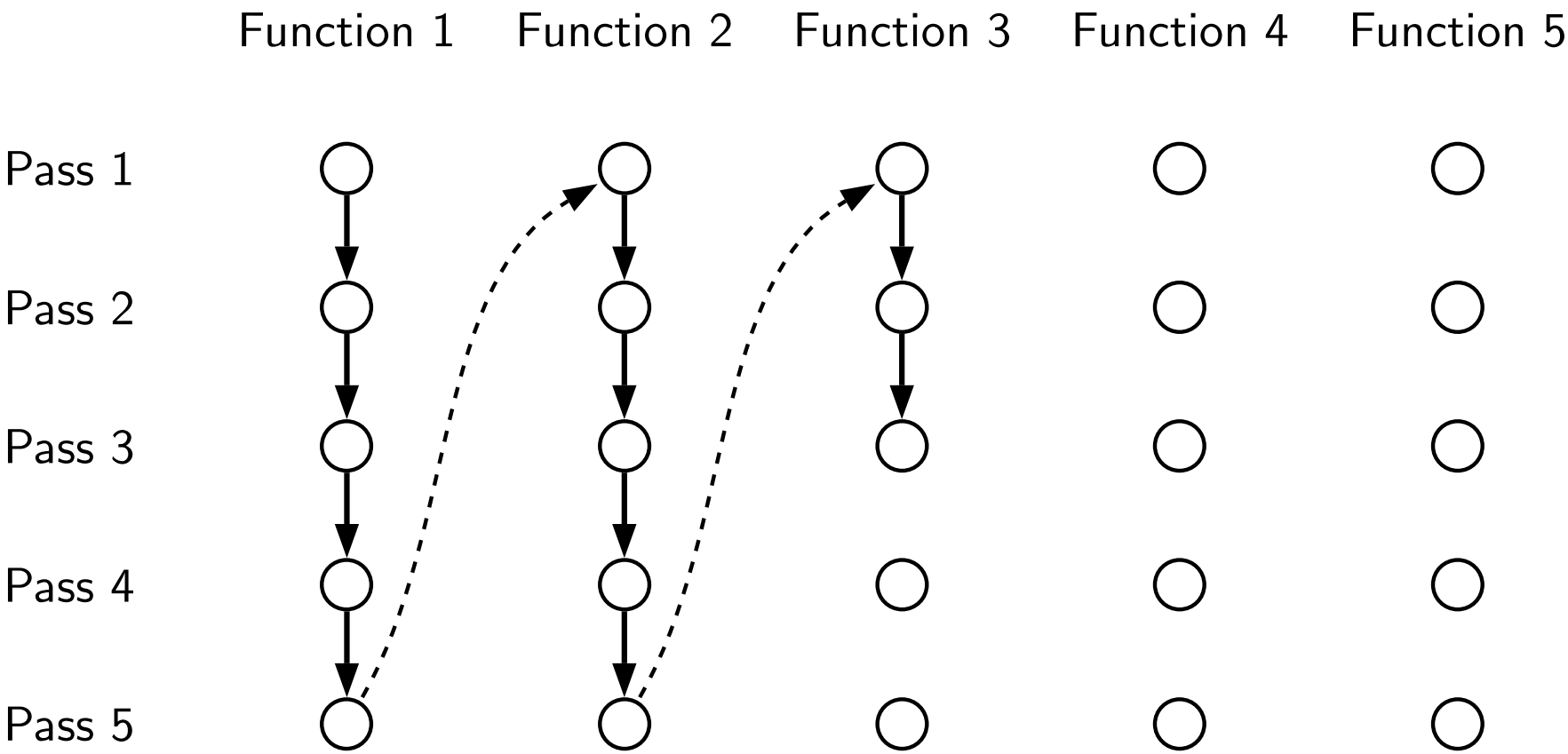

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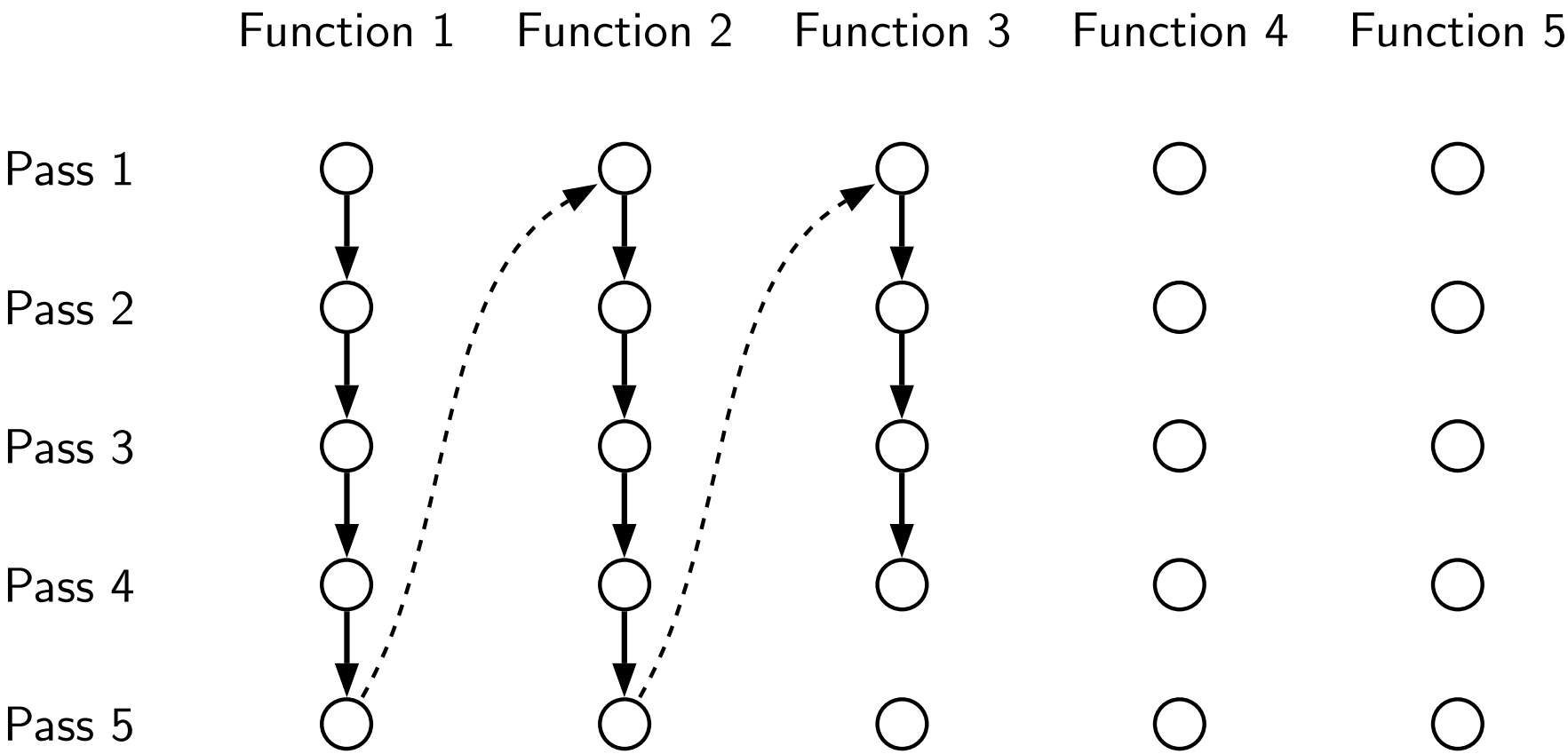

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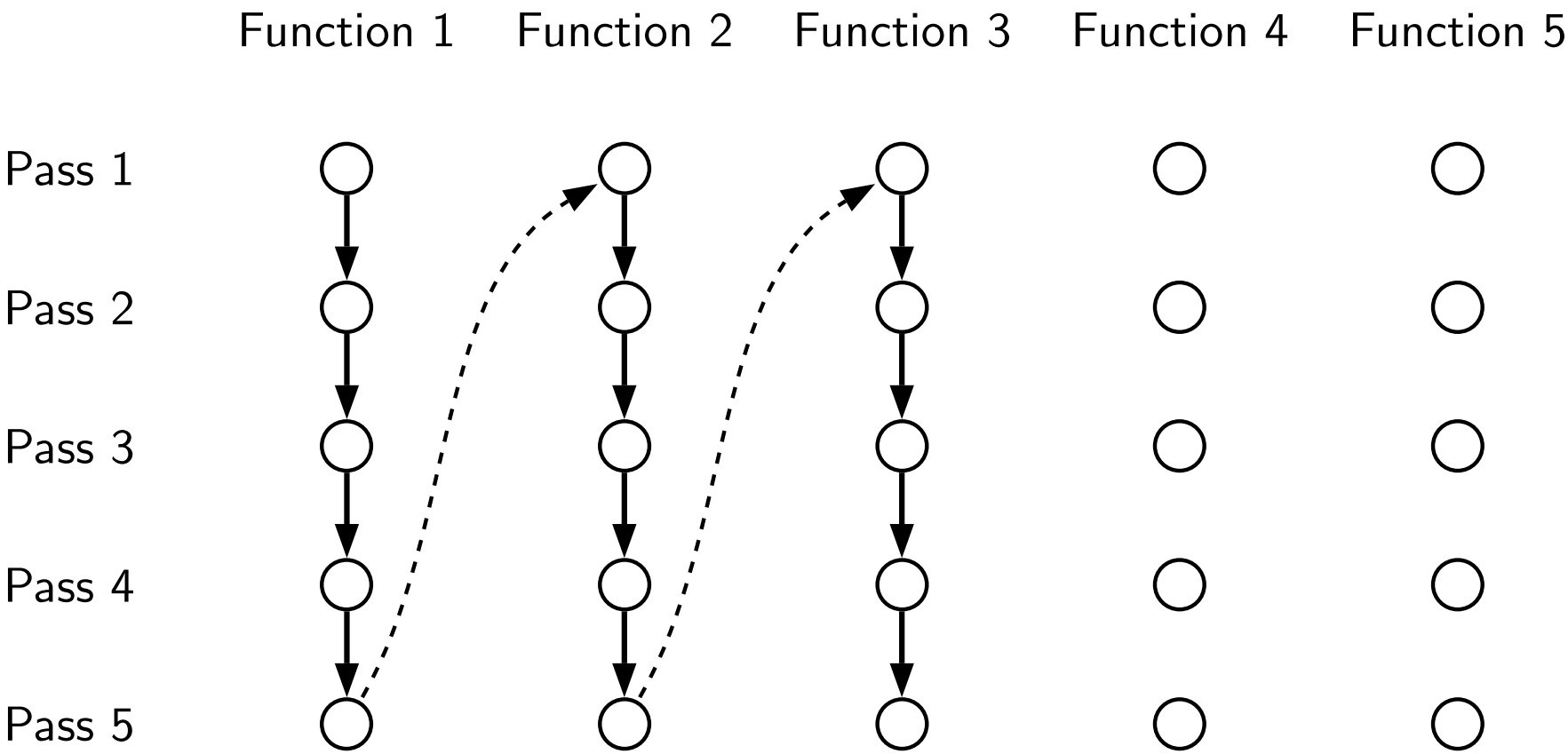

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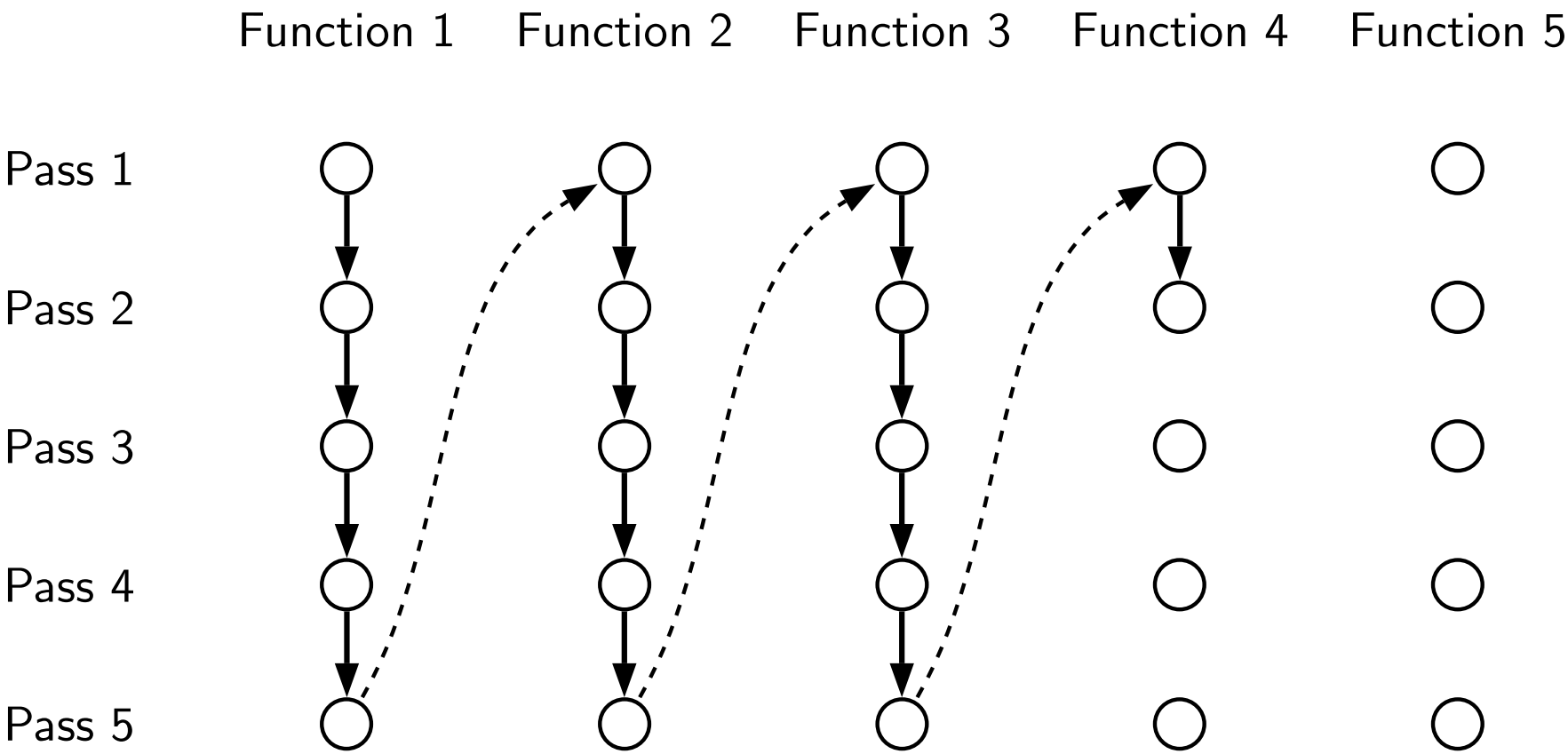

