Forward LTL_f Synthesis: DPLL At Work

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Abstract

This paper proposes a new AND-OR graph search framework for synthesis of Linear Temporal Logic on finite traces (LTL $_f$), that overcomes some limitations of previous approaches. Within such framework, I devise a procedure inspired by the Davis-Putnam-Logemann-Loveland (DPLL) algorithm to generate the next available agent-environment moves in a truly depth-first fashion, possibly avoiding exhaustive enumeration or costly compilations. I also propose a novel equivalence check for search nodes based on syntactic equivalence of state formulas. Since the resulting procedure is not guaranteed to terminate, I identify a stopping condition to abort execution and restart the search with stateequivalence checking based on Binary Decision Diagrams (BDD), which I show to be correct. The experimental results show that in many cases the proposed techniques outperform other state-of-the-art approaches.

1 Introduction

Program synthesis is the task of finding a program that provably satisfies a given high-level formal specification [Church, 1963]. A commonly used logic for program synthesis is Linear Temporal Logic (LTL) [Pnueli, 1977; Pnueli and Rosner, 1989], typically used also in model checking [Baier and Katoen, 2008]. LTL on finite traces (LTL_f) [De Giacomo and Vardi, 2013], a variant of LTL to specify *finite*-horizon temporal properties, has been recently proposed as specification language for temporal synthesis [De Giacomo and Vardi, 2015]. The LTL_f synthesis setting considers a set of variables controllable by the agent, a (disjoint) set of variables controlled by the environment, and a LTL $_f$ specification that specifies which finite traces over such variables are desirable. The problem of LTL $_f$ synthesis consists of finding a finite-state controller (i.e. the program) that at every time step, given the values of the environment variables in the history so far, sets the next values for each agent proposition such that the generated traces comply with the LTL_f specification.

The basic technique for solving LTL_f synthesis amounts to constructing a deterministic finite automaton (DFA) corresponding to the LTL_f specification, and then considering it

as a game arena where the agent tries to get to an accepting state regardless of the environment's moves. Then, a winning strategy, i.e. a finite controller returned by the synthesis procedure, can be obtained through a backward fixpoint computation for adversarial reachability of the DFA accepting state. Related works. State-of-the-art tools such as Lydia [De Giacomo and Favorito, 2021] and Lisa [Bansal et al., 2020a] are based on the classical approach. The main drawback of this technique is that it requires to compute the entire DFA of the LTL $_f$ specification, which in the worst case can be doubly exponential in the size of the formula. Therefore, the DFA construction step becomes the main bottleneck.

A natural idea is to consider a forward search approach that expands the arena on-the-fly while searching for a solution, possibly avoiding the construction of the entire arena. Forward-based approaches are at the core of the best solution methods designed for other AI problems: Planning with fully observable non-deterministic domains (FOND) [Ghallab et al., 2004; Geffner and Bonet, 2013; Cimatti et al., 1998; Cimatti et al., 2003], where the agent has to reach the goal, despite that the environment may choose adversarially the effects of the agent actions, and Planning in partially observable nondeterministic domains (POND), also known as contingent planning, where the search procedure must be performed over the belief-states [Reif, 1984; Goldman and Boddy, 1996; Bertoli et al., 2006]. However, techniques developed for such problems cannot be applied to ours: in a FOND planning problem, represented with PDDL [Haslum et al., 2019], the search space is at most single-exponential [Rintanen, 2004], whereas for LTL_f synthesis the state space can be of doubleexponential size wrt the size fo the formula; in a POND planning problem, despite the double-exponential size of the state space, belief-states have a specific structure [Bertoli et al., 2006; Thanh To et al., 2009], and therefore techniques for solving it cannot be directly applied to LTL f synthesis.

For these reasons, researchers have been looking into forward search techniques specifically conceived for solving LTL_f synthesis. Two notable attempts in this direction have been presented in [Xiao *et al.*, 2021] and [De Giacomo *et al.*, 2022]. The former work presents an on-the-fly synthesis approach via conducting a so-called Transition-based Deterministic Finite Automata (TDFA) game, where the acceptance condition is defined on transitions, instead of states. The main issue of that approach is the full enumeration of

agent-environment moves, which are exponentially many in the number of variables. Moreover, due to the fact that the acceptance condition is defined on transitions, every generated transition has to be checked for acceptance. The latter work instead proposes a search framework for LTL_f synthesis, where the DFA arena is seen as an AND-OR graph, and the available moves are found according to the formula associated to the current search node, by means of a Knowledge Compilation (KC) technique: Sentential Decision Diagrams (SDD) [Darwiche, 2011]. Notably, they are able to branch on propositional formulas, representing several evaluations, instead of individual ones. This can drastically reduce the branching factor. Nevertheless, for certain types of problem instances, the approach can get stuck with demanding compilations of the state formulas, needed both for state equivalence checking and for search node expansion. Moreover, the requirement of having irreducible representation of agent-env moves can be of little usefulness if the branching factor of the search problem is already high, hence resulting in an even greater compilation overhead.

Contributions. I think there is the need of a search approach that scales well with the increase of computational power, and that uses such power for actually exploring the search space, rather than wasting time either slavishly enumerating the exponentially many variable assignments, or by finding the minimal representation of the available search moves. My contributions are the following. First, I identify limitations of the previous AND-OR graph search framework, based on the EXPAND function, and propose a more general and versatile search framework for LTL f synthesis, based on two primitive operations: state-equivalence checking and search node expansion. Then, I propose two realizations of these operations in the context of LTL_f synthesis: one is a search graph expansion technique based on a procedure inspired by the famous Davis-Putnam-Logemann-Loveland (DPLL) algorithm; and the other is a state-equivalence checking technique based on structural equivalence of state formulas. Unfortunately, the resulting search algorithm does not terminate in general, but I designed a stopping condition to abort execution and resort to the KC-based state-equivalence checking using Binary Decision Diagrams (BDD) [Bryant, 1992], that I show to be correct. Finally, I describe my implementation in a new tool called Nike, and compare its performance on known benchmarks with other state-of-the-art tools, showing its surprising effectiveness.

2 Preliminaries

LTL_f **Basics.** Linear Temporal Logic over finite traces, called LTL_f [De Giacomo and Vardi, 2013] is a variant of Linear Temporal Logic (LTL) [Baier and Katoen, 2008] that is interpreted over finite traces rather than infinite traces (as in LTL). Given a set of propositions \mathcal{P} , the syntax of LTL_f is identical to LTL, and defined as (wlog, we require LTL_f formulas are in Negation Normal Form (NNF), i.e., negations only occur in front of atomic propositions): $\varphi ::= tt \mid ff \mid p \mid \neg p \mid \varphi_1 \wedge \varphi_2 \mid \varphi_1 \vee \varphi_2 \mid \bigcirc \varphi \mid -\varphi \mid \varphi_1 \mathcal{U} \varphi_2 \mid \varphi_1 \mathcal{R} \varphi_2$. tt is always true, tt is always false; tt is an atom, and tt is a negated atom (a literal tt is an atom or the negation of

an atom); \wedge (And) and \vee (Or) are the Boolean connectives; and \circ (Next), \bullet (Weak Next), \mathcal{U} (Until) and \mathcal{R} (Release) are temporal connectives. We use the usual abbreviations $true \equiv p \vee \neg p, false \equiv p \wedge \neg p, \Diamond \varphi \equiv true \, \mathcal{U} \, \varphi$ and $\Box \varphi \equiv false \, \mathcal{R} \, \varphi$. Also for convenience we consider traces $\rho \in (2^{\mathcal{P}})^*$, i.e., we consider also empty traces ϵ as in [Brafman et al., 2018]. More specifically, a trace $\rho = \rho[0], \rho[1], \ldots \in (2^{\mathcal{P}})^*$ is a finite sequence, where $\rho[i] \ (0 \leq i < |\rho|)$ denotes the i-th interpretation of ρ , which can be considered as the set of propositions that are true at instant i, and $|\rho|$ represents the length of ρ . We have that $\epsilon \models \varphi$ if φ is tt, an \mathcal{R} -formula or \bullet -formula, hence $\epsilon \models \Box false$. $\epsilon \not\models \varphi$ if φ is tt, a literal, \mathcal{U} -formula or \circ -formula, hence $\epsilon \not\models \varphi$ true. We consider the semantics of LTL f as presented in [Brafman et al., 2018].

We denote by $\operatorname{cl}(\varphi)$ the set of subformulas of φ , including tt and ff. We denote by $\operatorname{pa}(\varphi)\subseteq\operatorname{cl}(\varphi)$ the set of literals and temporal subformulas of φ whose primary connective is temporal [Li et al., 2019]. Formally, for an LTL_f formula φ in NNF, we have $\operatorname{pa}(\varphi)=\{\varphi\}$ if φ is a literal or temporal formula; and $\operatorname{pa}(\varphi)=\operatorname{pa}(\varphi_1)\cup\operatorname{pa}(\varphi_2)$ if $\varphi=(\varphi_1\wedge\varphi_2)$ or $\varphi=(\varphi_1\vee\varphi_2)$. Having LTL_f formula φ , replacing every temporal formula $\psi\in\operatorname{pa}(\varphi)$ with a propositional variable a_ψ gives us a propositional formula φ^p ; we call this operation $\operatorname{propositionalization} \operatorname{of} \varphi$. Note that $\varphi^p\in\mathcal{B}^+(\operatorname{cl}(\varphi))$, i.e. φ^p is a positive Boolean formula over variables $\operatorname{cl}(\varphi)$. Let $\varphi=\varphi^p$, we denote with $\varphi^{\operatorname{tf}}=\varphi$ the inverse operation of φ^p . Two formulas φ_1 and φ_2 are propositionally equivalent, denoted by $\varphi_1\sim_p \varphi_2$, if, $C\models\varphi_1^p\leftrightarrow C\models\varphi_2^p$ holds for every propositional assignment $C\in 2^{\operatorname{pa}(\varphi_1)\cup\operatorname{pa}(\varphi_2)}$.