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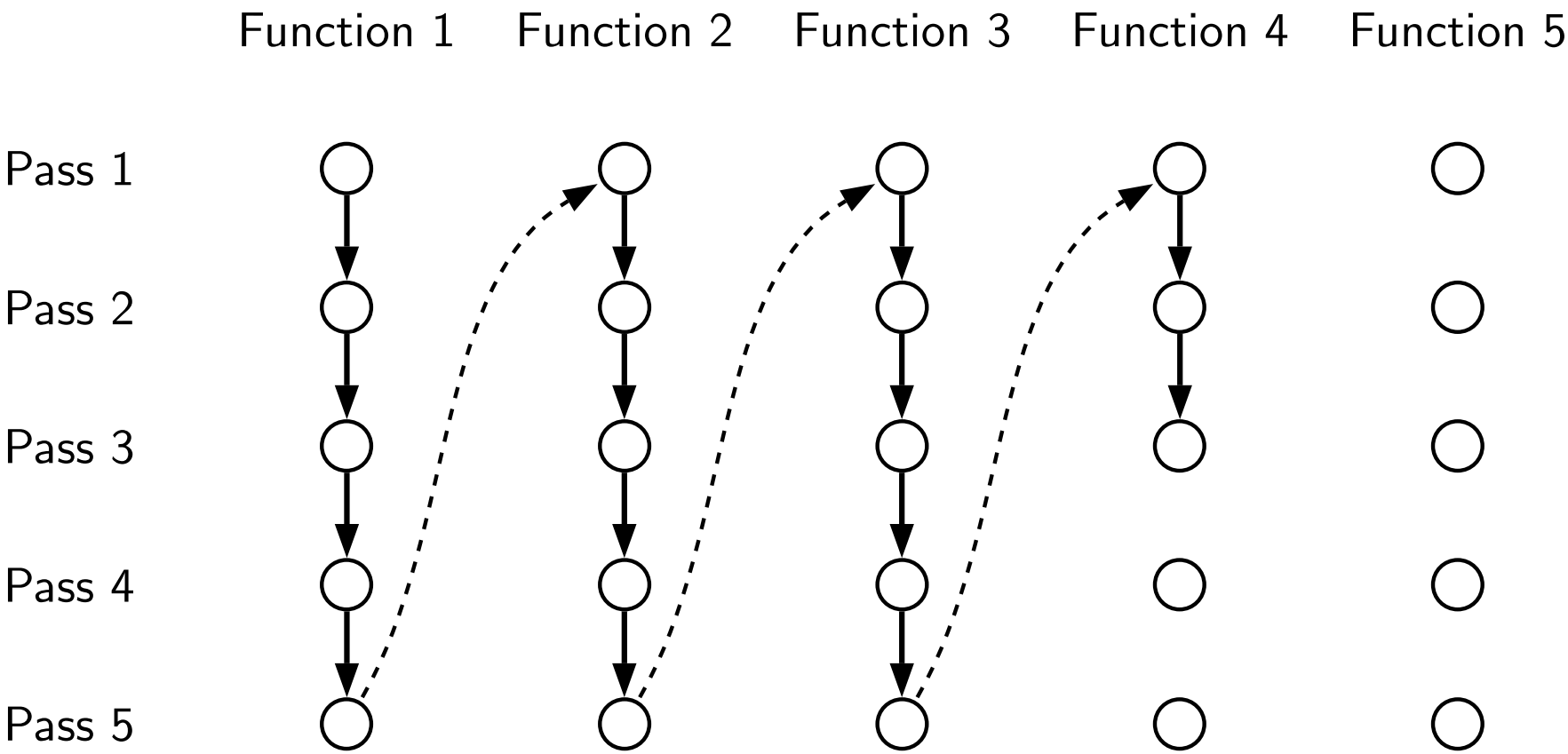

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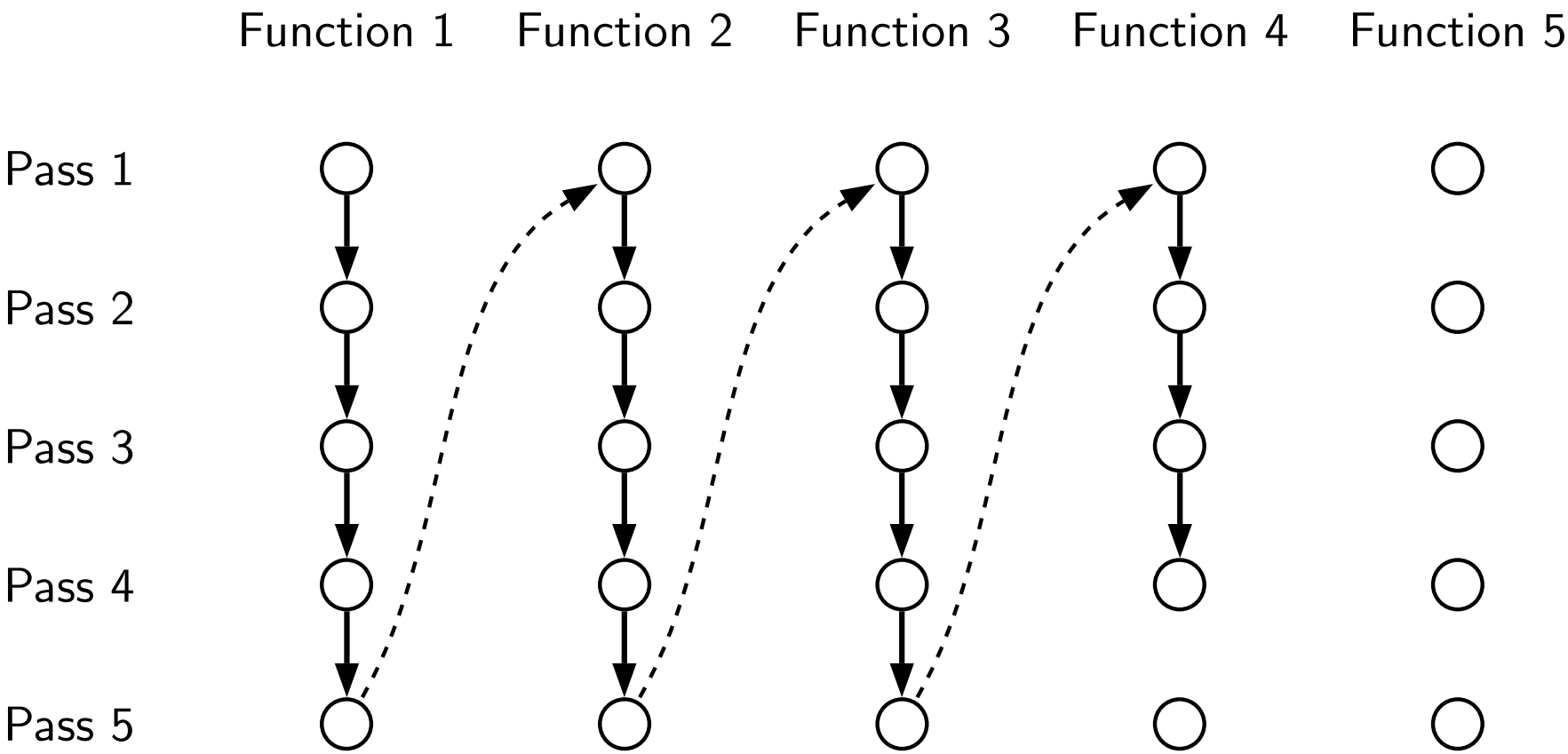

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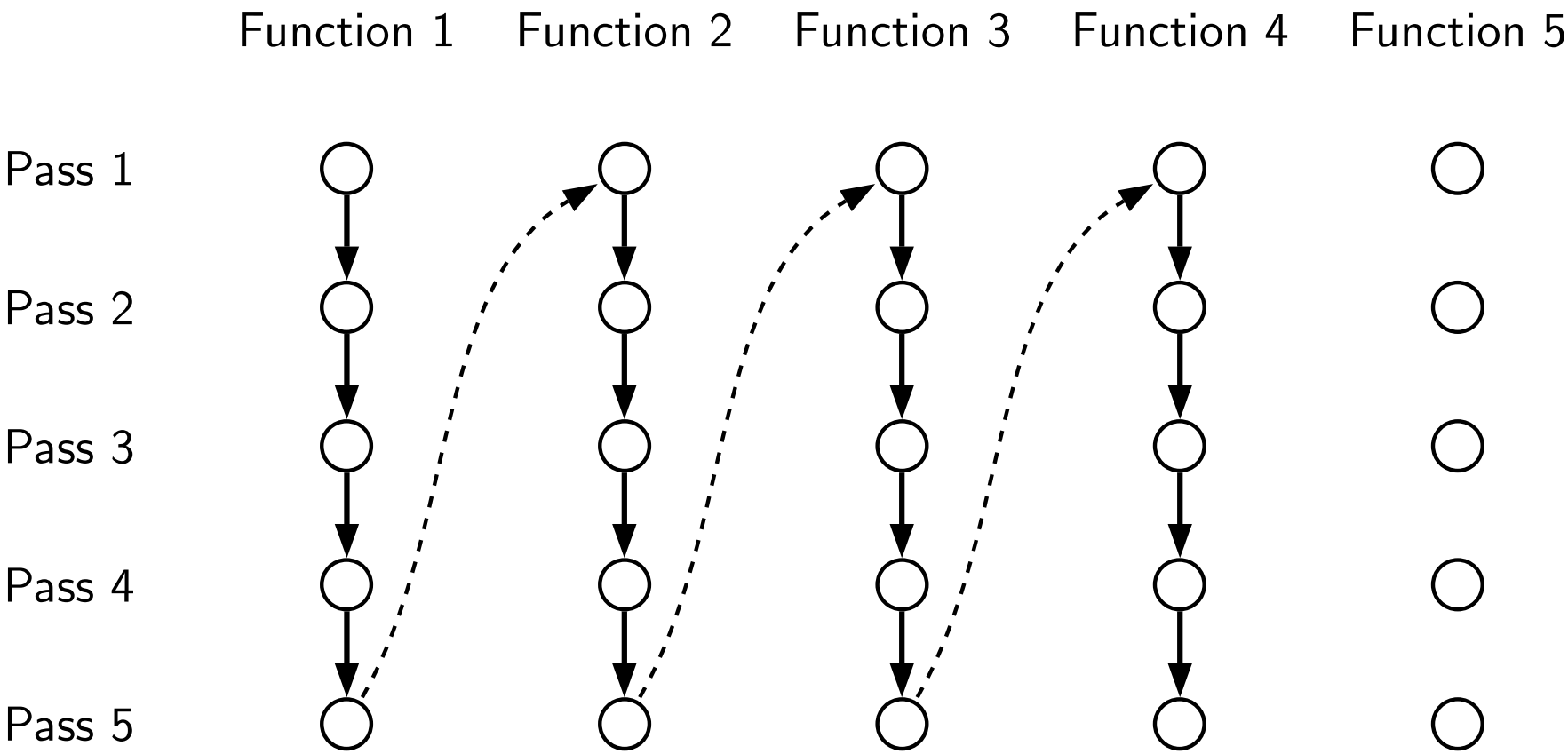

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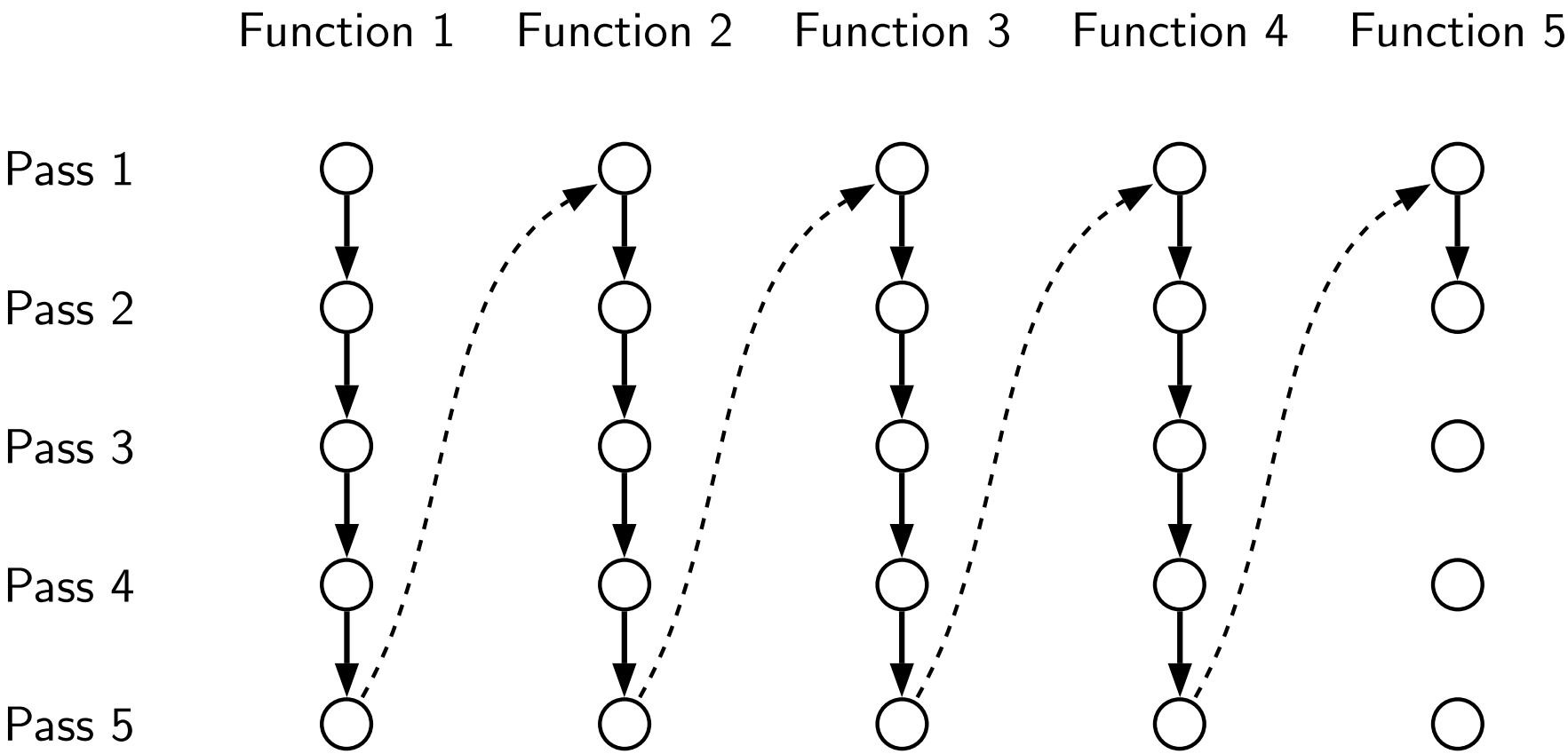

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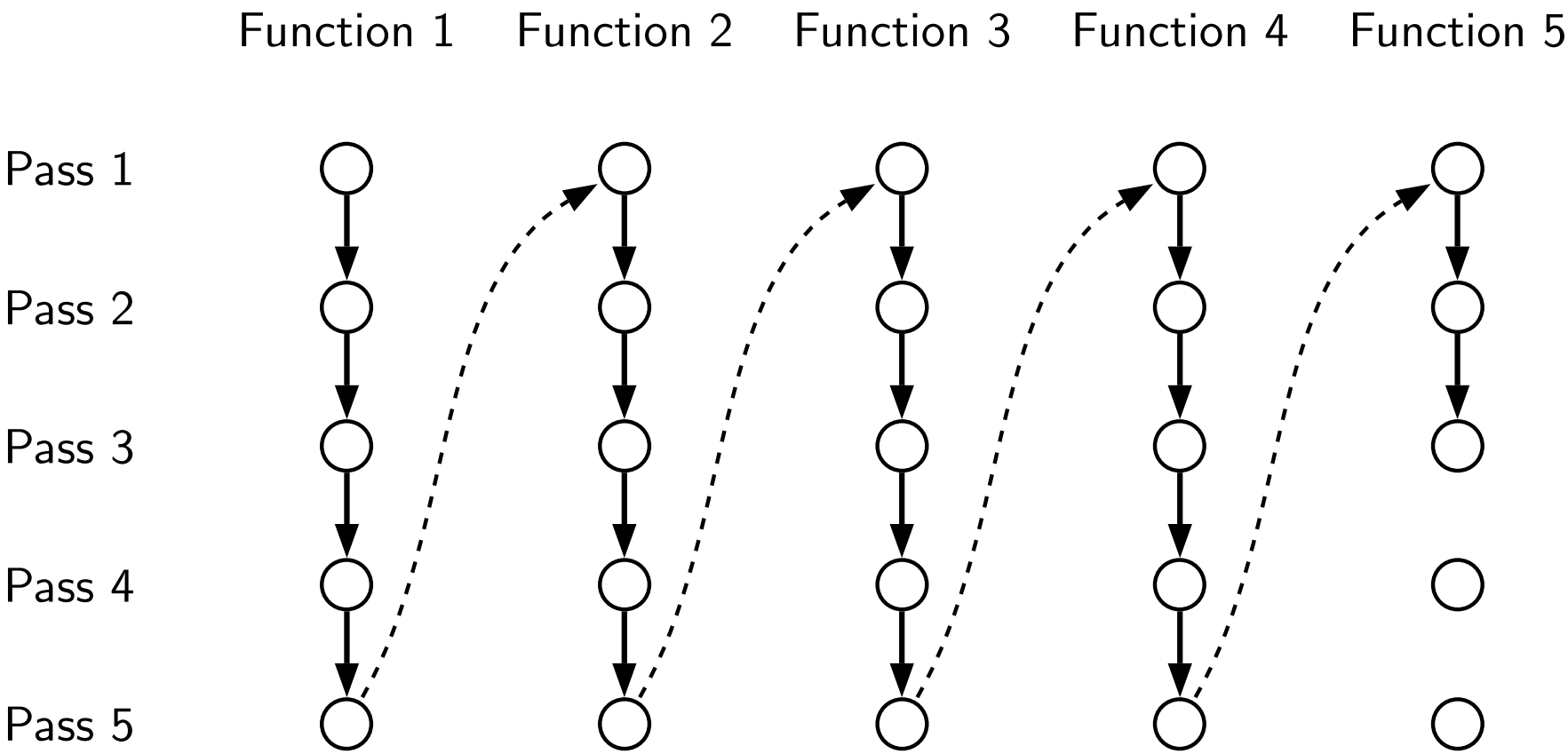

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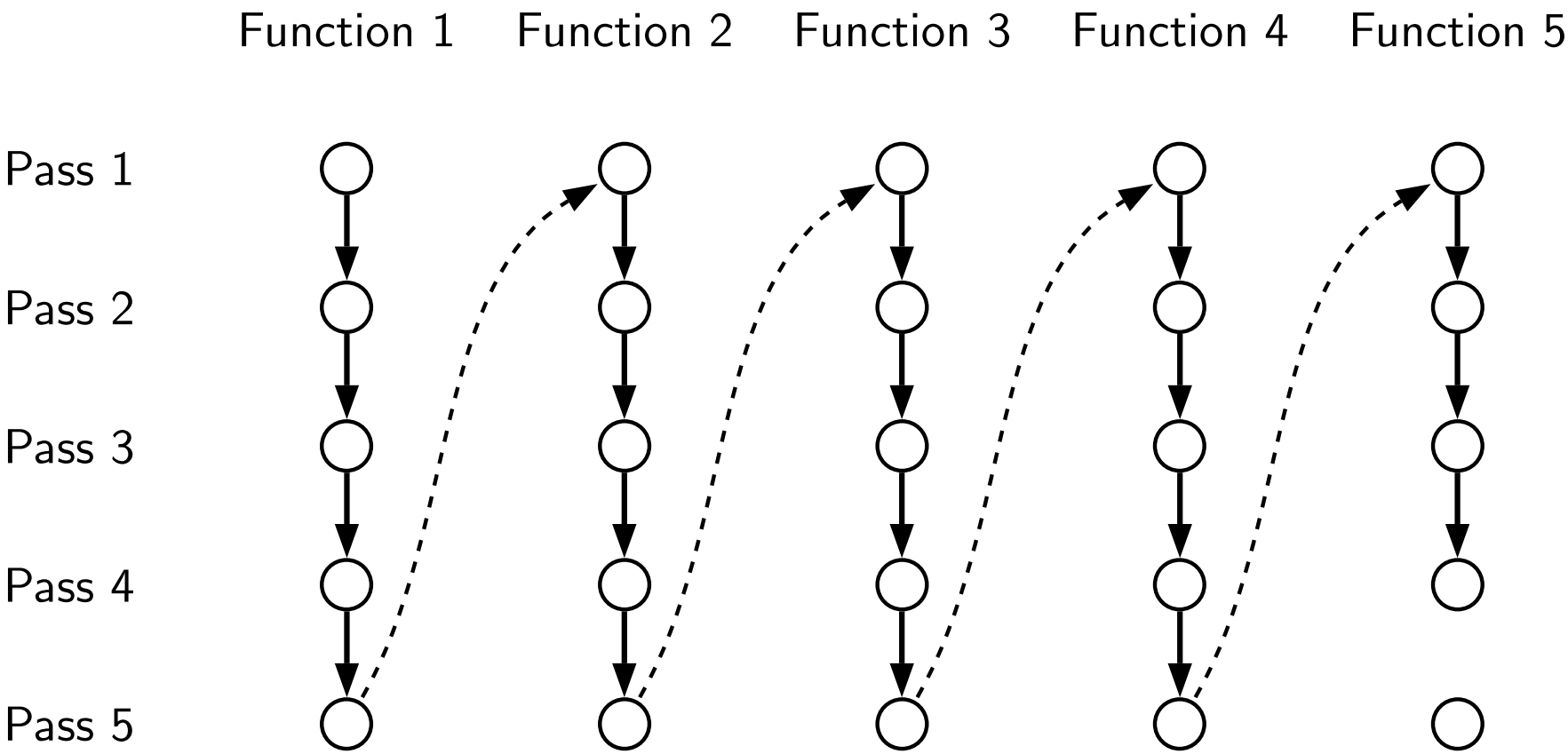

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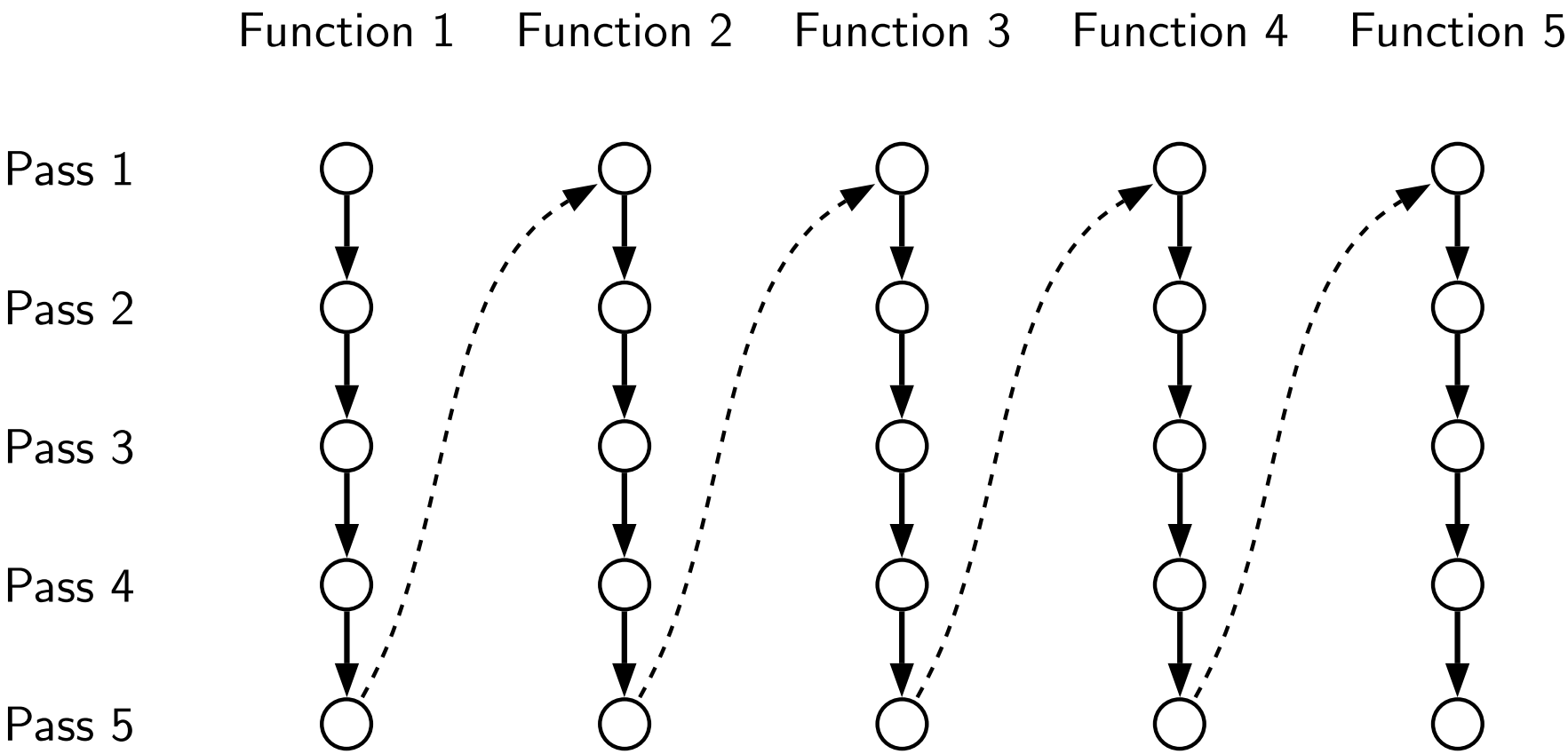

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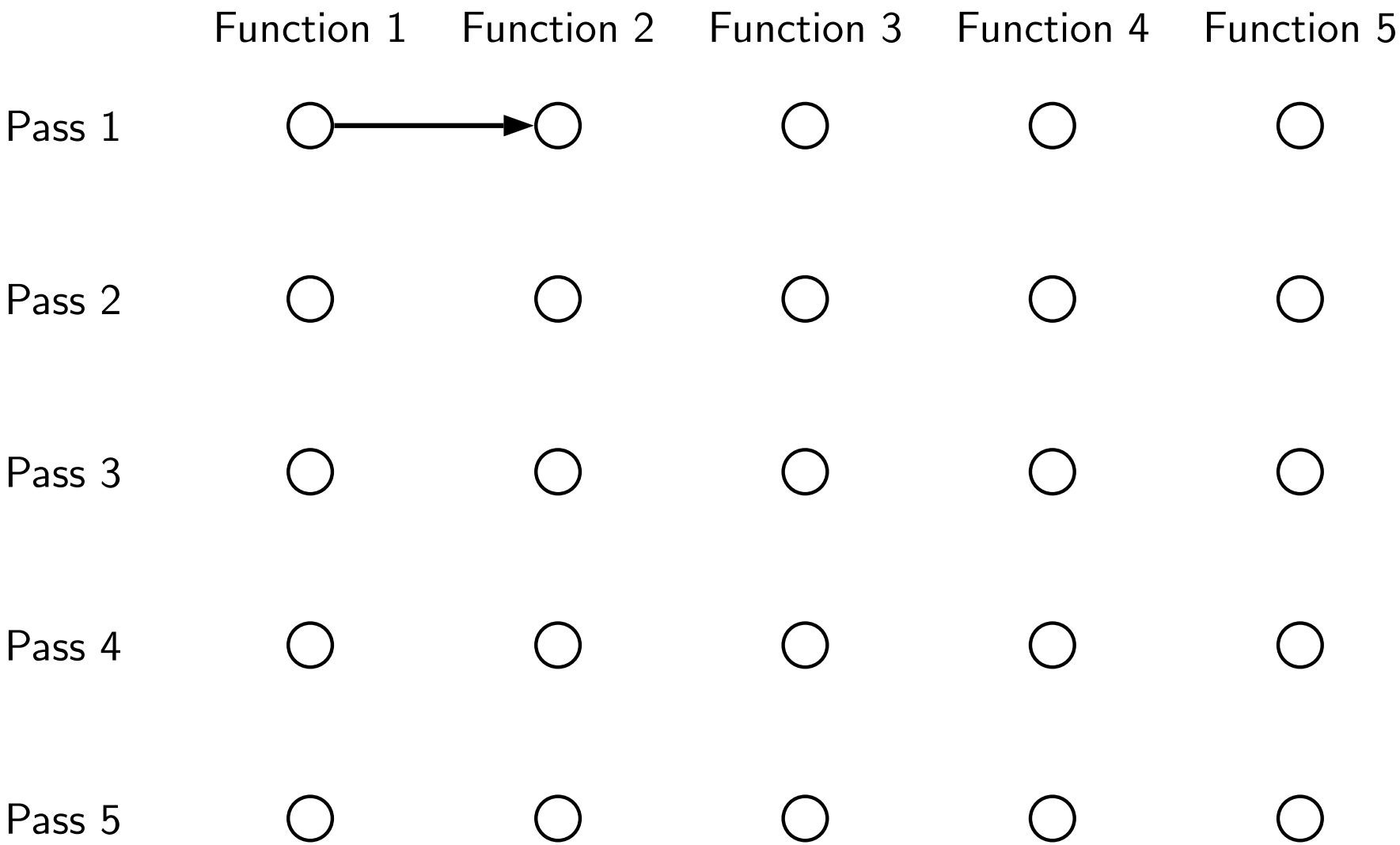