An LTL_f formula φ is in neXt Normal Form (XNF) if pa(φ) only includes literals, O- and \bullet -formulas. For an LTL_f formula φ in NNF, we can obtain its XNF by transformation function xnf(φ), defined as follows:

- $-\operatorname{xnf}(\varphi) = \varphi \text{ if } \varphi \text{ is a literal, } \Box false, \Diamond true, \bigcirc -, \bullet \text{-formula;}$
- $-\operatorname{xnf}(\varphi_1 \wedge \varphi_2) = \operatorname{xnf}(\varphi_1) \wedge \operatorname{xnf}(\varphi_2);$
- $-\operatorname{xnf}(\varphi_1\vee\varphi_2)=\operatorname{xnf}(\varphi_1)\vee\operatorname{xnf}(\varphi_2);$
- $-\operatorname{xnf}(\varphi_1 \mathcal{U} \varphi_2) = (\operatorname{xnf}(\varphi_2) \wedge \Diamond \operatorname{true}) \vee (\operatorname{xnf}(\varphi_1) \wedge \Diamond (\varphi_1 \mathcal{U} \varphi_2));$ - \text{xnf}(\varphi_1 \mathcal{R} \varphi_2) = (\text{xnf}(\varphi_2) \varphi \subseteq \delta \text{true}) \land (\text{xnf}(\varphi_1) \varphi \cdot (\varphi_1 \mathcal{R} \varphi_2)).

Note that $\lozenge true$ (resp. $\square false$) guarantees that empty trace is not (resp. is) accepted by \mathcal{U} -formulas (resp. \mathcal{R} -formulas).

Theorem 1 ([Li et al., 2019]). Every LTL_f formula φ in NNF can be converted, with linear time in the formula size, to an equivalent formula in XNF, denoted by xnf(φ).

LTL_f Formula Progression [De Giacomo et al., 2022]. Consider an LTL_f formula φ over \mathcal{P} and a finite trace $\rho = \rho[0], \rho[1], \ldots \in (2^{\mathcal{P}})^*$, in order to have $\rho \models \varphi$, we can start from φ , progress or push φ through ρ . The idea behind formula progression is to split an LTL_f formula φ into a requirement about $now \ \rho[i]$, which can be checked straightaway, and a requirement about the future that has to hold on the yet unavailable suffix. That is to say, formula progression looks at $\rho[i]$ and φ , and progresses a new formula $\operatorname{fp}(\varphi, \rho[i])$ such that $\rho, i \models \varphi$ iff $\rho, i + 1 \models \operatorname{fp}(\varphi, \rho[i])$. This procedure is analogous to DFA reading trace ρ , where reaching accepting states is essentially achieved by taking one transition after another. Formula progression has been studied in prior work, cf. [Emerson, 1990; Bacchus and Kabanza, 1998]. Here we use the formalization provided in [De Giacomo et al., 2022].

Note that, since ρ is a finite trace, it is necessary to clarify when the trace ends. To do so, two new formulas are introduced: $\Box false$ and $\Diamond true$, which, intuitively, refer to *finite trace ends* and *finite trace not ends*, respectively. For simplicity, we enrich $\operatorname{cl}(\varphi)$, the set of proper subformulas of φ , to include them such that $\operatorname{cl}(\varphi)$ is reloaded as $\operatorname{cl}(\varphi) \cup \operatorname{cl}(\Diamond true) \cup \operatorname{cl}(\Box false)$.

For an LTL_f formula φ in NNF, the *progression function* fp(φ , σ), where $\sigma \in 2^{\mathcal{P}}$, is defined as follows:

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Ip(\varphi, \sigma), where \sigma \in \mathcal{Z}, is defined as follows:

- fp(tt,\sigma) = tt and fp(ff,\sigma) = ff;

- fp(p,\sigma) = tt if p \in \sigma, otherwise ff;

- fp(\neg p,\sigma) = tt if p \notin \sigma, otherwise ff;

- fp(\varphi_1 \land \varphi_2, \sigma) = fp(\varphi_1, \sigma) \land fp(\varphi_2, \sigma);

- fp(\varphi_1 \lor \varphi_2, \sigma) = fp(\varphi_1, \sigma) \lor fp(\varphi_2, \sigma);

- fp(\varphi_0, \sigma) = \varphi \land \Diamond true;

- fp(\varphi_0, \sigma) = \varphi \lor \Box false;

- fp(\varphi_1 \mathcal{U}\varphi_2, \sigma) = fp(\varphi_2, \sigma) \lor (fp(\varphi_1, \sigma) \land fp(\Diamond(\varphi_1 \mathcal{U}\varphi_2), \sigma));

- fp(\varphi_1 \mathcal{U}\varphi_2, \sigma) = fp(\varphi_2, \sigma) \land (fp(\varphi_1, \sigma) \lor fp(\bullet(\varphi_1 \mathcal{U}\varphi_2), \sigma)).

Note that fp(\varphi, \sigma) is a positive Boolean formula on cl(\varphi), i.e., fp(\varphi, \sigma) \in \mathcal{B}^+(cl(\varphi)). The following two propositions show that fp(\varphi, \sigma) strictly follows LTL_f semantics and retains the propositional behavior of LTL_f formulas.
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Proposition 1. Let φ be an LTL_f formula over \mathcal{P} in NNF, ρ be a finite nonempty trace, $\mathsf{fp}(\varphi,\sigma)$ be as above. We have that $\rho, i \models \varphi$ iff $\rho, i+1 \models \mathsf{fp}(\varphi,\rho[i])$.

Proposition 2. Let φ and ψ be two LTL_f formulas over \mathcal{P} in NNF s.t. $\varphi \sim_p \psi$, and $\sigma \in 2^{\mathcal{P}}$. Then $\mathsf{fp}(\varphi, \sigma) \sim_p \mathsf{fp}(\psi, \sigma)$ holds.

We generalize LTL_f formula progression from single instants to finite traces by defining $\mathrm{fp}(\varphi,\epsilon)=\varphi$, and $\mathrm{fp}(\varphi,\sigma u)=\mathrm{fp}(\varphi,\sigma u)=\mathrm{fp}(\mathrm{fp}(\varphi,\sigma),u)$, where $\sigma\in 2^{\mathcal{P}}$ and $u\in (2^{\mathcal{P}})^*$.

Proposition 3. Let φ be an LTL_f formula over \mathcal{P} in NNF, ρ be a finite trace. We have that $\rho \models \varphi$ iff $\epsilon \models \mathsf{fp}(\varphi, \rho)$.

We take the definition of the *remove-next* function RMNEXT from [De Giacomo *et al.*, 2022], defined over propositionalized LTL_f formulas in XNF, φ^p :

```
- RMNEXT(\lozenge true) = tt, RMNEXT(\square false) = ff

- RMNEXT(\varphi_1 \land \varphi_2) = RMNEXT(\varphi_1) \land RMNEXT(\varphi_2)

- RMNEXT(\varphi_1 \lor \varphi_2) = RMNEXT(\varphi_1) \lor RMNEXT(\varphi_2)

- RMNEXT(\varphi_2) = \varphi \land \lozenge true, RMNEXT(\varphi_2) = \varphi \lor \square false
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Note that RMNEXT applies to neither \mathcal{U} -, \mathcal{R} - formulas, since they do not appear in XNF, nor literals $(p, \neg p)$, as the input of the function is a propositionalized LTL_f formula in XNF form. We have the following proposition:

Proposition 4. Given an LTL_f formula φ in NNF, $\forall \sigma \in 2^{\mathcal{P}}$, $\mathsf{fp}(\varphi, \sigma) \equiv \mathsf{RMNEXT}(\mathsf{xnf}(\varphi)^p|_{\sigma})$, where $\mathsf{xnf}(\varphi)^p|_{\sigma}$ stands for evaluating σ on $\mathsf{xnf}(\varphi)^p$.

LTL_f **Synthesis** The problem of LTL_f synthesis is described as a tuple $(\varphi, \mathcal{X}, \mathcal{Y})$, where φ is an LTL_f formula over $\mathcal{X} \cup \mathcal{Y}$, and \mathcal{X}, \mathcal{Y} are two disjoint sets of variables controlled by the *environment* and the *agent*, respectively.

Definition 1. The synthesis problem $(\varphi, \mathcal{X}, \mathcal{Y})$ aims to computing a strategy $g: (2^{\mathcal{X}})^* \to 2^{\mathcal{Y}}$, such that for an arbitrary infinite sequence $\lambda = X_0, X_1, \ldots \in (2^{\mathcal{X}})^{\omega}$, we can find $k \geq 0$ such that $\rho^k \models \varphi$, where $\rho^k = (X_0 \cup g(\epsilon)), (X_1 \cup g(X_0)), \ldots, (X_k \cup g(X_0, X_1, \ldots, X_{k-1}))$. If such a strategy does not exist, then φ is unrealizable.

Algorithm 1 SDD-based Forward Synthesis [De Giacomo *et al.*, 2022]