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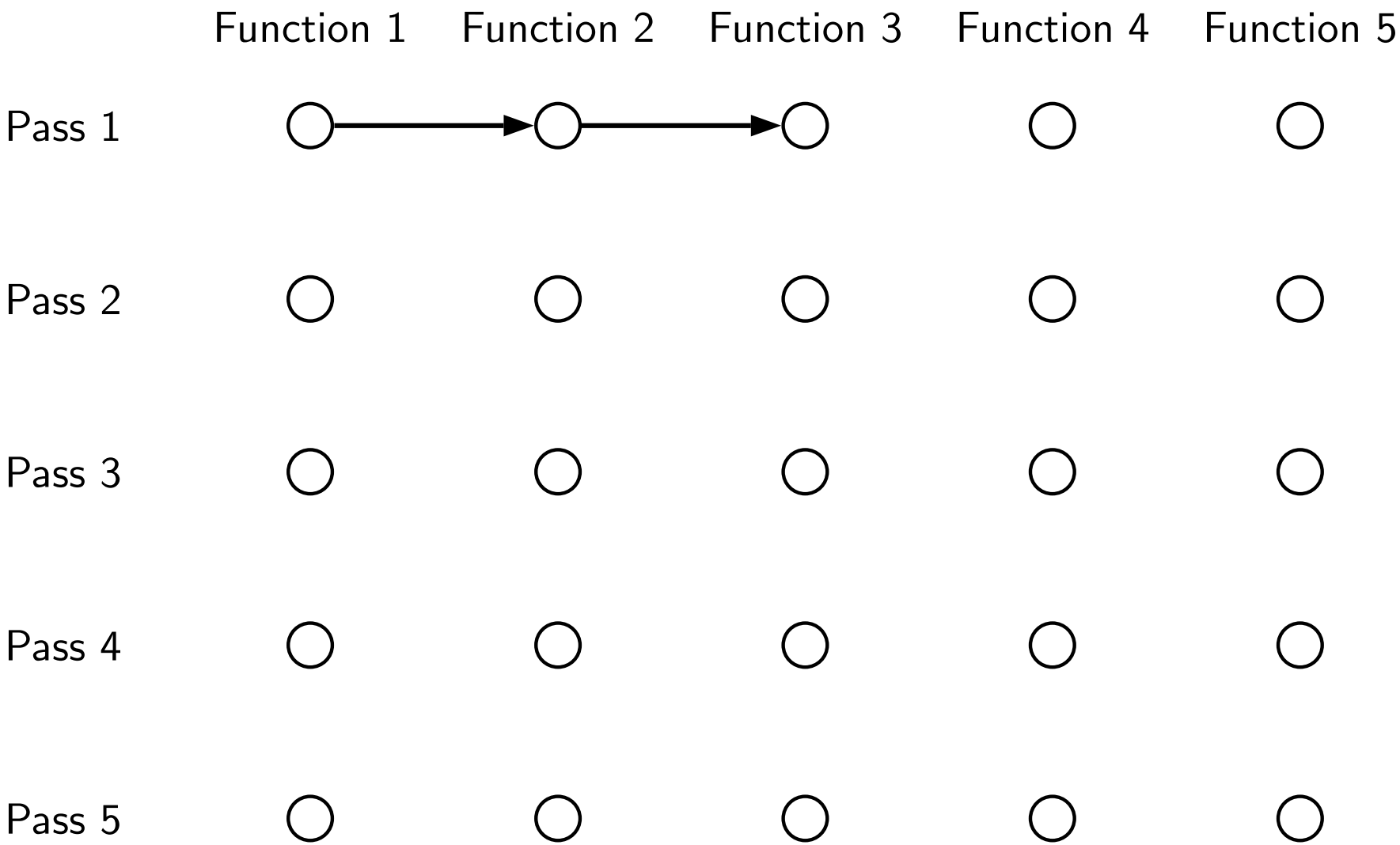

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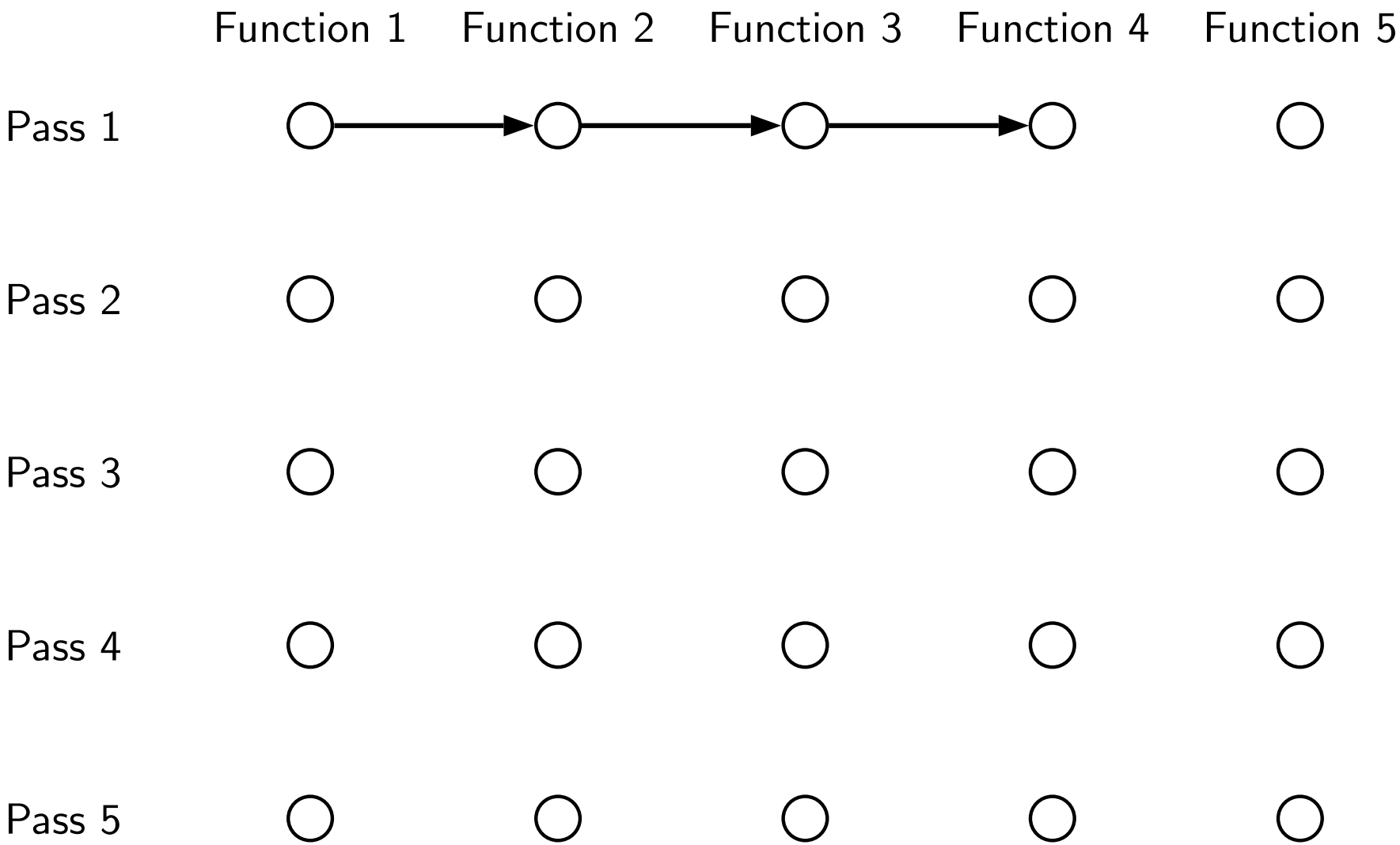

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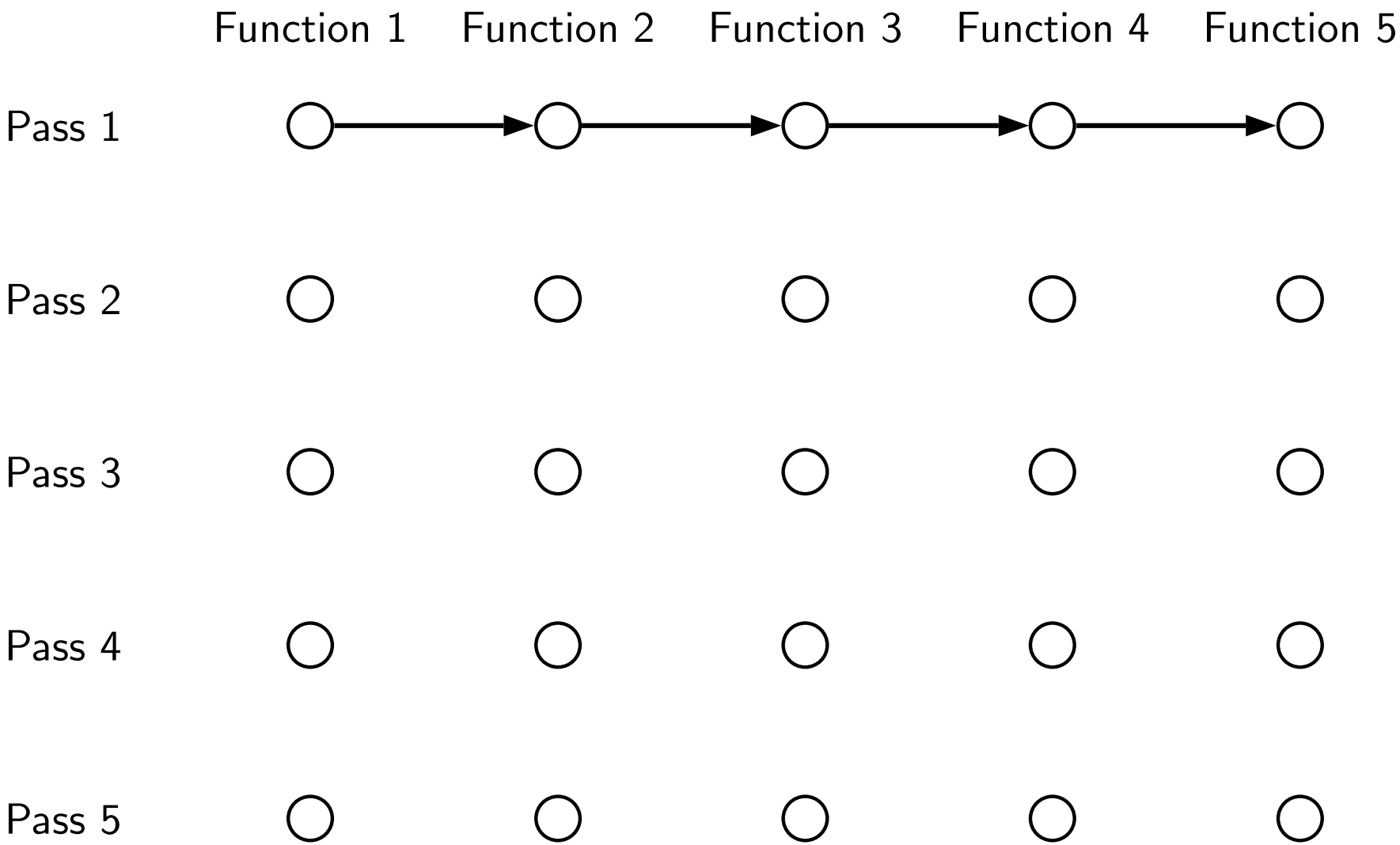

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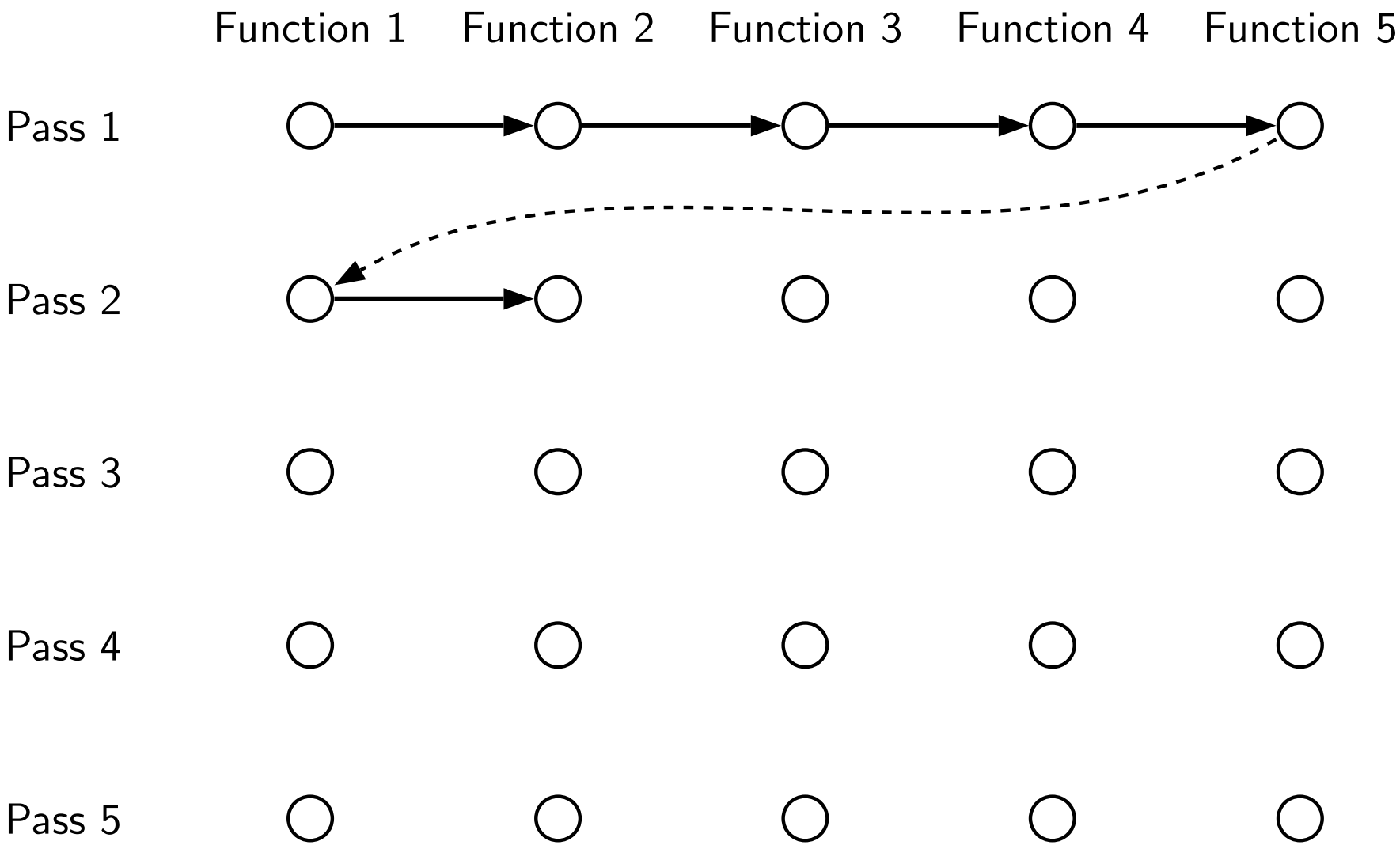

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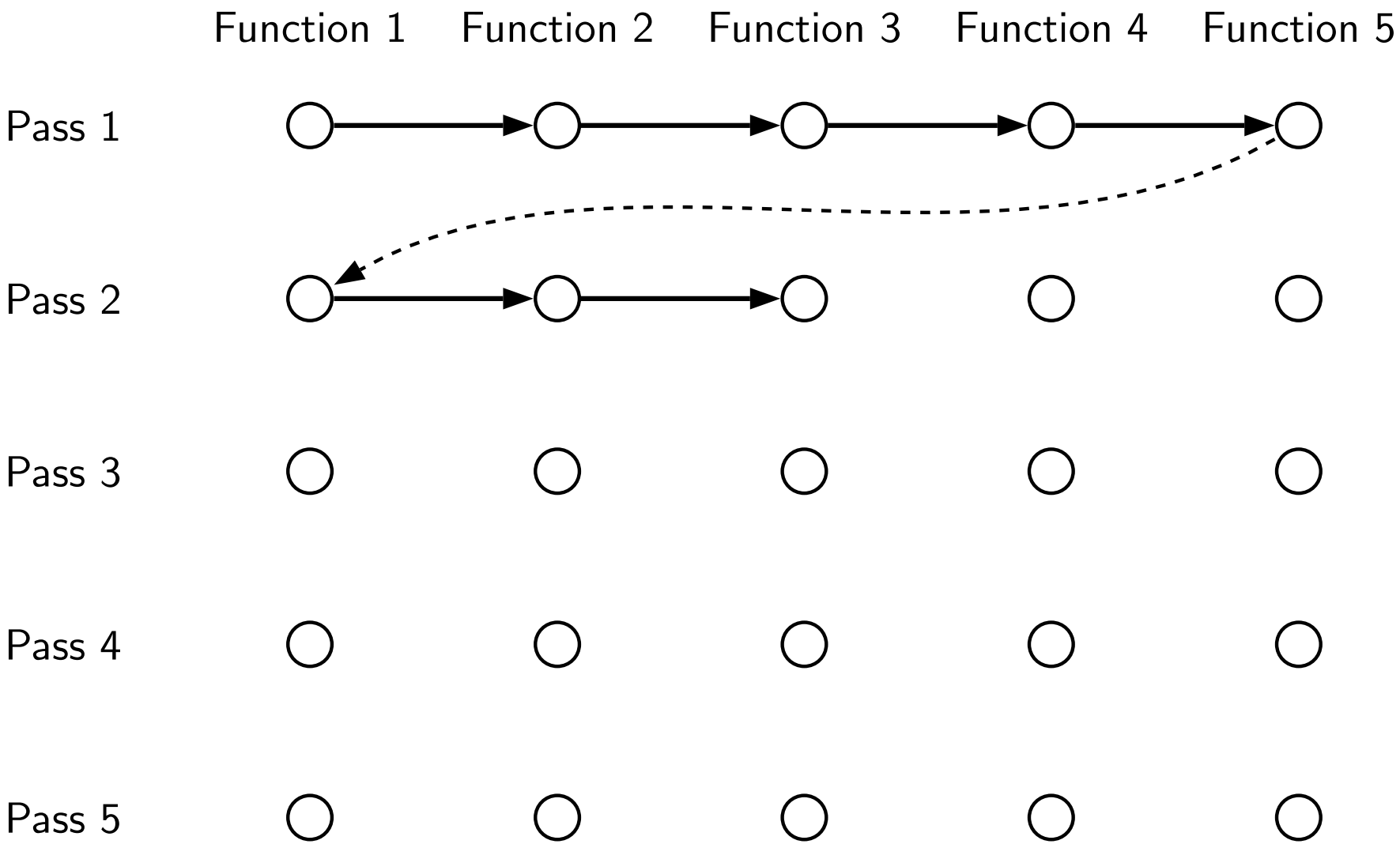

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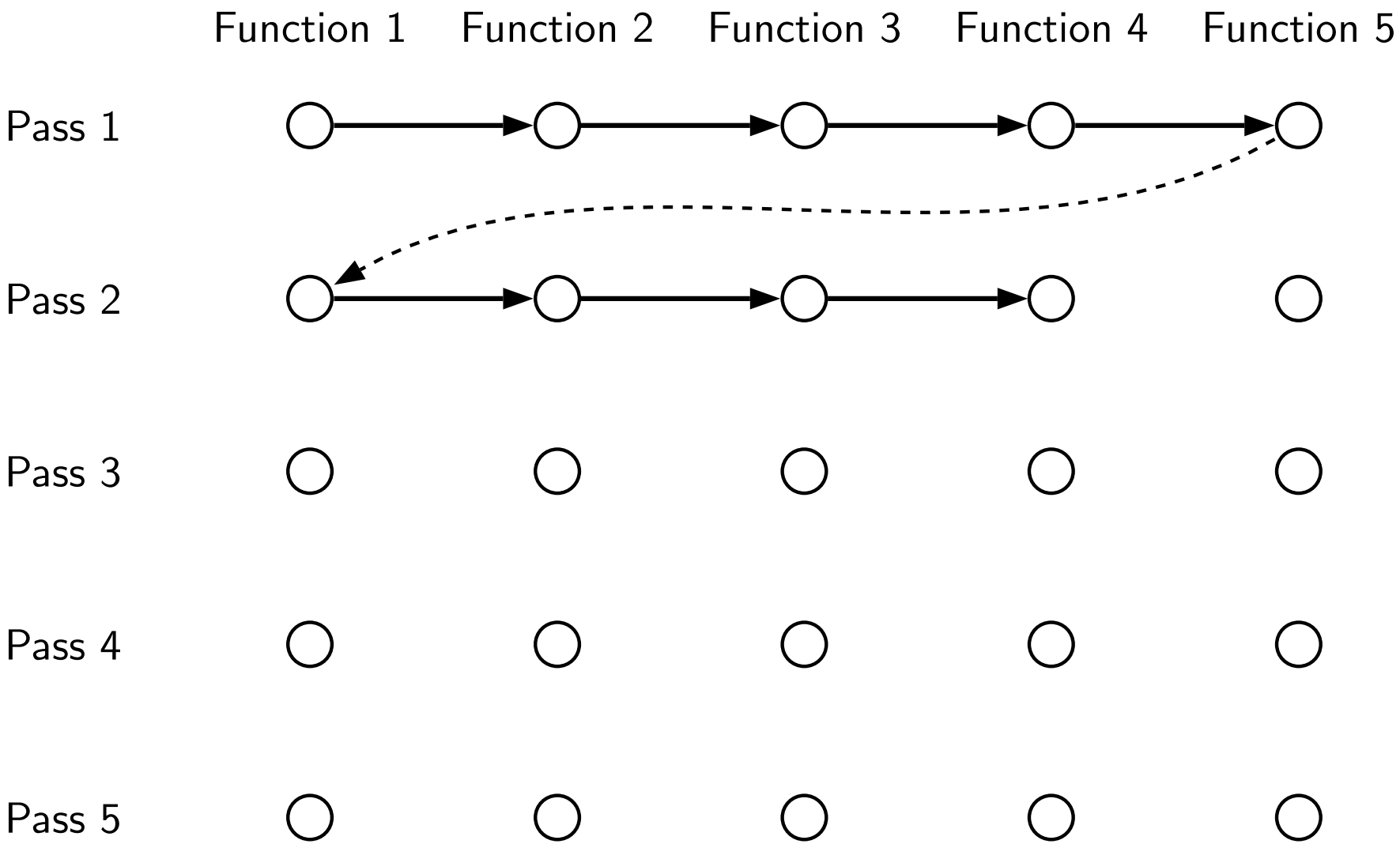

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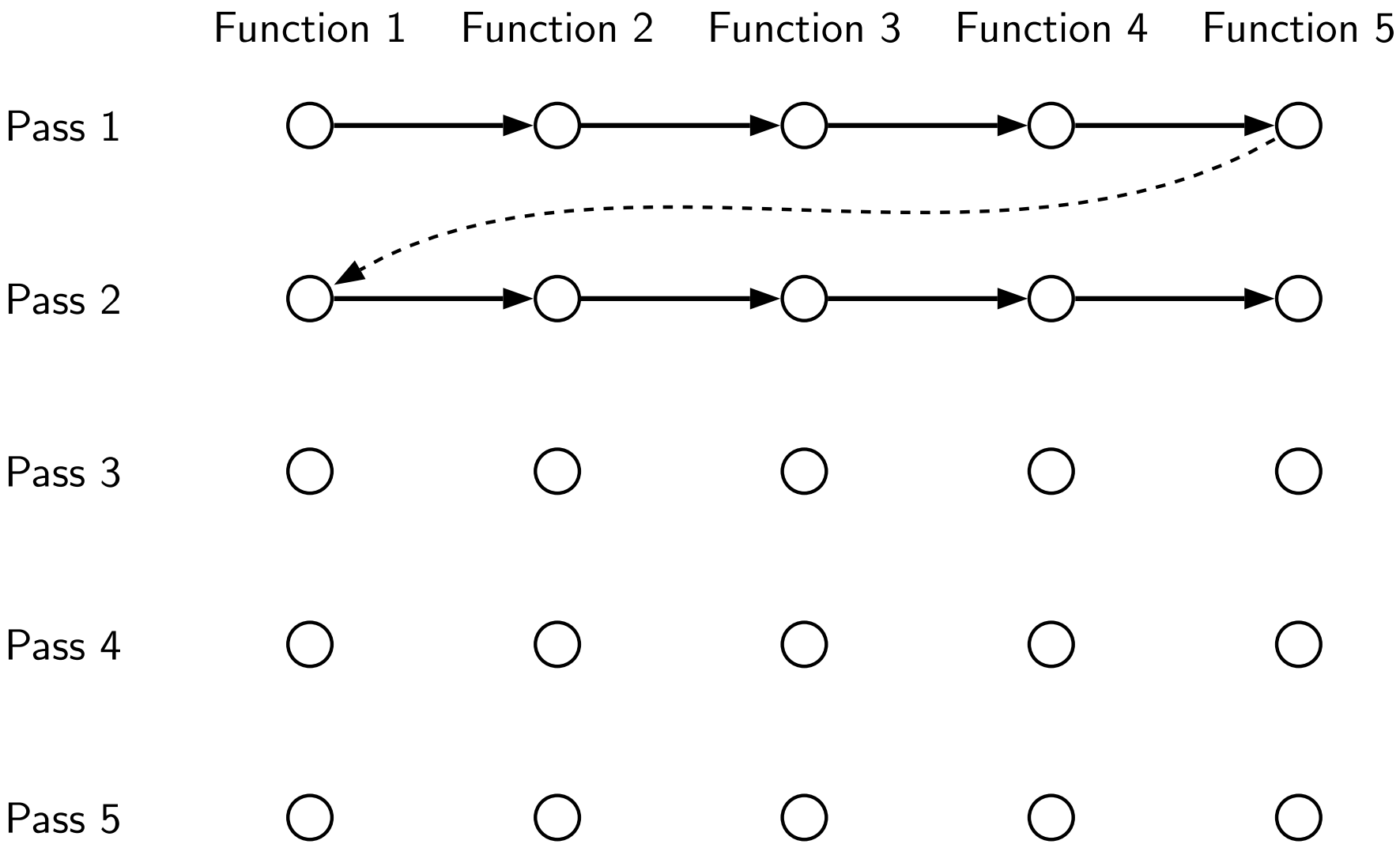

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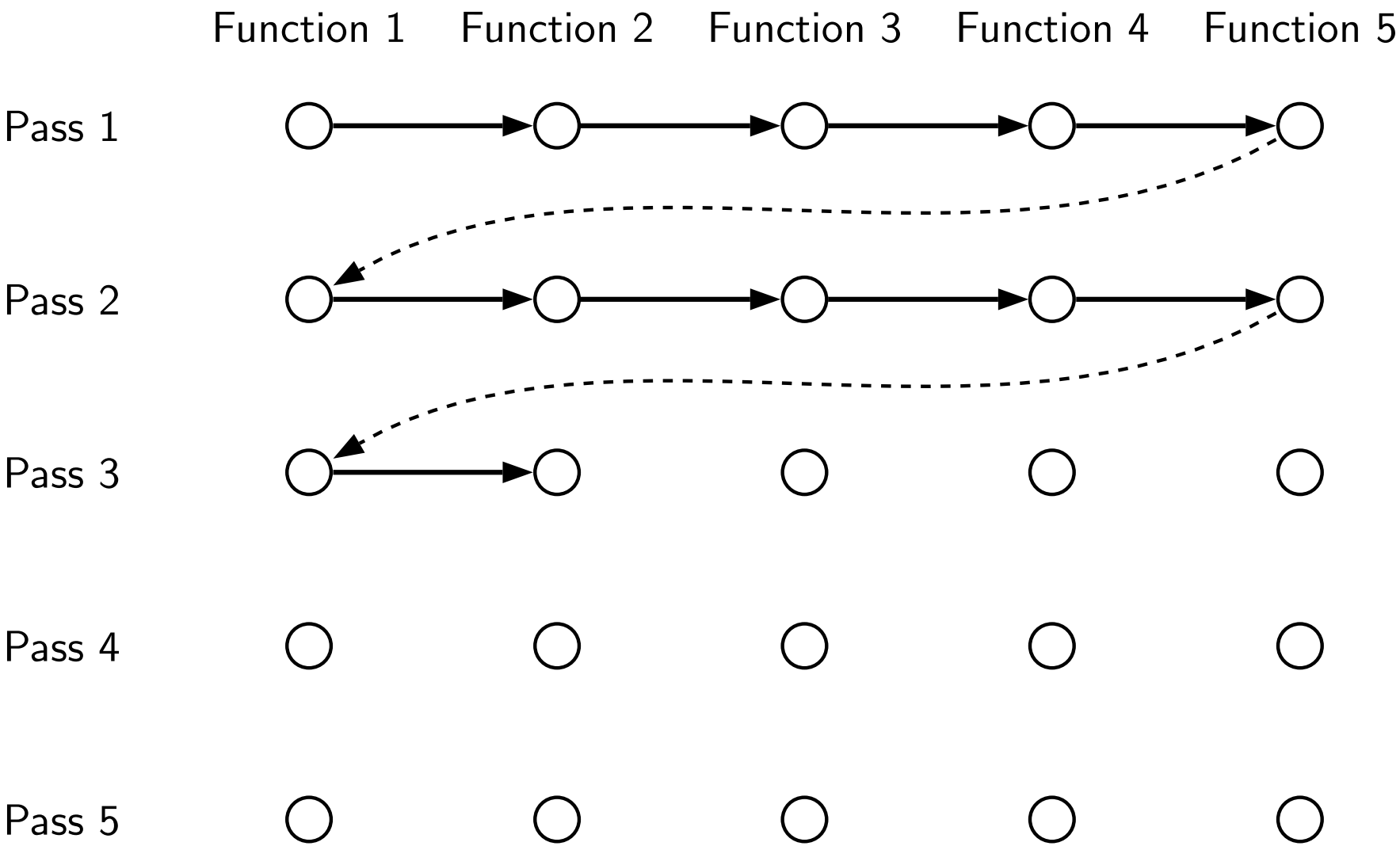