```
1: function Synthesis(\varphi) return strategy
       if IsAccepting(\varphi) then
 3:
           ADDToStrategy(\varphi, true)
 4:
           return GETSTRATEGY()
 5.
       InitialGraph(\varphi)
        n := GETGRAPHROOT()
       found := SEARCH(n, \emptyset)
       if found then return GETSTRATEGY()
       return EmptyStrategy() \triangleright \varphi is unrealizable
10: function SEARCH(n, path) return True/False
        if IsSuccessNode(n) then return True
12:
        if IsFailureNode(n) then return False
13:
        if InPath(n, path) then \triangleright We found a loop
14:
            TAGLOOP(n) return False
15:
        \psi := FORMULAOFNODE(n)
        if IsAccepting(\psi) then
16:
           TAGSUCCESSNODE(n)
17:
            ADDToSTRATEGY(\psi, true)
18:
19:
           return True
20:
        Expand (n) \triangleright Uses SDD to partition \psi wrt \mathcal{Y} and \mathcal{X}
        for (act, AndNd) \in GetOrArcs(n) do
21:
           for (resp, succ) \in \text{GetAndArcs}(AndNd) do
22:
                found := SEARCH(succ, [path|n])
23:
24:
               if ¬found then Break
25:
           if found then
26:
                TAGSUCCESSNODE(n)
27:
                ADDTOSTRATEGY(\psi, act)
               if IsTagLoop(n) then
29:
                   BACKPROP(n)
30:
               return True
31:
        TAGFAILURENODE(n)
        return False
```

LTL_f synthesis can be solved by reducing to an adversarial reachability game on the corresponding Deterministic Finite Automaton (DFA) [De Giacomo and Vardi, 2015]. Hence, a strategy can also be represented as a finite-state controller $g: \mathcal{S} \mapsto 2^{\mathcal{Y}}$, where \mathcal{S} denotes the state space of the DFA.

3 Limitations of Previous Works

The motivations for this work lie on the limitations of previous forward LTL_f synthesis approaches namely Xiao *et al.*'s and De Giacomo *et al.* works. Since the implementation of the former approach (Ltlfsyn) has been considered superseded by the latter (Cynthia) in terms of performance, here I focus on Cynthia, although my arguments can be considered more general and not just applicable to specific techniques.

The state-of-the-art forward technique [De Giacomo et al., 2022], implemented in the tool Cynthia, is described by the pseudocode in Algorithm 1. The algorithm is basically a topdown, depth-first traversal of the AND-OR graph induced by the on-the-fly DFA construction, proceeding forward from the initial state, and excluding strategies that lead to loops. The forward-based generation of the AND-OR graph is based on formula progression and on an abstract EXPAND function (Line 20) that, taken in input a search node n, it produces the next available actions and successor states. The presence of loops must be carefully handled; when a loop is detected at node n, the procedure returns false, temporarily considering n as a failure node. Note that node n is not tagged as failure, since it is unknown whether all the or-arcs of n are explored. If later during the search n is discovered as a success node, such information must be propagated from n backwards to the ancestor nodes of n. It should be noted that, in a forward search on an AND-OR graph, it is critical to handle loops with the assistance of this backward propagation, implemented in BACKPROP (Line 29), as illustrated in [Scutellà, 1990]. For more details on the search algorithm, please refer to the original paper [De Giacomo et al., 2022]. The realization of the abstract EXPAND function was based on Sentential Decision Diagrams (SDDs) [Darwiche, 2011]. The SDDs have been used for two subtasks: (i) stateequivalence checking, i.e. checking whether two states are equivalent, and (ii) search node expansion, i.e. identifying the next AND-OR arcs. The experimental evaluation of De Giacomo et al.'s technique is rather impressive, as its implementation Cynthia, outperformed other state-of-the-art tools on challenging benchmarks, e.g. on the Nim benchmark [Bouton, 1901]. However, as already acknowledged by the authors (cfr. Section 5 of [De Giacomo et al., 2022]), the tool performed poorly on the variant of the Double Counters benchmark used in [De Giacomo et al., 2022]. I discovered that the main reason is that the search gets stuck with the search node expansion to compute the next agent's and environment's moves, whose number grows exponentially with the scaling parameter n, the number of bits of the counters. In general, I identify at least three factors that hinder the scalability of Cynthia:

(i) Disjoint & covering moves. Ltlfsyn, which naively enumerates all the exponentially-many agent's and env's moves, has been surpassed by Cynthia. Cynthia is able to branch on disjoint and covering propositional formulas, rather than individual evaluations of agent's and env's variables, and therefore ending up, most of the times, in a more succinct representation of the next players' moves. Nevertheless, for problem instances where the branching factor is very high, the compilation by means of SDDs does not bring much more benefits than exhaustive enumeration, ending up in a huge computational overhead with little usefulness.

(ii) No visit before all moves are computed. The search algorithm is constrained by how the identification of the next moves works. That is, the search procedure cannot visit children nodes before all OR arcs, and subsequent AND arcs, have been computed from the current OR-node being expanded. Obviously, a breadth-first search procedure (e.g. AO* [J. Nilsson, 1982]) will need to consider all the children of the current search node before proceeding. The point is that, if a search procedure does not need to know in advance all the children of the current node, like Algorithm 1, then it must be able to do so.

(iii) Monolithic. It is not necessary to tighten together the two tasks of state-equivalence checking and search node expansion. They can be implemented in different ways according to the desired computation trade-offs (e.g. space vs time).

3.1 A new framework.

My aim is to propose a new framework that tries to overcome the above limitations that we consider crucial for a scalable approach. To do so, I consider a slightly more general version of Algorithm 1. The generalization is not on the search algorithm being used, but rather on the building blocks that make any AND-OR search algorithm actually suitable for solving LTL_f synthesis in a forward fashion. In particular, I make a step further from the framework introduced in [De Giacomo et al., 2022], which formalizes the search algorithm on top of the EXPAND function. Instead, the two primitive operations that I consider are: EQUIVALENCECHECK (n_1, n_2) , that checks whether the search nodes n_1 and n_2 can be considered equivalent wrt the current AND-OR search problem; and GETARCS(n), that returns an *iterator* of AND-arcs (ORarcs resp.) of the AND-node (OR-node, resp.) n. In Algorithm 1, the EQUIVALENCECHECK procedure is (implicitly) used to check whether a node has been already visited (e.g. see the INPATH function of Line 13) or to retrieve search tags (e.g. see IsSuccessNode, IsFailureNode and IsTa-GLOOP). The GETARCS procedure would be used in place of GETORARCS and GETANDARCS in Algorithm 1, at lines 21 and 22, respectively. For the rest of the paper, I consider such modified Algorithm 1 as the basis of my techniques.

The crucial observation is that $\operatorname{GETARCS}(n)$ does not require that the arcs of search node n have already been computed or, in other words, that the node n has been fully expanded (as done by EXPAND function). As per specification, $\operatorname{GETARCS}(n)$ is an iterator over the available moves from n. The concept of iterator is well-known in the computer science community as a way to decouple algorithms from containers [Gamma $et\ al.$, 1995]. More interestingly, a special case of iterators, generators [Murer $et\ al.$, 1996], would allow to compute the next players' moves iteratively "on-demand", therefore allowing a depth-first search algorithm to visit the next arc returned by the generator even if all arcs have not been computed yet. I will use a generator-based realization of the abstract function GETARCS in the next sections.