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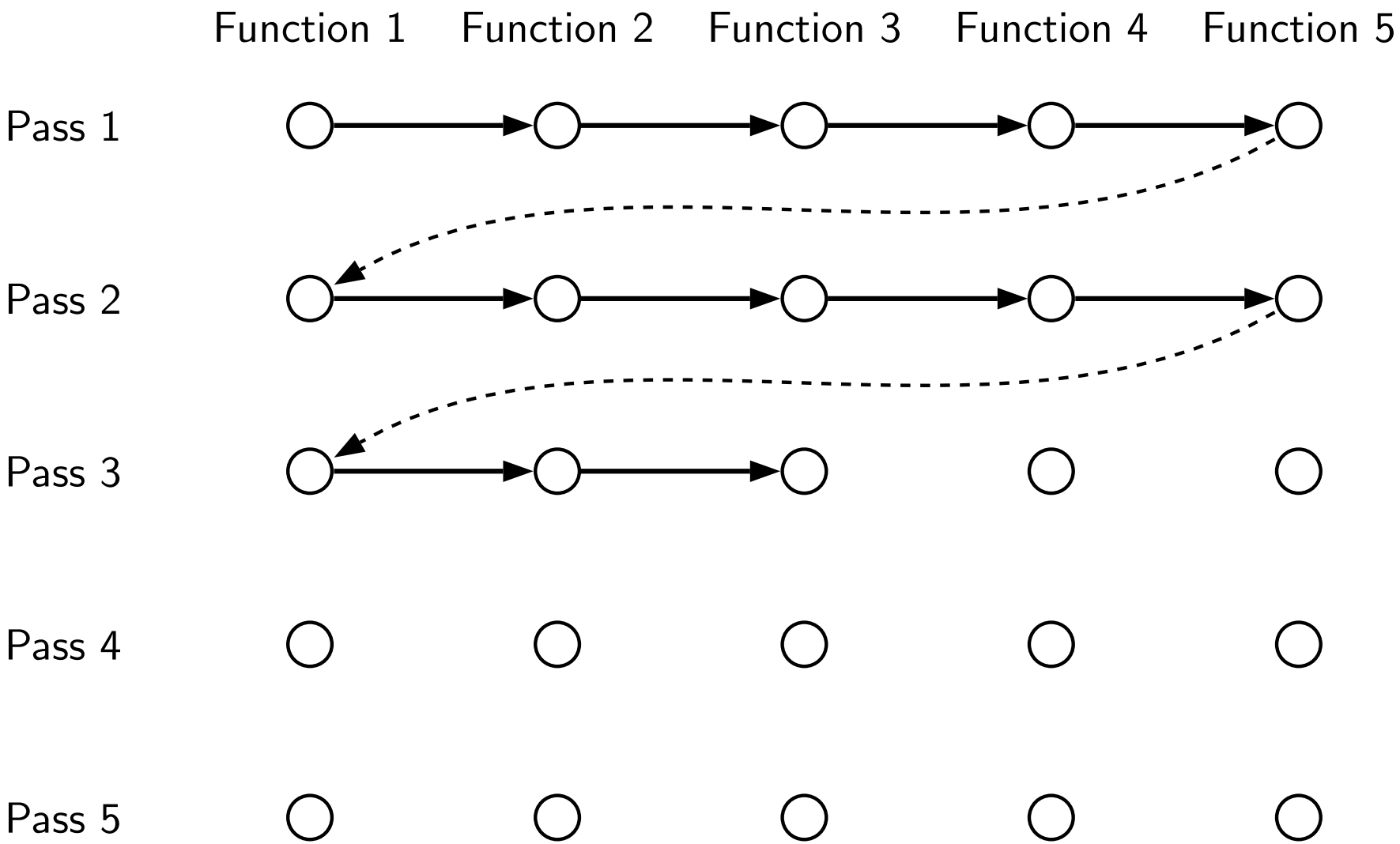

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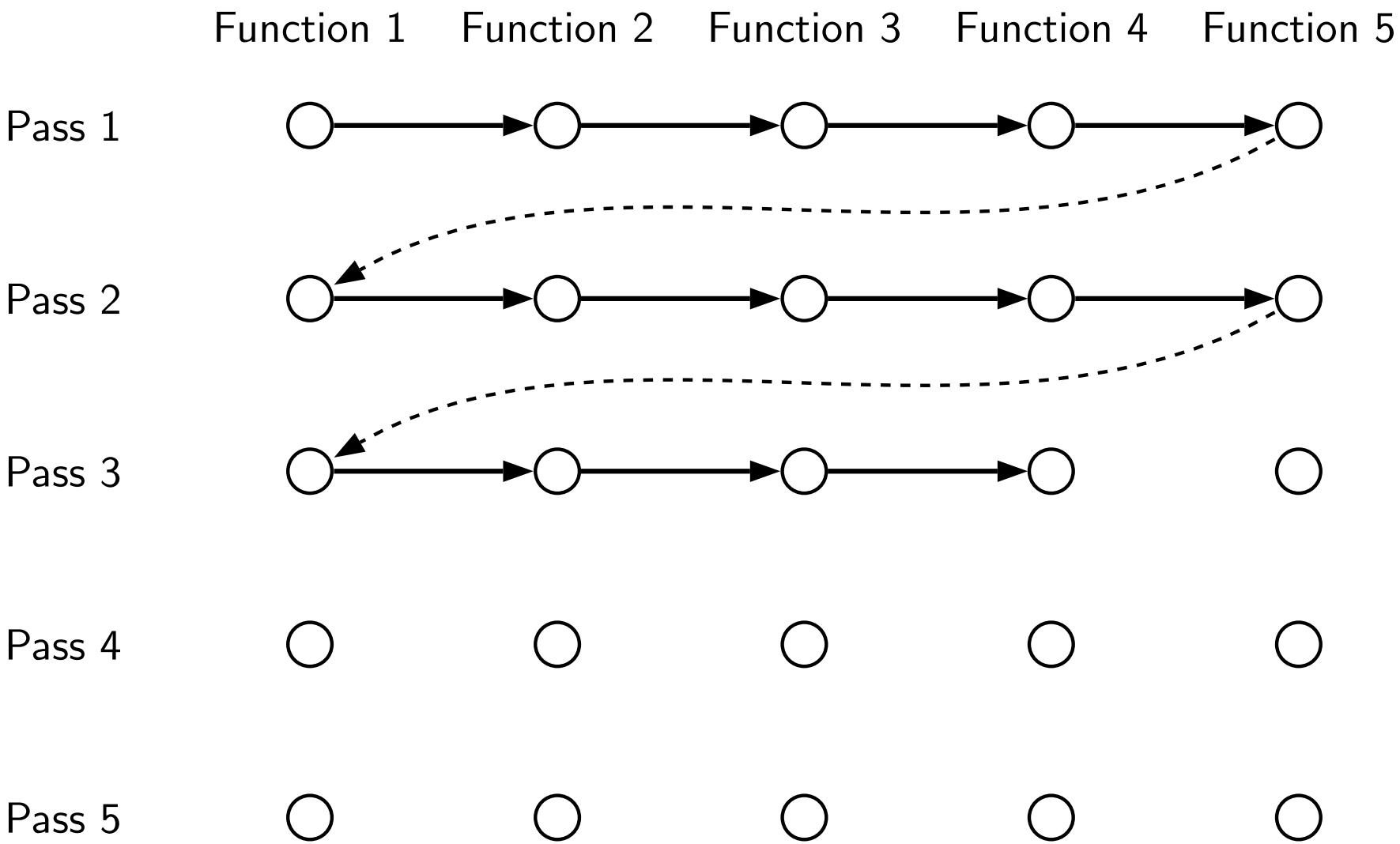

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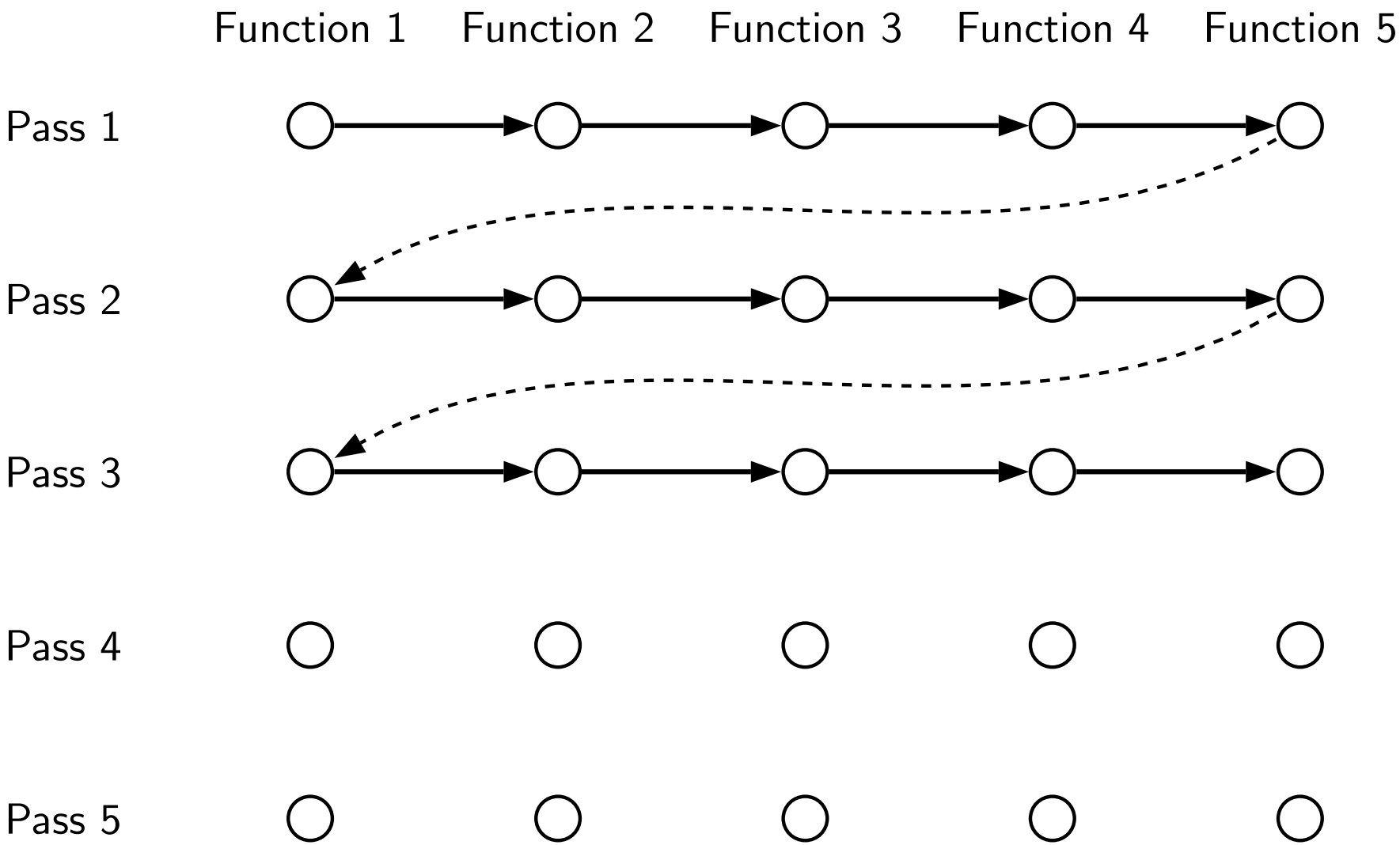