In fact, De Giacomo et al.'s approach can be seen as a special case of the proposed framework, in which both EQUIVA-LENCECHECK and GETARCS are implemented using SDDs: two search nodes are equivalent if they point to the same SDD node, and GETARCS is an iterator that simply scans the children of the root SDD node of n. However, this framework can easily overcome the limiting factors identified earlier in this section, namely: (i) computed moves do not have to be disjoint and covering (i.e. different moves that lead to the same successor are allowed, although preferably avoided); (ii) if GETARCS is implemented using a generator-like approach, the visit of a child node can happen far before the computation of all the available moves; and (iii) the two main search subtasks, state-equivalence checking and a search node expansion, are implemented by two potentially decoupled functions (EQUIVALENCECHECK and GETARCS, respectively).

4 DPLL-based Forward Synthesis

In this section, I describe my main novel approach for forward LTL $_f$ synthesis of an LTL $_f$ formula φ , as an instantiation of the abstract framework presented in Section 3. In particular, EQUIVALENCECHECK is implemented using BDDs, and GETARCS is implemented using a Davis-Putnam-Logemann-Loveland-like (DPLL) procedure (Algorithm 2). While the knowledge-compilation-based equivalence check is not new, as it is very similar to what has been already done for other forward LTL $_f$ synthesis approaches, I claim the DPLL-based

GETARCS to be novel and effective for solving our problem, and it is one of the core contributions of the paper.

BDD-based EQUIVALENCE CHECK. The BDD-based equivalence check is similar to the SDD-based equivalence check performed by Cynthia. That is, for a search node n, we take its associated LTL f formula ψ with FORMULAOFN-ODE (remember that search node is associated to an LTL_f formula). Then, we compute $xnf(\psi)$, which is propositionally equivalent to ψ . $xnf(\bar{\psi})$, by construction, is defined over the set of variables $\mathcal{Y} \cup \mathcal{X} \cup \mathcal{Z}$, where $\mathcal{Z} = \bigcup_{\theta \in \mathsf{cl}(\varphi)} \{z_{\alpha} | \alpha \in \mathcal{Z} \in \mathcal{Z} \}$ $pa(xnf(\theta)), \alpha$ not literal}. Finally, we get its BDD representation, i.e. $B_{\psi} := BDDREPRESENTATION(xnf(\psi)^p)$. We do these operations both for n_1 and n_2 , yielding $B_{\mathsf{xnf}(\psi_1)}$ and $B_{\mathsf{xnf}(\psi_2)}$. The equivalence check whether the two BDDs point to the same BDD node $(B_{\mathsf{xnf}(\psi_1)} = B_{\mathsf{xnf}(\psi_2)})$. If that is the case then it means, thanks to the canonicity property of BDDs, that the associated (propositionalized) formulas are propositionally equivalent. I preferred the use of BDDs instead of SDDs since we do not need the decomposing feature of SDDs, and also because robust and optimized implementations for BDDs already exists, e.g. CUDD [Somenzi, 2016], with useful features such as dynamic variable reordering.

DPLL-based GETARCS. The DPLL algorithm [Davis and Putnam, 1960; Davis *et al.*, 1962] is a very famous algorithm for deciding the satisfiability of proposition logic formulas in conjunctive normal form (CNF). Many variants of it have been proposed that work for general non-clausal formulas [Thiffault *et al.*, 2004; Jain and Clarke, 2009], motivated by the fact that, quite often, conversion of a boolean formula to CNF is both unnecessary and undesirable, e.g. because of loss of structural information and due to the worst-case exponential blow-up of the size of the formula. I agree with this view, and in the following we assume to deal with propositionalized LTL *f* formulas in non-clausal form.

I am interested in designing a DPLL-like procedure to identify the next moves and successor nodes from a search node n. My proposed procedure (Algorithm 2), like any DPLL procedure, runs by choosing a literal, assigning a truth value to it, simplifying the formula and then recursively applying the same procedure to the simplified formula, until there are no agent or environment variables to branch on. Both the computed set of assignments resulting from the sequence of recursive calls, ass (initialized at Line 3), and what remains of the formula $\phi = \text{xnf}(\text{FORMULAOFNODE}(n))^p$ after the chosen literals have been replaced with their assigned truth value, are yielded such that they can be consumed by the caller function (see Line 17 and 28; the instruction yield allows a generator to provide a value to the caller).

Given a search node n, DPLLGETARCS returns a generator over pairs (move, node), where move is a mapping from variables to truth values (the absence of a variable is considered a $don't\ care$), and node is a LTL $_f$ formula that, as required by mine and De Giacomo $et\ al.$'s search framework, represents a search node (either AND or OR). Depending on whether n is an OR-node or an AND-node, the DPLLGETORARCS function (Line 5) or the DPLLGETANDARCS function (Line 7) is called, respectively. The DPLLGETORARCS function takes in input a propositionalization of ψ , ϕ , and the current variables' assignment ass. If there is still some agent variable

in \mathcal{Y} to assign (Line 9), then we decide the next branching literal ℓ (by calling the function GETBRANCHINGLIT-ERAL, Line 11), we substitute its truth value to the formula ϕ , and simplify it by calling the function REPLACE (Line 12), obtaining ϕ_{ℓ} . Then, we do the recursive call to DPLLGE-TORARCS with the new propositionalized formula ϕ_{ℓ} and updated assignment $ass \cup \{\ell\}$, and start generating the next moves with a fixed value for literal ℓ . Intuitively, this step represents a transition to another node of the search tree of a DPLL algorithm. The instruction yield from allows a generator to forward the generation of results to another generating function. When the generation terminates, the negated literal $\neg \ell$ is replaced to the original formula ϕ , yielding another propositionalized LTL_f formula $\phi_{\neg \ell}$, and the available moves starting from this branch are generated. Intuitively, the last step represents the exploration of the opposite branch of the current node of the DPLL search tree, with the branching literal ℓ set at the opposite truth value $\neg \ell$. Note that in the base case, we return the pair (ass, ϕ^{tf}) , where ass contains all the chosen literals in the current final assignment, and ϕ^{tf} is the LTL formula that represents the next AND node. The DPLLGETANDARCS is analogous to DPLLGE-TORARCS but for AND nodes; therefore, it aims at finding an assignment of env variables \mathcal{X} rather than of agent variables Y. Another difference with DPLLGETANDARCS is that in the base case, we use the propositional formula Ψ (the result of the substitutions of chosen literals and the subsequent simplifications) to compute the next search node formula ψ' , using the function RMNEXT, at Line 27. Note that, at this stage, Ψ is a propositional formula over $\mathcal Z$ state variables only. By Proposition 8, since $\Psi = \mathsf{xnf}(\psi)^p|_{\sigma}$, we have that $\psi' = \text{RMNEXT}(\Psi) = \text{fp}(\psi, \sigma)$, i.e. the correct next state.

According to the needs of the search algorithm, the procedure can be run exhaustively, i.e. until all available moves from node n have been produced. Still, the simplification step can possibly avoid a large part of the naive search space over \mathcal{Y} and \mathcal{X} ; this is an improvement wrt the Ltlfsyn approach, which blindly enumerates all possible assignments. The simplification step recursively applies the usual propositional simplification rules, e.g. considering the absorbing or neutral boolean values of binary operators. I suggest to simplify the propositional formula to a great extent, but without resorting to any compilations. Instead, we leave the formula in non-clausal form, aiming at eliminating branching variables from the resulting formula. Such variables will be considered as don't care in the current assignment.

I argue that such kind of procedures, like the one described in Algorithm 2, are suitable for our use-case because of their depth-first nature, which implies a low-space requirement, and because of their "responsive" nature: a candidate move is proposed in linear time on the number of variables (possibly better thanks to simplifications). Note that Alg. 2 is an abstract specification that can be customized by different realizations of GetbranchingLiteral and Replace.

Theorem 2. Modified Algorithm 1 with BDDBASEDE-QCHECK for state-equivalence checking and Algorithm 2 for search node expansion is correct and always terminates.

Proof sketch. Termination follows from canonicity of BDD

Algorithm 2 DPLL-based GETARCS