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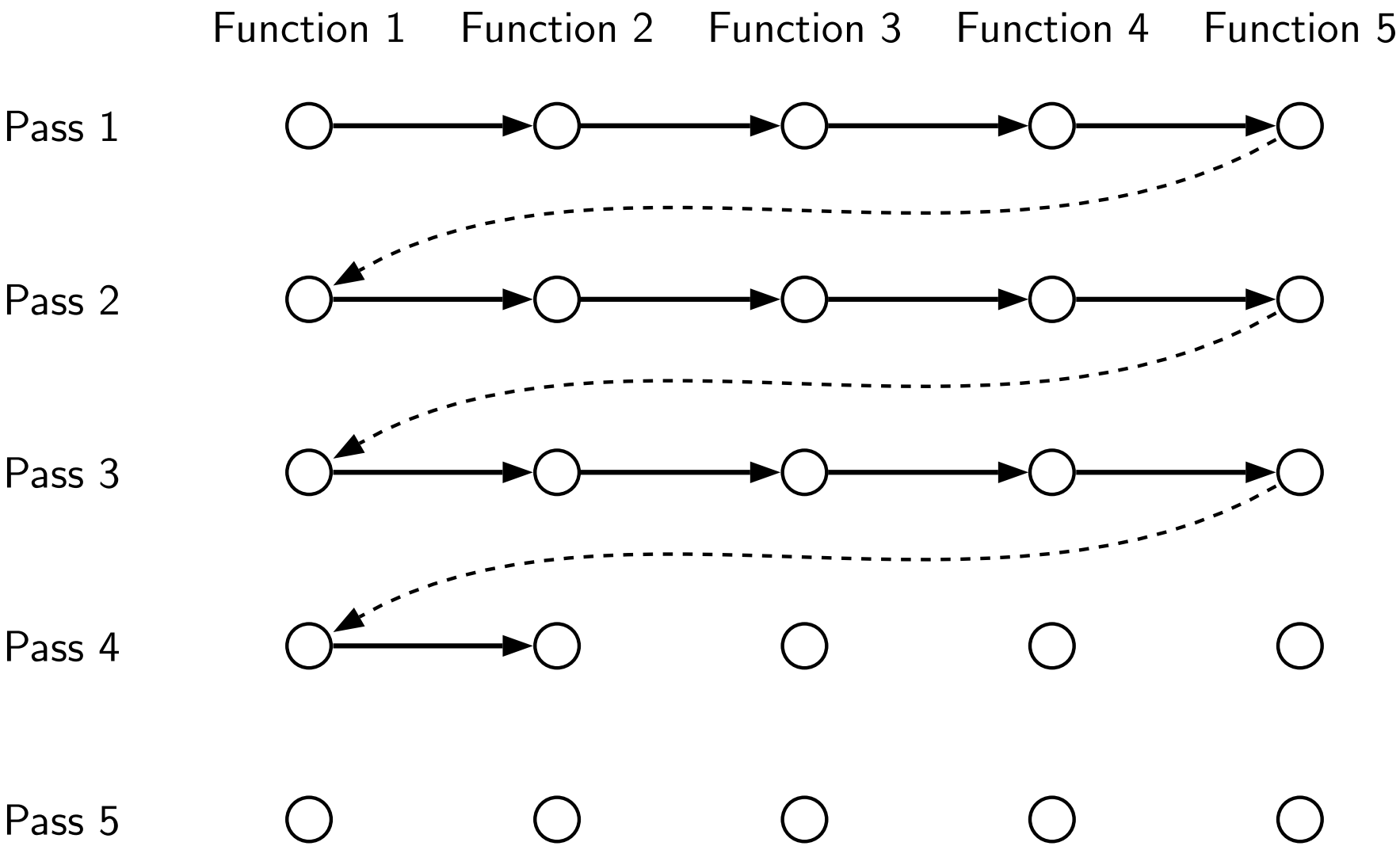

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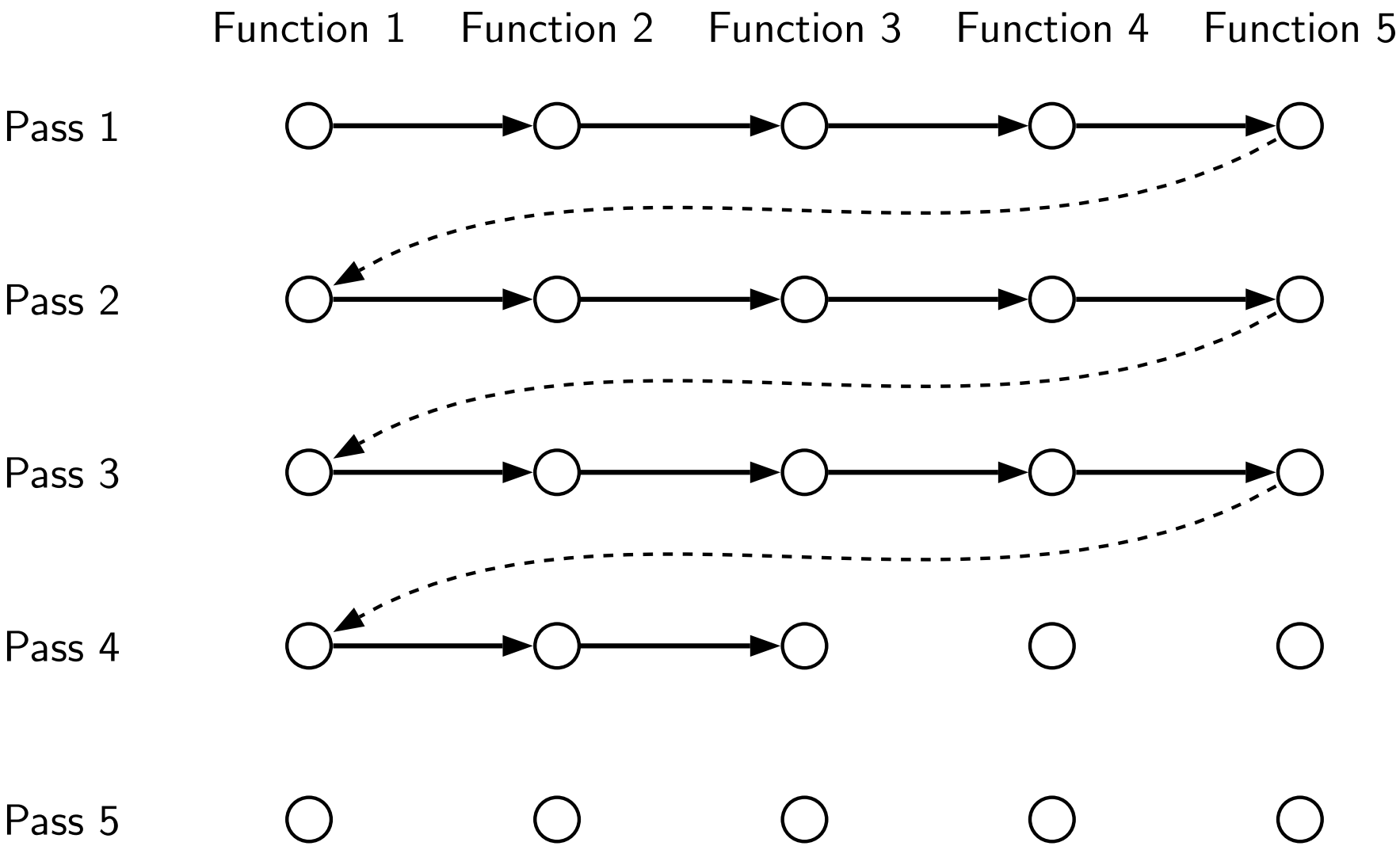

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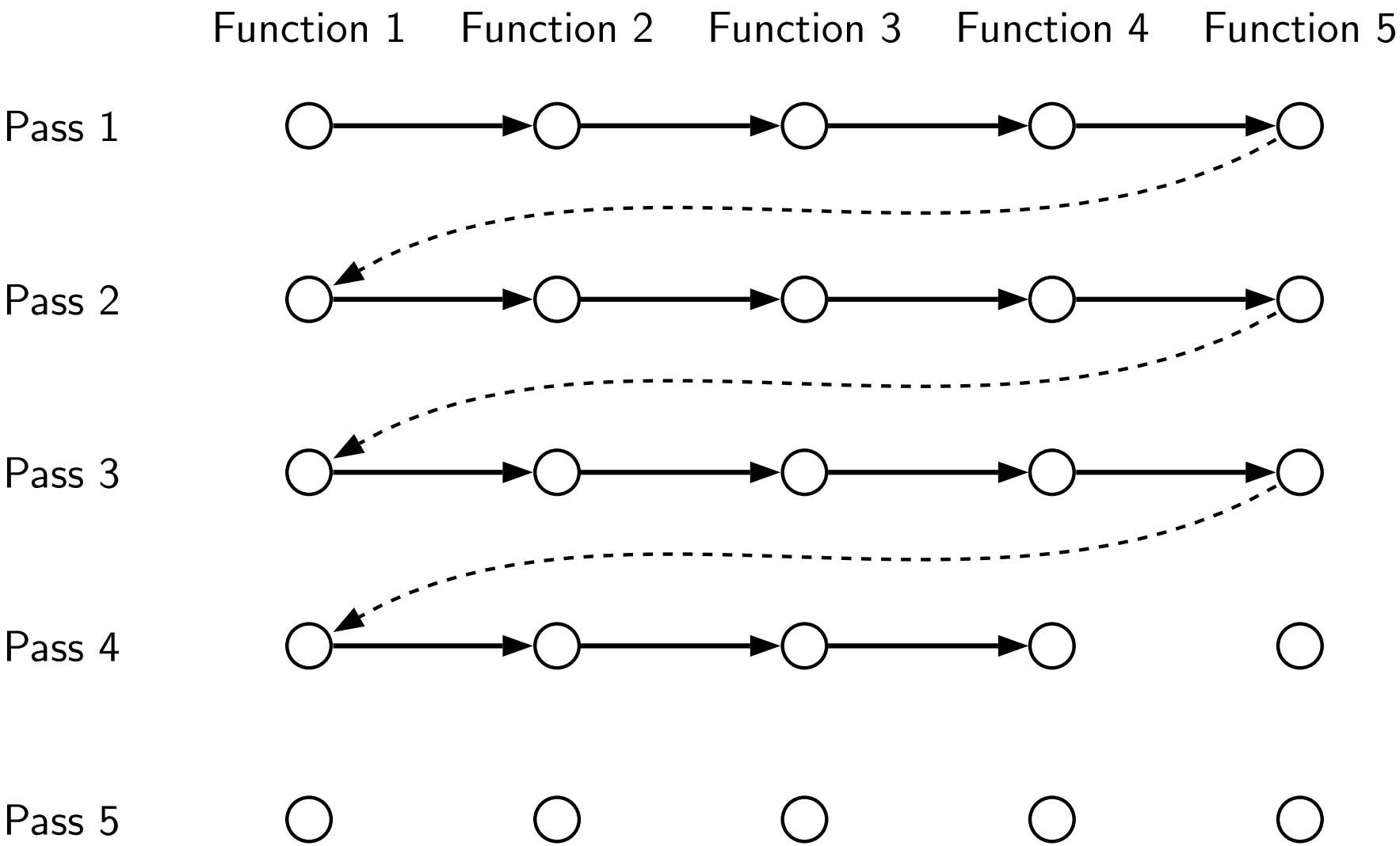