```
1: function DPLLGETARCS(n) return Gen[move, node]
 2:
         \psi \leftarrow \mathsf{xnf}(\mathsf{FORMULaOfNODE}(n))
 3:
         ass \leftarrow \{\}
                                                    ▷ propositional assignment
 4:
         if IsOrNode(n) then
 5:
              yield from DPLLGETORARCS (\psi^p, ass)
 6:
              yield from DPLLGETANDARCS (\psi^p, ass)
 7:
 8: function DPLLGETORARCS(\phi, ass)
 9:
         \mathcal{Y}' \leftarrow \text{GETAGENTVARS}(\phi)
         if \mathcal{Y}' \neq \emptyset then
10:
              \ell \leftarrow \text{GetBranchingLiteral}(\phi)
11:
12:
              \phi_{\ell} \leftarrow \text{REPLACE}(\phi, \ell)
13:
              yield from DPLLGETORARCS(\phi_{\ell}, ass \cup \{\ell\})
14:
              \phi_{\neg \ell} \leftarrow \text{REPLACE}(\phi, \neg \ell)
15:
              yield from DPLLGETORARCS(\phi_{\neg \ell}, ass \cup \{\neg \ell\})
16:
         else
                               ⊳ No branching on agent variables available
              yield (ass, \phi^{tf})
17:
                                                    \triangleright \phi^{\mathsf{tf}} is the next AND node
18: function DPLLGETANDARCS(\Psi, ass)
          \mathcal{X}' \leftarrow \mathsf{GETENVVARS}(\Psi)
19:
          if \mathcal{X}' \neq \emptyset then
20:
21:
              \ell \leftarrow \text{GetBranchingLiteral}(\Psi)
22:
              \Psi_{\ell} \leftarrow \text{REPLACE}(\Psi, \ell)
23:
              yield from DPLLGETANDARCS(\Psi_{\ell}, ass \cup \ell)
24:
              \Psi_{\neg \ell} \leftarrow \text{REPLACE}(\Psi, \neg \ell)
              yield from DPLLGETANDARCS(\Psi_{\neg \ell}, ass \cup \neg \ell)
25:
26:
                                 ▷ No branching on env variables available
              \psi' \leftarrow \text{RMNext}(\Psi)
27:
28:
              yield (ass, \psi')
                                                       \triangleright \psi' is the next OR node
```

representation of search nodes and Theorem 4 of [De Giacomo *et al.*, 2022]. Correctness holds by observing that, by construction, Ψ at Line 27 is equal to $xnf(\psi)^p|_{\sigma}$; putting it together with Proposition 8 and Theorem 5 of [De Giacomo *et al.*, 2022], we get the thesis.

5 Hash-Consing-based Equivalence Check

In this section, I devise a variant of the search algorithm proposed in Section 4, where we replace the BD-DBASEDEQCHECK with a check based on *structural equivalence*: two search nodes n_1 and n_2 are considered equivalent if their formulas ψ_1 and ψ_2 have the same syntax tree, i.e.: HASHCONSINGEQCHECK (n_1, n_2) := FORMULAOFNODE (n_1) = FORMULAOFNODE (n_2) . To make the comparison fast, we can use *hash consing* [Deutsch, 1973] which is a technique used to share values that are structurally equal. Using hash consing, two formulas can be stated as structurally equivalent if they point to the same memory address, achieving constant time equality check. Unfortunately, we have the following negative result:

Theorem 3. The modified Algorithm 1 with HASHCON-SINGEQCHECK for EQUIVALENCECHECK and Algorithm 2 for GETARCS is sound but not complete for LTL_f synthesis.

Proof sketch. Soundness follows from correctness of DPLL-GETARCS and by the soundness of hash-consing based equivalence check. To disprove completeness, consider the synthesis problem with $\varphi = \Box a \mathcal{U} \Diamond b$, $\mathcal{Y} = \{a\}$ and $\mathcal{X} = \{b\}$. Repeatedly taking agent-environment move corresponding to assignment $\sigma = \{a\}$ produces ever bigger, but proposi-

tionally equivalent, state formulas, ending up in an infinite recursion. See the supplementary material for more details. \Box

At the core of the issue is that, by how the formula progression works, there are some cases in which a new structurally different formula can be always produced by some particular sequence of applications of formula progression rules, although propositionally equivalent formulas have been already produced earlier during the search. Nevertheless, the hash-consing based equivalence check is very computationally cheap and, as we shall see in the experimental section, often it performs better than the BDD-based equivalence check.

To guarantee the termination of this version of the search algorithm, I propose the following procedure: given a synthesis problem, first execute the modified Algorithm 1 with HASHCONSINGEQCHECK as equivalence check and DPLL-GETARCS for search node expansion. As soon as, during the execution, the size of the formula of any generated search node becomes greater than a given threshold t, then abort the execution and resort to the search algorithm described in Section 4, i.e. Algorithm 1 based on BDDBASEDEQCHECK and DPLLGETARCS. In other words, if the problem does not present the pathological corner case shown in the proof of Theorem 4, then try to solve it, without getting stuck with onerous BDD-based compilations. The threshold guarantees that only a finite number of structurally equivalent formulas can be computed. Empirically, we found that a good threshold that suitably postpones the detection of pathological instances is three times the size of the initial formula: $t = 3 \cdot |\varphi|$.

6 Implementation and Experiments

I implemented the presented synthesis methods in a tool called Nike, in C++ 1 . Nike takes in input an LTL $_f$ synthesis problem and constructs a strategy that realizes the specification, if one exists. I use the CUDD library (github.com/ivmai/cudd) to handle all BDD related operations. Nike, as Cynthia and Ltlfsyn, applies some optimizations to speed up the synthesis procedure. First, when visiting an OR-node n for the first time, we perform the preprocessing techniques described in [Xiao $et\ al.$, 2021]. More specifically, we check: (i) there exists a one-step strategy that reaches accepting states from n, then n is tagged as success; or (ii) there does not exist an agent move that can avoid sink state (a non-accepting state only going back to itself) from n, then n is tagged as failure.

Nike can run in two modes: using BDD-based state-eq checking (BDD), and hash-consing-based state eq checking (Hash). In the DPLL-based search node expansion, I considered variables in alphabetical order, and I combined them with three simple branching strategies: *True-first* (TF) that first sets variables to true, *False-first* (FF) that first sets variables to false; and *Random* (Rand) that sets variables at random. This yields six combinations of Nike that I included in these experiments. I also include a parallel version of Nike, Nike-P, that runs in hash-consing-based modes all the three branching strategies in parallel.

¹Source code will be available upon request.

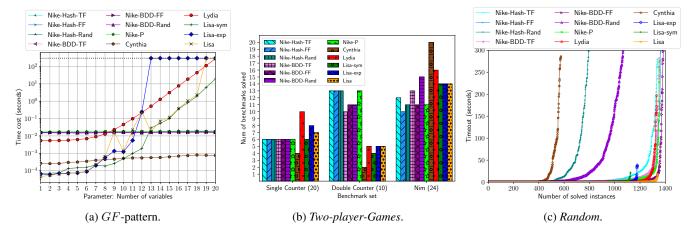


Figure 1: Comparison results on all benchmarks.

Experimental Methodology. I evaluated the efficiency of all variants of Nike, by comparing against the following tools: Lisa [Bansal et al., 2020a] and Lydia [De Giacomo and Favorito, 2021] are state-of-the-art backward LTL_f synthesis approaches. Both tools compute the complete DFA first, and then solve an adversarial reachability game following the symbolic backward computation technique described in [Zhu et al., 2017b]. I excluded Ltlfsyn from the comparison because it has been already shown to be superseded by Cynthia. Experiment Setup. Experiments were run on a VM instance on Google Cloud, type c2-standard-4, endowed with Intel(R) Xeon(R) CPU 3.10GHz, 4 logical CPU threads, 16 GB of memory and 300 seconds of time limit. The correctness of Nike was empirically verified by comparing the results with those from all baseline tools. No inconsistency was found.

Benchmarks. We collected, in total, 1494 LTL $_f$ synthesis instances from literature: 40 Patterns instances (GF- and U-patterns) [Xiao $et\ al.$, 2021]; 54 Two-player-Games instances: Single-Counter, Double-Counter and Nim [Tabajara and Vardi, 2019; Bansal $et\ al.$, 2020a]; and 1400 Random instances [Zhu $et\ al.$, 2017b; De Giacomo and Favorito, 2021].

Analysis. Figure 4 shows the running time of each tool on every instance of the GF-pattern dataset. Across these instances, we can observe that all variants of Nike solve instances very quickly, thanks to the pre-processing techniques. This is done with much less time comparing to backward approaches, represented by Lisa and Lydia, simply because these tool do not have such optimizations. Cynthia solved in less time in logarithmic scale, but I attribute this to the set up time of the CUDD BDD manager that worsen the performances. Nevertheless, this amount to a negligible time cost difference of $\ll 1$ second. Similar results are for the *U*-pattern dataset, shown in the supplementary material. On the Two-player-Games benchmarks, see Figure 5, we observe that Nike variants dominate all other tools on the Double-Counter instances, while competing with backward approaches on the other instances. On Nim, Cynthia is the best performing tool, but on the other benchmarks Nike shows to be better. The Nike-BDD combinations performs slightly worse on Double Counter than the Nike-Hash combinations. On the *Random* benchmarks, all variants of Nike, but the ones using Rand branching strategy, are competitive with state-of-the-art backward approaches, and far better than Cynthia.

It is clear from the plots that Nike, in general, shows an overall better performance than Cynthia, illustrating the efficiency and better scalability of my approach. In particular, there is a notable outperformance of Cynthia on the Double-Counter and in the Random instances. I attribute this to the ability of Nike to not being stuck with compilation processes that can easily become intractable, both on handdesigned datasets like *Double-Counter*, and in randomly generated intractable cases. Moreover, despite the simplicity of the DPLL-based expansion, performances are very surprising with respect to backward approaches; this suggests that my approach is very promising and worth of future research. The worse performance of the Rand branching strategy on the Random benchmark can be explained by the fact that the TF and the FF strategies might exploit a particular problem structure of these instances, that allow to easily arrive to success nodes or failure nodes, and saves the algorithm to explore more moves thanks to the short-circuit evaluation of the search outcome (see Lines 24 and 25 in the modified Algorithm 1). The best configuration is Nike-BDD-FF, which suggests that for this benchmark the state compilation is not too hard and the canonicity of the representation helps to prevent the revisit of propositionally-equivalent states.

7 Conclusions

I proposed the best forward search LTL_f synthesis approach so far, and the first that is truly competitive with the considered state-of-the-art tools based on backward computation (as in the *Random* benchmark). I think this work sets the foundations for a new family of forward LTL_f synthesis algorithms, and opens several research avenues for investigating effective branching heuristics [Silva, 1999] for the DPLL-based search graph expansion (e.g. non-chronological backtracking), or better termination strategies for searching with hash-consing-based state-equivalence checking.

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A Preliminaries

LTL_f Basics. Linear Temporal Logic over finite traces, called LTL_f [De Giacomo and Vardi, 2013] is a variant of Linear Temporal Logic (LTL) [Baier and Katoen, 2008] that is interpreted over finite traces rather than infinite traces (as in LTL). Given a set of propositions \mathcal{P} , the syntax of LTL_f is identical to LTL, and defined as (wlog, we require LTL_f formulas are in Negation Normal Form (NNF), i.e., negations only occur in front of atomic propositions): $\varphi := tt \mid ff \mid p \mid \neg p \mid$ $\varphi_1 \wedge \varphi_2 \mid \varphi_1 \vee \varphi_2 \mid \Diamond \varphi \mid \bullet \varphi \mid \varphi_1 \mathcal{U} \varphi_2 \mid \varphi_1 \mathcal{R} \varphi_2. \ tt \ is$ always true, ff is always false; $p \in \mathcal{P}$ is an atom, and $\neg p$ is a negated atom (a literal l is an atom or the negation of an atom); \land (And) and \lor (Or) are the Boolean connectives; and ○ (Next), ● (Weak Next), U (Until) and R (Release) are temporal connectives. We use the usual abbreviations $true \equiv$ $p \vee \neg p$, $false \equiv p \wedge \neg p$, $\Diamond \varphi \equiv true \ \mathcal{U} \ \varphi$ and $\Box \varphi \equiv false \ \mathcal{R} \ \varphi$. Also for convenience we consider traces $\rho \in (2^{\mathcal{P}})^*$, i.e., we consider also empty traces ϵ as in [Brafman et al., 2018]. More specifically, a trace $\rho = \rho[0], \rho[1], \ldots \in (2^{\mathcal{P}})^*$ is a finite sequence, where $\rho[i]$ $(0 \le i < |\rho|)$ denotes the *i*-th interpretation of ρ , which can be considered as the set of propositions that are true at instant i, and $|\rho|$ represents the length of ρ . We have that $\epsilon \models \varphi$ if φ is tt, an \mathcal{R} -formula or \bullet formula, hence $\epsilon \models \Box false$. $\epsilon \not\models \varphi$ if φ is ff, a literal, \mathcal{U} -formula or \circ -formula, hence $\epsilon \not\models \Diamond true$. We consider the semantics of LTL $_f$ as presented in [Brafman et al., 2018].

We denote by $\operatorname{cl}(\varphi)$ the set of subformulas of φ , including tt and ff. We denote by $\operatorname{pa}(\varphi)\subseteq\operatorname{cl}(\varphi)$ the set of literals and temporal subformulas of φ whose primary connective is temporal [Li et al., 2019]. Formally, for an LTL_f formula φ in NNF, we have $\operatorname{pa}(\varphi)=\{\varphi\}$ if φ is a literal or temporal formula; and $\operatorname{pa}(\varphi)=\operatorname{pa}(\varphi_1)\cup\operatorname{pa}(\varphi_2)$ if $\varphi=(\varphi_1\wedge\varphi_2)$ or $\varphi=(\varphi_1\vee\varphi_2)$. Having LTL_f formula φ , replacing every temporal formula $\psi\in\operatorname{pa}(\varphi)$ with a propositional variable a_ψ gives us a propositional formula φ^p ; we call this operation $\operatorname{propositionalization}$ of φ . Note that $\varphi^p\in\mathcal{B}^+(\operatorname{cl}(\varphi))$, i.e. φ^p is a positive Boolean formula over variables $\operatorname{cl}(\varphi)$. Let $\varphi=\varphi^p$, we denote with $\varphi^{\operatorname{tf}}=\varphi$ the inverse operation of φ^p . Two formulas φ_1 and φ_2 are propositionally equivalent, denoted by $\varphi_1\sim_p \varphi_2$, if, $C\models\varphi_1^p\leftrightarrow C\models\varphi_2^p$ holds for every propositional assignment $C\in 2^{\operatorname{pa}(\varphi_1)\cup\operatorname{pa}(\varphi_2)}$.

An LTL_f formula φ is in neXt Normal Form (XNF) if pa(φ) only includes literals, \bigcirc - and \bullet -formulas. For an LTL_f formula φ in NNF, we can obtain its XNF by transformation function xnf(φ), defined as follows:

```
-\operatorname{xnf}(\varphi) = \varphi \text{ if } \varphi \text{ is a literal, } \Box false, \Diamond true, \bigcirc -, \bullet \text{-formula;}
```

Note that $\lozenge true$ (resp. $\square false$) guarantees that empty trace is not (resp. is) accepted by \mathcal{U} -formulas (resp. \mathcal{R} -formulas).

Theorem 4 ([Li et al., 2019]). Every LTL_f formula φ in NNF can be converted, with linear time in the formula size, to an equivalent formula in XNF, denoted by $xnf(\varphi)$.

LTL_f Formula Progression [De Giacomo et al., 2022]. Consider an LTL_f formula φ over \mathcal{P} and a finite trace $\rho = \rho[0], \rho[1], \ldots \in (2^{\mathcal{P}})^*$, in order to have $\rho \models \varphi$, we can

start from φ , progress or push φ through ρ . The idea behind *formula progression* is to consider LTL_f formula φ into a requirement about $now \ \rho[i]$, which can be checked straightaway, and a requirement about the future that has to hold on the yet unavailable suffix. That is to say, formula progression looks at $\rho[i]$ and φ , and progresses a new formula $fp(\varphi, \rho[i])$ such that $\rho, i \models \varphi$ iff $\rho, i + 1 \models fp(\varphi, \rho[i])$. This procedure is analogous to DFA reading trace ρ , where reaching accepting states is essentially achieved by taking one transition after another. Formula progression has been studied in prior work, cf. [Emerson, 1990; Bacchus and Kabanza, 1998]. Here we use the formalization provided in [De Giacomo $et \ al.$, 2022].

Note that, since ρ is a finite trace, it is necessary to clarify when the trace ends. To do so, two new formulas are introduced: $\Box false$ and $\Diamond true$, which, intuitively, refer to *finite trace ends* and *finite trace not ends*, respectively. For simplicity, we enrich $\operatorname{cl}(\varphi)$, the set of proper subformulas of φ , to include them such that $\operatorname{cl}(\varphi)$ is reloaded as $\operatorname{cl}(\varphi) \cup \operatorname{cl}(\Diamond true) \cup \operatorname{cl}(\Box false)$.

For an LTL_f formula φ in NNF, the *progression function* fp(φ , σ), where $\sigma \in 2^{\mathcal{P}}$, is defined as follows:

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- fp(tt, \sigma) = tt and fp(ff, \sigma) = ff;
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- $\operatorname{fp}(p,\sigma)=tt$ if $p\in\sigma,$ otherwise $f\!f;$
- $fp(\neg p, \sigma) = tt \text{ if } p \notin \sigma, \text{ otherwise } ff;$
- $fp(\varphi_1 \wedge \varphi_2, \sigma) = fp(\varphi_1, \sigma) \wedge fp(\varphi_2, \sigma);$
- $-\operatorname{fp}(\varphi_1 \vee \varphi_2, \sigma) = \operatorname{fp}(\varphi_1, \sigma) \vee \operatorname{fp}(\varphi_2, \sigma);$
- $fp(\bigcirc \varphi, \sigma) = \varphi \land \Diamond true;$
- $fp(\bullet\varphi,\sigma) = \varphi \vee \Box false;$
- $-\operatorname{fp}(\varphi_1\mathcal{U}\varphi_2,\sigma)\!=\!\operatorname{fp}(\varphi_2,\sigma)\vee(\operatorname{fp}(\varphi_1,\sigma)\wedge\operatorname{fp}(\bigcirc(\varphi_1\mathcal{U}\varphi_2),\sigma));$

- $\operatorname{fp}(\varphi_1\mathcal{R}\varphi_2,\sigma) = \operatorname{fp}(\varphi_2,\sigma) \wedge (\operatorname{fp}(\varphi_1,\sigma) \vee \operatorname{fp}(\bullet(\varphi_1\mathcal{R}\varphi_2),\sigma))$. Note that $\operatorname{fp}(\varphi,\sigma)$ is a positive Boolean formula on $\operatorname{cl}(\varphi)$, i.e., $\operatorname{fp}(\varphi,\sigma) \in \mathcal{B}^+(\operatorname{cl}(\varphi))$. The following two propositions show that $\operatorname{fp}(\varphi,\sigma)$ strictly follows LTL_f semantics and retains the propositional behavior of LTL_f formulas.

Proposition 5. Let φ be an LTL_f formula over \mathcal{P} in NNF, ρ be a finite nonempty trace, $\mathsf{fp}(\varphi, \sigma)$ be as above. We have that $\rho, i \models \varphi$ iff $\rho, i + 1 \models \mathsf{fp}(\varphi, \rho[i])$.

Proposition 6. Let φ and ψ be two LTL_f formulas over \mathcal{P} in NNF s.t. $\varphi \sim_p \psi$, and $\sigma \in 2^{\mathcal{P}}$. Then $\mathsf{fp}(\varphi, \sigma) \sim_p \mathsf{fp}(\psi, \sigma)$ holds.

We generalize LTL_f formula progression from single instants to finite traces by defining $fp(\varphi, \epsilon) = \varphi$, and $fp(\varphi, \sigma u) = fp(fp(\varphi, \sigma), u)$, where $\sigma \in 2^{\mathcal{P}}$ and $u \in (2^{\mathcal{P}})^*$.

Proposition 7. Let φ be an LTL_f formula over \mathcal{P} in NNF, ρ be a finite trace. We have that $\rho \models \varphi$ iff $\epsilon \models \mathsf{fp}(\varphi, \rho)$.

We take the definition of the *remove-next* function RMNEXT from [De Giacomo *et al.*, 2022], defined over propositionalized LTL_f formulas in XNF, φ^p :

- RMNEXT($\Diamond true$) = tt, RMNEXT($\Box false$) = ff
- RMNEXT $(\varphi_1 \land \varphi_2)$ = RMNEXT $(\varphi_1) \land$ RMNEXT (φ_2)
- RMNEXT $(\varphi_1 \lor \varphi_2)$ = RMNEXT $(\varphi_1) \lor$ RMNEXT (φ_2) - RMNEXT $(\Diamond \varphi) = \varphi \land \Diamond true$, RMNEXT $(\bullet \varphi) = \varphi \lor \Box false$
- Note that RMNEXT applies to neither \mathcal{U} -, \mathcal{R} formulas, since they do not appear in XNF, nor literals $(p, \neg p)$, as the input of the function is a propositionalized LTL_f formula in XNF form. We have the following proposition:

 $^{-\}operatorname{xnf}(\varphi_1 \wedge \varphi_2) = \operatorname{xnf}(\varphi_1) \wedge \operatorname{xnf}(\varphi_2);$

 $^{-\}operatorname{xnf}(\varphi_1\vee\varphi_2)=\operatorname{xnf}(\varphi_1)\vee\operatorname{xnf}(\varphi_2);$

 $^{-\}operatorname{xnf}(\varphi_1 \mathcal{U}\varphi_2) = (\operatorname{xnf}(\varphi_2) \wedge \Diamond \operatorname{true}) \vee (\operatorname{xnf}(\varphi_1) \wedge \operatorname{O}(\varphi_1 \mathcal{U}\varphi_2));$ - $\operatorname{xnf}(\varphi_1 \mathcal{R}\varphi_2) = (\operatorname{xnf}(\varphi_2) \vee \Box \operatorname{false}) \wedge (\operatorname{xnf}(\varphi_1) \vee \bullet (\varphi_1 \mathcal{R}\varphi_2)).$

Proposition 8. Given an LTL_f formula φ in NNF, $\forall \sigma \in 2^{\mathcal{P}}$, $\mathsf{fp}(\varphi, \sigma) \equiv \mathsf{RMNEXT}(\mathsf{xnf}(\varphi)^p|_{\sigma})$, where $\mathsf{xnf}(\varphi)^p|_{\sigma}$ stands for evaluating σ on $\mathsf{xnf}(\varphi)^p$.

AND-OR Graph Search. Being a popular topic in AI, AND-OR graph search has attracted extensive studies. Following [Nilsson, 1971; J. Nilsson, 1982], an AND/OR graph can be considered as a generalization of a directed graph, where there are a set of nodes \mathcal{V} and generalized connectors (edges) between nodes. Every connector links one single node $v \in \mathcal{V}$ to a set of nodes $V \subseteq \mathcal{V}$, where n is the number of nodes in the graph. A connector is called an AND (resp. OR) connector, if there is a logical AND (resp. OR) relationship among V. It should be noted that in this work I only focus on specific AND-OR graphs, where every node has only one connector leading to its successor nodes. Therefore, we have AND-nodes with an AND connector, and OR-nodes with an OR connector. Moreover, the set of goal nodes V_g only consists of OR-nodes.

The AND-OR graph search problem was first introduced in [Nilsson, 1971]. Intuitively speaking, the searching procedure aims to find a winning plan that encodes a path leading from the initial node to goal nodes. It is possible to involve both kinds of nodes in the winning plan, therefore, the plan lists one outgoing option at OR-nodes, and all outgoing options at AND-nodes leading to branches. Therefore, a winning plan is essentially a tree such that all leaves are goal nodes. There has been extensive studies on AND-OR graph search techniques [Mahanti and Bagchi, 1985; Chakrabarti, 1994; Jiménez and Torras, 2000], and have been utilized in a lot of applications, e.g., FOND planning [Mattmüller *et al.*, 2010; Mattmüller, 2013; Geffner and Bonet, 2013].

Knowledge Compilation: BDDs and SDDs. Knowledge Compilation [Darwiche and Marquis, 2002] is a family of approaches for dealing with the computational intractability of general propositional reasoning. A propositional theory is compiled off-line into a target language, which is then used on-line to answer a large number of queries in polytime. The key motivation behind knowledge compilation is to push as much of the computational overhead into the off-line phase, which is amortized over all on-line queries. There are a plethora of knowledge compilation techniques. Perhaps the first knowledge compilation technique are (Ordered) Binary Decision Diagrams (BDDs) [Bryant, 1992], where in order to represent a Boolean function, the classical method is applying Shannon decomposition. Intuitively, BDD decomposes Boolean functions with one variable at a time. Therefore, the canonicity of BDD is determined wrt a specific ordering of variables. Crucially, propositional equivalence between two propositional formulas can be done in constant time once both formulas are converted into BDDs. The more recent Sentential Decision Diagrams (SDDs) [Darwiche, 2011] utilize a more general decomposition technique that decomposes Boolean functions with a set of variables at each round. Let $f(\mathcal{Y} \cup \mathcal{X})$ be a Boolean function over variables $\mathcal{Y} \cup \mathcal{X}$, where \mathcal{Y}, \mathcal{X} are disjoint. Given an $(\mathcal{Y}, \mathcal{X})$ -partition, where \mathcal{Y} variables are considered primary and $\mathcal X$ variables are considered subsequent, the SDD of f, with respect to the $(\mathcal{Y}, \mathcal{X})$ - partition, can be written as $\bigvee_{i=1}^n[\operatorname{prime}_i(\mathcal{Y}) \wedge \operatorname{sub}_i(\mathcal{X})]$. Intuitively, SDD decomposes f into n children, each of which consists of Boolean functions $\operatorname{prime}_i(\mathcal{Y})$ (what are satisfied in $\operatorname{primary}$) and $\operatorname{sub}_i(\mathcal{X})$ (what should be satisfied in $\operatorname{subsequent}$, according to $\operatorname{prime}_i(\mathcal{Y})$). In particular, besides that all the primes are disjoint and covering, i.e., $\operatorname{prime}_i \wedge \operatorname{prime}_j = \operatorname{false}$ for $i \neq j$, and $\bigvee_{i=1}^n \operatorname{prime}_i = \operatorname{true}$, SDD also guarantees that all the subs are compressed, i.e., $\operatorname{sub}_i(\mathcal{X}) \neq \operatorname{sub}_j(\mathcal{X})$ for $i \neq j$. Hence, the canonicity of SDDs is determined wrt a specific partition of variables.

LTL_f **Synthesis** The problem of LTL_f synthesis is described as a tuple $(\varphi, \mathcal{X}, \mathcal{Y})$, where φ is an LTL_f formula over $\mathcal{X} \cup \mathcal{Y}$, and \mathcal{X}, \mathcal{Y} are two disjoint sets of variables controlled by the *environment* and the *agent*, respectively.

Definition 2. The synthesis problem $(\varphi, \mathcal{X}, \mathcal{Y})$ aims to computing a strategy $g: (2^{\mathcal{X}})^* \to 2^{\mathcal{Y}}$, such that for an arbitrary infinite sequence $\lambda = X_0, X_1, \ldots \in (2^{\mathcal{X}})^{\omega}$, we can find $k \geq 0$ such that $\rho^k \models \varphi$, where $\rho^k = (X_0 \cup g(\epsilon)), (X_1 \cup g(X_0)), \ldots, (X_k \cup g(X_0, X_1, \ldots, X_{k-1}))$. If such a strategy does not exist, then φ is unrealizable.

LTL_f synthesis can be solved by reducing to an adversarial reachability game on the corresponding Deterministic Finite Automaton (DFA) [De Giacomo and Vardi, 2015]. Hence, a strategy can also be represented as a finite-state controller $g: \mathcal{S} \mapsto 2^{\mathcal{Y}}$, where \mathcal{S} denotes the state space of the DFA.

B Proofs

B.1 Algorithm 1 + BDDBASEDEQCHECK + DPLLGETARCS

I now formally argue about the correctness of Algorithm 1 when combined with BDDBASEDEQCHECK (Algorithm 2) and DPLLGETARCS (Algorithm 3).

Lemma 1. Let $(\varphi, \mathcal{X}, \mathcal{Y})$ be a LTL_f synthesis problem instance. The BDDBASEDEQCHECK procedure for such instance induces a search space for Algorithm 1 with no more than $2^{2^{|\mathcal{O}(\mathrm{cl}(\varphi))|}}$ search nodes.

Proof. Any LTL $_f$ formula ψ associated to some search node n of Algorithm 1 is such that $\mathsf{xnf}(\psi)^p \in \mathcal{B}^+(\mathcal{Y} \cup \mathcal{X} \cup \mathcal{Z})$. Since there are at most $2^{|\mathcal{Y} \cup \mathcal{X} \cup \mathcal{Z}|}$ models, thanks to the canonicity property of BDDs, there can be at most $2^{2^{|\mathcal{Y} \cup \mathcal{X} \cup \mathcal{Z}|}}$ propositionally equivalent formulas. Since $\mathcal{Y} \cup \mathcal{X} \cup \mathcal{Z} = \mathcal{O}(\mathsf{cl}(\varphi))$, we get the claim.

Lemma 2. Let $(\varphi, \mathcal{X}, \mathcal{Y})$ be a LTL_f synthesis problem instance. The DPLLGETARCS procedure correctly expands the search graph for Algorithm 1.

Proof Sketch. Correctness holds by observing that, by construction, Ψ at Line 27 is equal to $\mathsf{xnf}(\psi)^p|_\sigma$; putting it together with Proposition 8 and Theorem 5 of [De Giacomo *et al.*, 2022], we get the thesis.

Theorem 5. Modified Algorithm 1 with BDDBASEDE-QCHECK for state-equivalence checking and Algorithm 2 for search node expansion is correct and always terminates.

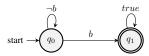


Figure 2: Minimal DFA of $\varphi = \Box a \mathcal{U} \Diamond b$

Proof. Termination follows from Lemma 1 and Theorem 4 of [De Giacomo *et al.*, 2022]. Correctness follows from Lemma 1, Lemma 2, and Theorem 5 of [De Giacomo *et al.*, 2022]. □

B.2 Algorithm 1 + HASHCONSINGEQCHECK + DPLLGETARCS

Theorem 4. Modified Algorithm 1 with Equation 1 for EQUIVALENCECHECK and Algorithm 2 for GETARCS is sound but not complete for LTL_f synthesis.

Proof. Soundness follows from correctness of DPLL-GETARCS, from the soundness of hash-consing based equivalence check, and the correctness of Algorithm 1 (Theorem 5 of [De Giacomo *et al.*, 2022]).

To disprove completeness, I show there exist a synthesis problem $(\varphi, \mathcal{X}, \mathcal{Y})$ such that the algorithm does not terminate. Let $\varphi = \Box a \mathcal{U} \lozenge b$, with $\mathcal{Y} = \{a\}$ and $\mathcal{X} = \{b\}$. The equivalent automaton of φ is shown in Figure 2. Consider any assignment with b set to false, e.g. $\sigma = \{a\}$. The repeated exploration of the agent-env move pair equivalent to σ makes the formula progression to produce ever bigger state formulas, hence making the hash-consing-based equivalence check to return false, although the associated state of the minimal DFA is always the same (q_0) , see again Figure 2.

In particular, we prove by induction the following statement. Let $\varphi_0 = \varphi$ and $\varphi_n = \operatorname{fp}(\varphi_{n-1}, \sigma)$. For all $n \geq 1$, we have:

$$\begin{split} \mathsf{xnf}(\varphi_n) = & (((b \land \lozenge true) \lor \circ \lozenge b) \land \lozenge true) \\ & \lor (\\ & \mathsf{xnf}(\varphi_{n-1}) \\ & \land (((a \lor \Box false) \land \bullet \Box a) \lor \Box false) \\ & \land \lozenge true \\) \end{split}$$

Base step n=1: the initial state formula in XNF form $\mathsf{xnf}(\varphi)$ is the following:

$$\begin{split} \mathsf{xnf}(\varphi) = & (((b \land \lozenge true) \lor \circ \lozenge b) \land \lozenge true) \\ \lor \\ & (((a \lor \Box false) \land \bullet \Box a \land \circ (\Box a \, \mathcal{U} \, \lozenge b))) \end{split}$$

After applying the transformation to move to the next state, $RMNEXT(xnf(\varphi)^p|_{\sigma})$, or, equivalently, $fp(\varphi, \sigma)$, we get a

new LTL_f formula, φ_1 , that in XNF form becomes xnf(φ_1):

$$\mathsf{xnf}(\varphi_1) = (((b \land \lozenge true) \lor \Diamond \lozenge b) \land \lozenge true)$$

$$\lor ($$

$$\mathsf{xnf}(\varphi_0)$$

$$\land (((a \lor \Box false) \land \bullet \Box a) \lor \Box false)$$

$$\land \lozenge true$$

Note that the original formula $xnf(\varphi)$ appears in the formula $xnf(\varphi_0)$. Therefore, the claim holds.

Inductive step. Let the claim hold for all $i \le n$, we need to prove that the claim holds for n+1. By inductive hypothesis, we have that

$$\mathsf{xnf}(\varphi_n) = (((b \land \lozenge true) \lor \circ \lozenge b) \land \lozenge true)$$

$$\lor ($$

$$\mathsf{xnf}(\varphi_{n-1})$$

$$\land (((a \lor \Box false) \land \bullet \Box a) \lor \Box false)$$

$$\land \lozenge true$$
)

Once applying again the same transformation but for formula φ_{n+1} , i.e. $\operatorname{fp}(\operatorname{xnf}(\varphi_n), \sigma)$, and then applying the XNF, it can be shown that we obtain the formula $\operatorname{xnf}(\varphi_{n+1})$:

$$\begin{split} \mathsf{xnf}(\varphi_{n+1}) = & (((b \land \lozenge true) \lor \circ \lozenge b) \land \lozenge true) \\ & \lor (\\ & \mathsf{xnf}(\varphi_n) \\ & \land (((a \lor \Box false) \land \bullet \Box a) \lor \Box false) \\ & \land \lozenge true \end{split}$$

note that we have a pattern: the new formula contains as a subformula the formulas computed at the previous steps.

Moreover, it can be shown that the formulas are semantically equivalent, i.e. $\varphi_n \equiv \varphi_{n-1}$ for all $n \geq 1$ (e.g. using any LTL_f-to-DFA tool, like Lydia), and therefore, the search will loop in the same semantically equivalent state, but on structurally different state formulas, hence without progresses of the search. See the script in benchmark/proof-theorem-3.py in the supplementary material.

C Empirical Evaluations

Benchmarks

I collected, in total, 1494 LTL $_f$ synthesis instances from literature, consisting of 3 benchmark families: 40 patterned

instances from the *Patterns* benchmark family [Xiao *et al.*, 2021], split into the GF-pattern and U-pattern datasets; 54 instances from the *Two-player-Games* benchmark family [Tabajara and Vardi, 2019; Bansal *et al.*, 2020b], split into Single-Counter, Double-Counters and Nim datasets. Since the formulation there assumes that the environment acts first, the LTL $_f$ instances had to be modified slightly to adapt to our setting, where the agent acts first; 1400 randomly conjuncted instances taken from [Zhu *et al.*, 2017a; De Giacomo and Favorito, 2021].

Patterns. There are 20 unrealizable GF-pattern instances, and 20 realizable U-pattern instances, constructed in the following ways, respectively.

$$GF(n) = G(p_1) \wedge F(q_2) \wedge F(q_3) \wedge \ldots \wedge F(q_n)$$