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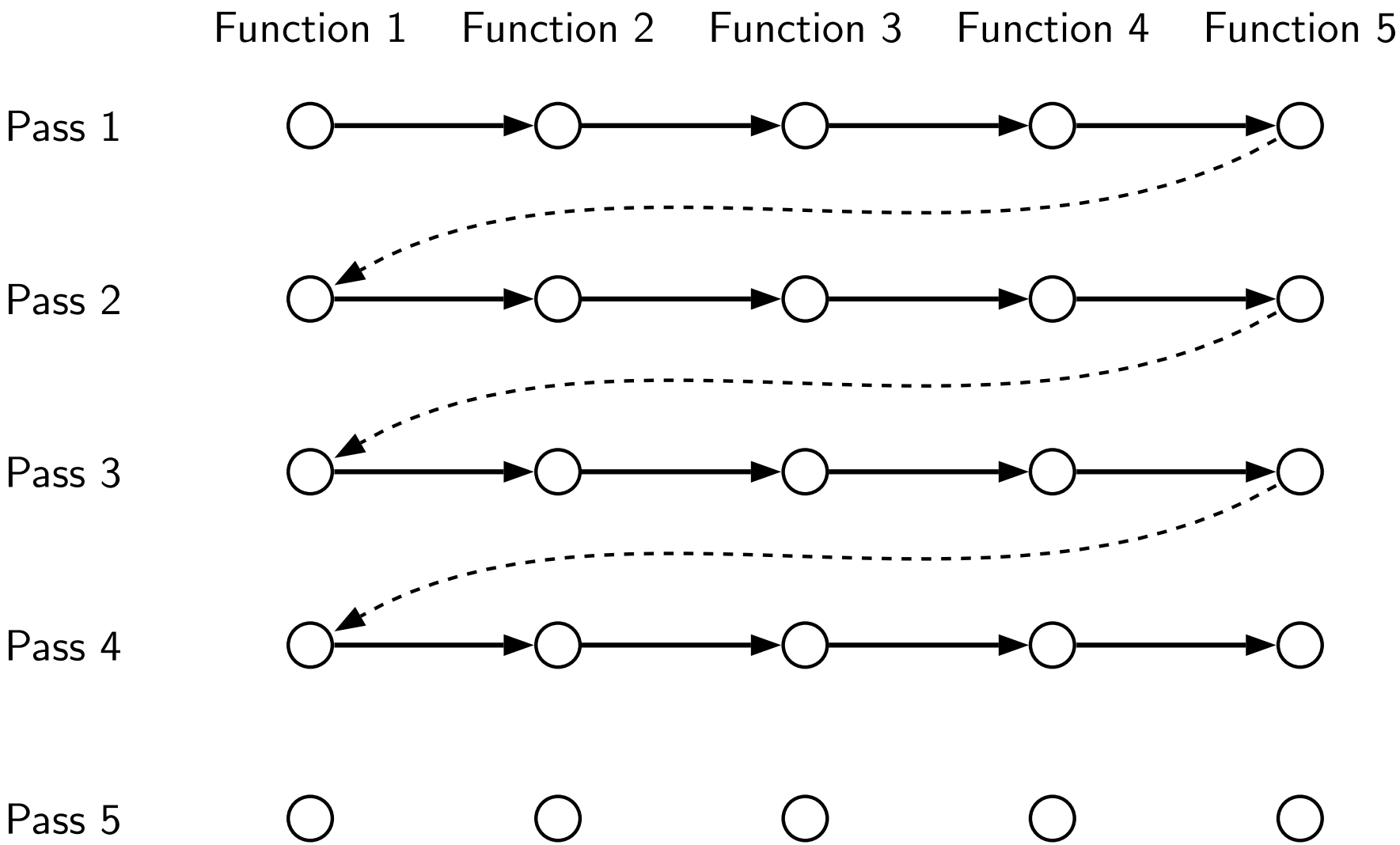
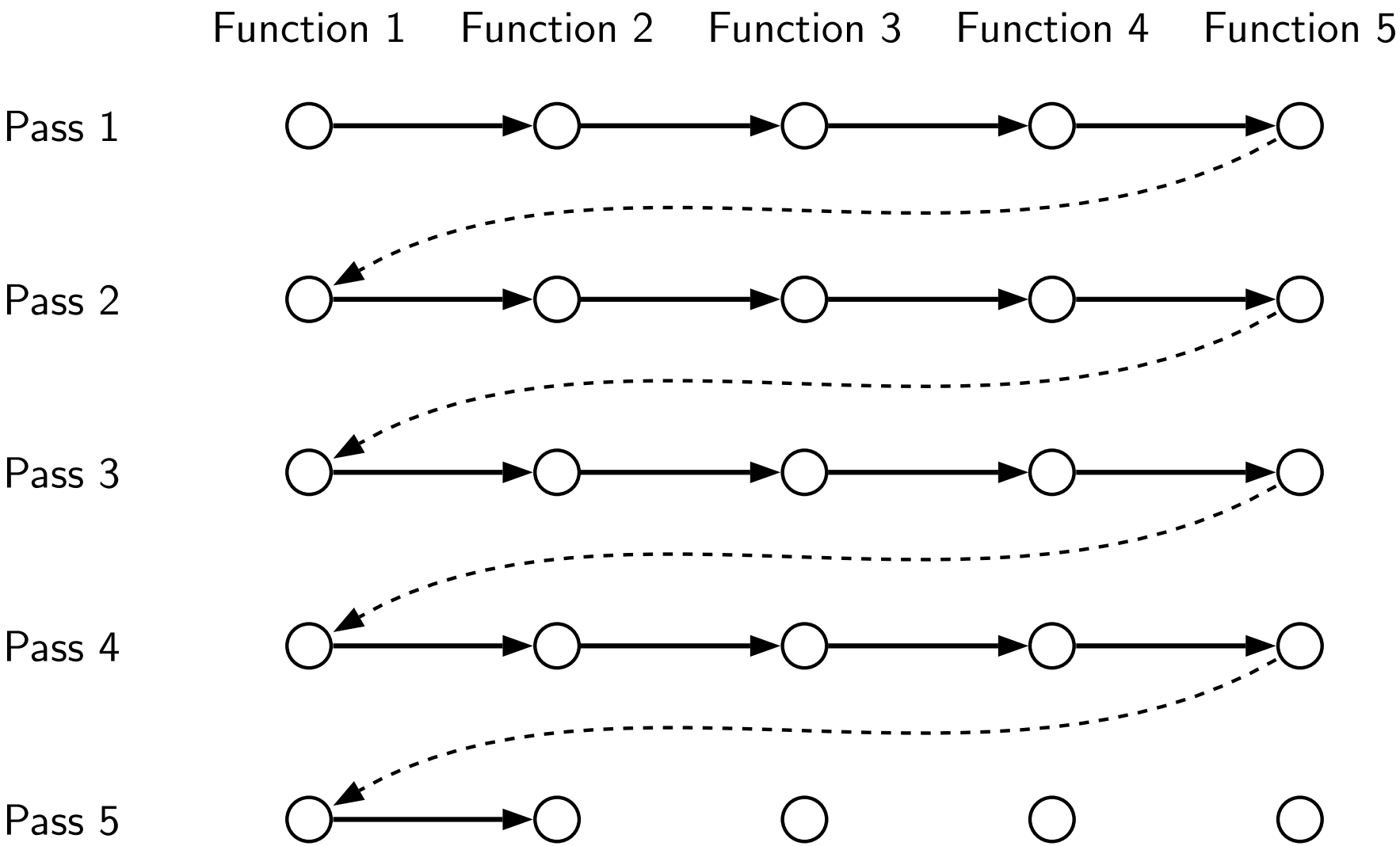
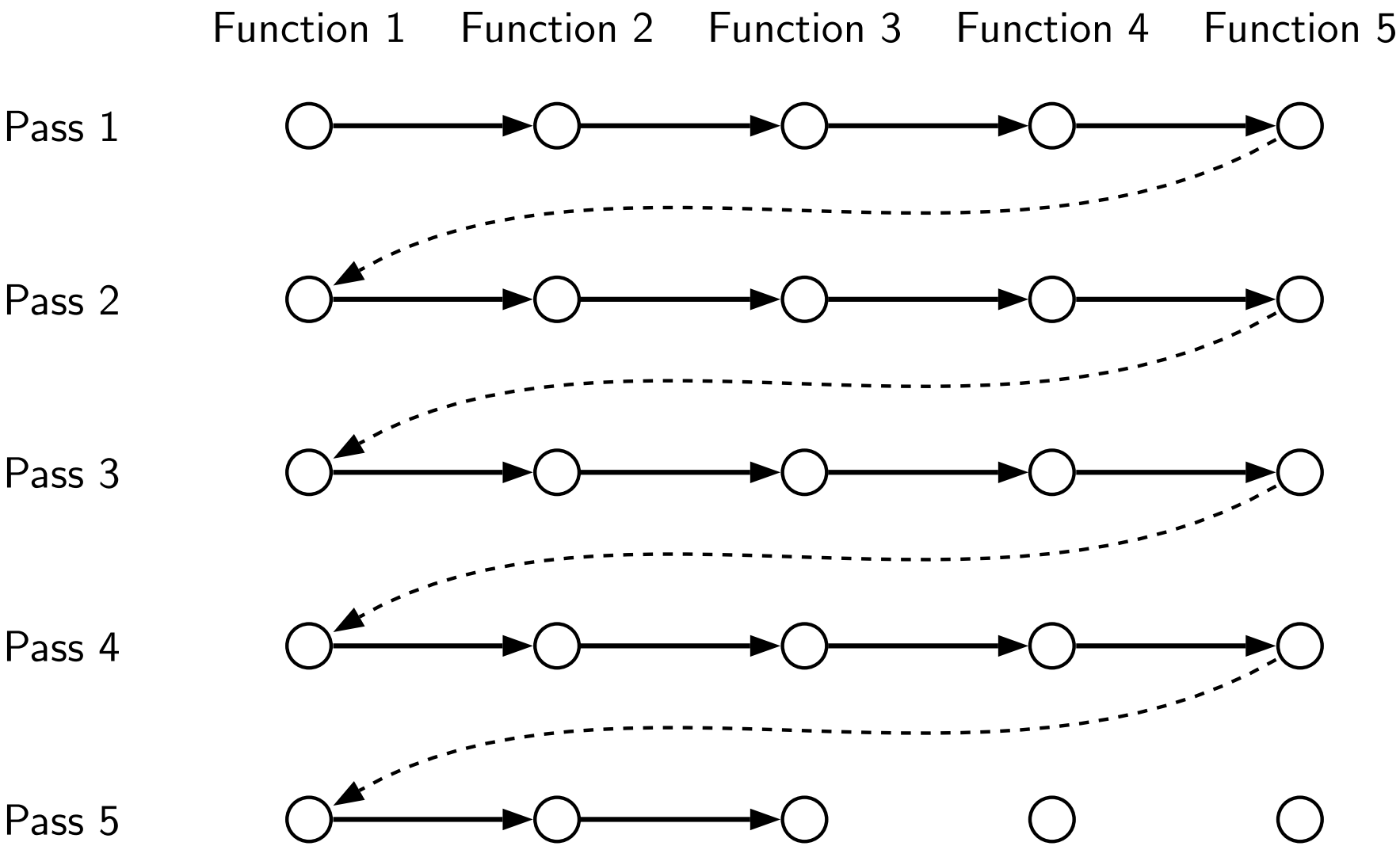


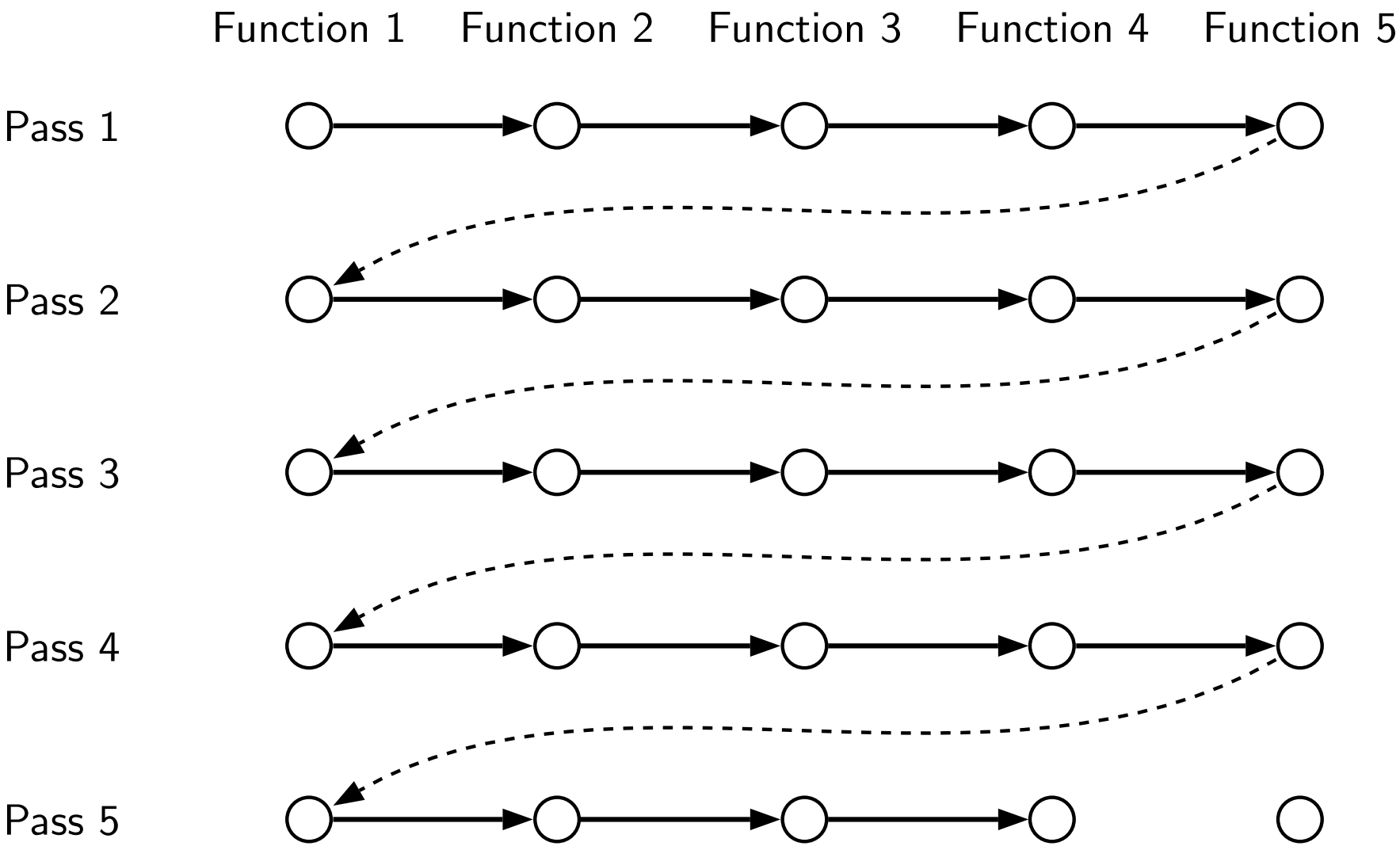
Execution Order in Interprocedural Passes



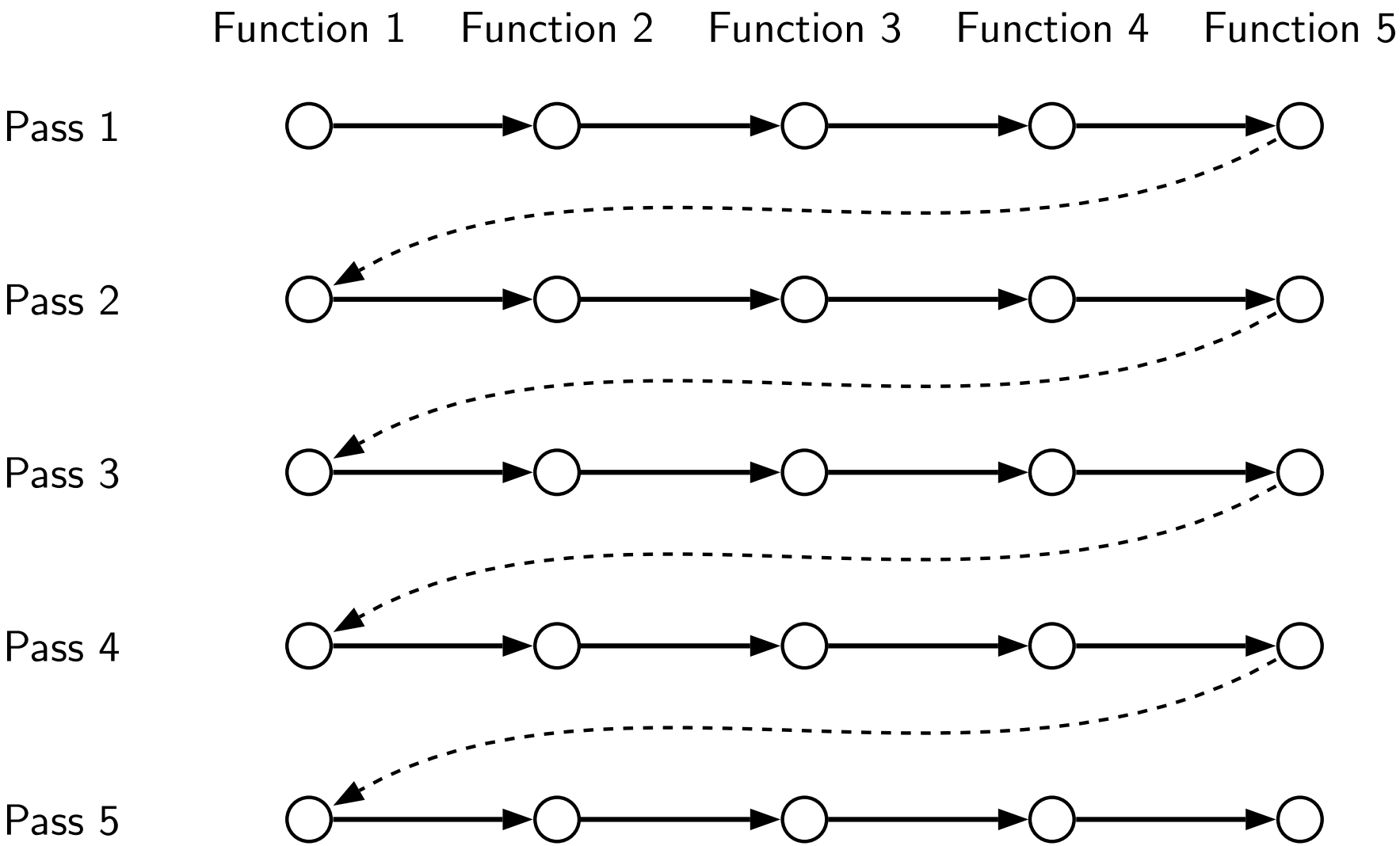
Execution Order in Interprocedural Passes



Execution Order in Interprocedural Passes



Execution Order in Interprocedural Passes



cc1 Control Flow: GIMPLE to RTL Expansion (pass_expand)

```
gimple_expand_cfg
   expand_gimple_basic_block(bb)
      expand_gimple_cond(stmt)
      expand_gimple_stmt(stmt)
         expand_gimple_stmt_1 (stmt)
            expand_expr_real_2
               expand_expr   /* Operands */
                  expand_expr_real
               optab_for_tree_code
               expand_binop /* Now we have rtx for operands */
                  expand_binop_directly
                    /* The plugin for a machine */
                    code=optab_handler(binoptab,mode);
                    GEN_FCN
                    emit_insn
```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                    expand_binop /* Now we have rtx for operands */
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                          /* The plugin for a machine */
                          code=optab_handler(binoptab,mode);
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```