$$U(n) = p_1 U(p_2 U(\ldots p_{n-1} U p_n))$$

More specifically, G stands for \square (Always), F stands for \lozenge (Eventually), and U stands for $\mathcal U$ (Until). The variables in the formulas are roughly equally partitioned into $\mathcal X$ and $\mathcal Y$ at random. In particular, for GF-pattern instances, the first variable p_1 is always assigned as environment variable such that all generated instances are guaranteed to be unrealizable. Moreover, for U-pattern instances, the last variable p_n ($n \geq 2$) is always assigned as agent variable such that all generated instances are guaranteed to be realizable.

Two-player-Games. Single-Counter is a simple example where the behavior of the agent is completely determined by the actions of the environment. Therefore, the challenge in this family lies mostly in proving that the specification is realizable. The agent stores an n-bit counter (where n is the scaling parameter) which it must increment upon a signal by the environment. The agent wins if the counter eventually overflows to 0. To guarantee that the game is winning for the agent, the specification assumes that the environment will send the increment signal at least once every two timesteps.

Double-Counter is similar to the Single-Counter one, except that in this case there are two n-bit counters, one incremented by the environment and another by the agent. The goal of the agent is for its counter to eventually catch up with the environment's counter. To guarantee that this is achievable, the specification assumes that the environment cannot increment its counter twice in a row.

Nim describes a generalized version of the game of Nim [Bouton, 1901] with n heaps of m tokens each. The environment and the agent take turns removing any number of tokens from one of the heaps, and the player who removes the last token loses.

Random. This benchmark family has 1400 instances, from which there are 1000 instances from [Zhu et~al., 2017a], and 400 instances from [De Giacomo and Favorito, 2021]. The instances in this benchmark family are constructed from basic cases taken from LTL synthesis datasets Lily [Jobstmann and Bloem, 2006] and Load balancer [Ehlers, 2010]. Formally, a random conjunction formula RC(L) has the form: $RC(L) = \bigwedge_{1 \leq i \leq L} P_i(v_1, v_2, ..., v_k)$, where L is the number of conjuncts, or the length of the formula, and P_i is a randomly selected basic case. Variables v_1, v_2, \ldots, v_k are chosen randomly from a set of m candidate variables. Given L

and m (the size of the candidate variable set), we generate a formula RC(L) in the following way:

- 1. Randomly select L basic cases;
- 2. For each case φ , substitute every variable v with a random new variable v' chosen from m atomic propositions. If v is an environment-variable in φ , then v' is also an environment-variable in RC(L). The same applies to the agent-variables.

D Plots

Here I provide the full set of experimental results.

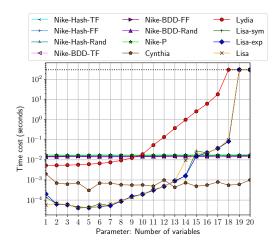


Figure 3: *U*-pattern.

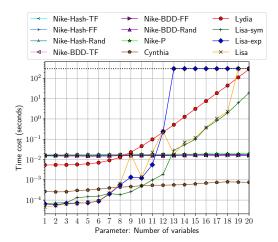


Figure 4: *GF*-pattern.

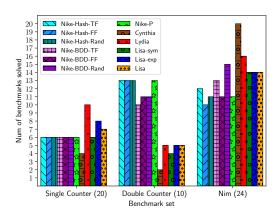


Figure 5: Two-player-Games.

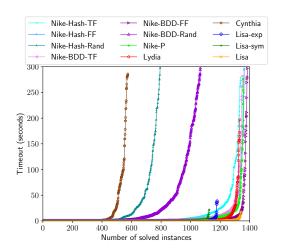


Figure 6: Random.

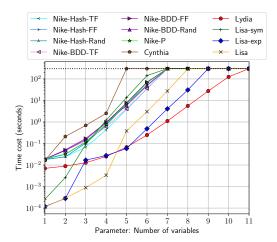


Figure 7: Single Counter.

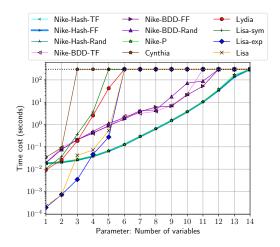


Figure 8: Double Counter.

E Results

In this section, we show all the running times for each formula of each dataset.

Table 1: Results on *Double Counter*, time in milliseconds.

name	Nike Hash True First	Nike Hash False First	Nike Hash Random	Nike Bdd True First	Nike Bdd False First	Nike Bdd Random	Nike Multithreaded	Cynthia	Lydia	Lisa Symbolic	Lisa Explicit	Lisa
counters_01	18.596958	18.268062	18.403466	19.253715	19.107806	19.412668	19.18572	34.500707	9.291831	10.6135	0.190149	0.225103
counters_02	20.013578	20.253191	19.492336	94.904176	76.403862	76.833945	21.537058	90.045937	26.0702	36.6841	0.720083	0.717793
counters_03	26.794465	25.526104	25.295872	209.794823	208.677393	207.428727	26.971165	_	184.525338	365.612	3.43736	41.6974
counters_04	38.482922	37.337264	37.016285	395.887396	423.36698	486.792135	39.26482	_	2540.111074	3641.88	45.9793	72.3087
counters_05	64.703472	65.006299	64.764067	836.840309	881.468907	1140.178069	66.213866	_	42335.932599	_	274.254	535.203
counters_06	124.922986	126.558988	127.267784	2382.959143	1774.30815	1982.499516	126.82075	_	_	_	_	
counters_07	286.805523	286.526689	289.076264	3131.282049	3796.194518	4199.210945	296.109436	_			_	
counters_08	635.702561	641.023385	640.855101	3890.729399	6052.720747	4515.436942	658.951354	_	_	_	_	
counters_09	1493.792054	1499.60723	1488.196646	7136.020836	6689.333873	17742.916155	1542.665715	_		_	_	
counters_10	3701.410377	3718.6171	3718.25314	23013.174684	21104.923093	71939.556943	3809.848841				_	
counters_11	10280.095406	10302.711746	10233.461024	_	52653.794598	88255.826057	10521.924337	_	_	_	_	
counters_12	33571.724906	34019.643973	33479.800756	_	_	_	38028.041671	_		_	_	
counters_13	137444.743261	137462.759548	137221.411248	_	_	_	168220.51415	_	_	_	_	
counters_14	_	_	_	_	_	_	_	_	_	_	_	

Table 2: Results on *Gfand*, time in milliseconds.

name	Nike Hash True First	Nike Hash False First	Nike Hash Random	Nike Bdd True First	Nike Bdd False First	Nike Bdd Random	Nike Multithreaded	Cynthia	Lydia	Lisa Symbolic	Lisa Explicit	Lisa
gfand01	14.664404	15.476503	16.250197	15.496387	15.251414	16.007296	17.336509	0.266138	5.364753	0.066774	0.065305	0.045994
gfand02	15.081269	15.645543	15.272277	15.701056	15.220697	16.059728	17.27196	0.253074	5.435404	0.071976	0.057631	0.053326
gfand03	15.476061	15.80807	15.131336	16.069496	14.850944	15.798273	17.655924	0.258545	5.442908	0.074251	0.069557	0.064516
gfand04	15.985911	15.636417	16.25583	16.285712	15.024169	15.766807	17.971768	0.297777	5.679279	0.132932	0.071209	0.066989
gfand05	16.089714	15.721872	16.024327	15.85085	14.484887	15.269209	18.114179	0.313383	6.147079	0.146031	0.074355	0.076898
gfand06	15.740626	16.710326	15.815687	15.737012	14.742387	15.401362	17.966487	0.34558	6.979331	0.157342	0.088702	0.091956
gfand07	15.730463	16.658157	15.415758	15.91973	14.870688	15.4181	18.026563	0.395522	9.083914	0.212142	0.199394	0.2188
gfand08	16.389749	16.398688	15.871325	17.086864	15.363899	15.821777	18.168269	0.435402	12.807384	0.183314	0.558514	0.641949
gfand09	16.040045	16.271029	16.079457	17.072917	16.543945	15.585794	18.624364	0.460944	23.038721	0.257216	1.34533	17.8815
gfand10	15.999361	15.719367	15.88747	16.66938	16.642694	15.92157	18.241217	0.51344	45.503634	0.48844	1.22901	1.33807
gfand11	16.556774	15.795863	16.99089	16.948603	15.476833	15.640557	18.007788	0.540068	98.035326	0.976966	5.52441	22.4268
gfand12	16.112348	15.954323	16.938068	17.02628	16.220457	15.255452	18.40826	0.542533	221.638825	1.87119	235.082	247.046
gfand13	16.312971	16.503906	16.578508	15.655115	15.743175	16.046211	18.336155	0.558839	516.309332	28.8656	_	17.8299
gfand14	16.554934	16.482217	16.076889	15.698039	16.815838	16.176841	18.573829	0.574802	1273.111451	52.5136	_	70.9903
gfand15	17.415826	16.363838	16.67325	15.840495	16.912334	16.859937	18.297912	0.625352	3132.349671	98.9009	_	119.025
gfand16	17.963636	16.808938	17.181037	15.809993	16.506084	17.695604	19.236552	0.692731	7597.368526	361.028	_	376.954
gfand17	17.364304	17.217969	16.823467	16.197285	15.790041	17.33682	19.108987	0.740725	18622.289185	811.707	_	1046.99
gfand18	17.597947	18.341532	17.178884	16.768091	16.089661	17.332376	19.336902	0.796435	44042.081704	1966.76	_	2329.31
gfand19	17.501234	18.12741	16.667382	16.797178	15.800645	17.688795	19.150142	0.770764	112126.560954	6231.58	_	
gfand20	17.96385	16.980853	16.880816	17.293062	15.652091	16.575834	19.382017	0.754719	280759.10069	19257.5		

Table 3: Results on Nim 01, time in milliseconds.

name	Nike Hash True First	Nike Hash False First	Nike Hash Random	Nike Bdd True First	Nike Bdd False First	Nike Bdd Random	Nike Multithreaded	Cynthia	Lydia	Lisa Symbolic	Lisa Explicit	Lisa
nim_01_01	21.652504	21.852993	22.425201	22.51097	22.575411	22.619657	22.869925	10.701386	9.243031	0.511151	0.054589	0.039505
nim_01_02	36.510922	32.635422	29.130419	51.644759	46.93518	42.953328	33.937856	34.209743	14.044925	0.783896	0.107531	0.108793
nim_01_03	124.350392	748.812837	71.802001	147.81038	500.318885	94.538401	124.496853	50.863318	28.067614	1.39775	0.165809	0.159741
nim_01_04	655.990604	5078.174691	346.277822	478.273479	3572.571717	175.8517	636.957444	51.149021	148.985605	1.90265	0.253887	0.216297
nim_01_05	3951.684383	31716.609289	2088.068016	1893.314961	23764.470102	322.293758	3939.678555	83.136903	648.186875	2.67965	0.354514	0.33663
nim_01_06	25804.192511	185198.807923	14973.912576	8558.792909	146791.191633	607.119617	27804.395652	117.085951	2835.283053	4.26119	0.491802	0.509569
nim_01_07	180527.335506		104195.615515	40304.12107	_	1784.890989	106272.648966	173.173464	12656.386116	6.0989	0.713635	0.713666
nim_01_08	_	_	_	191314.266217	_	5567.172292	-	223.023923	49118.665584	_	_	_
nim_01_09	_		_	_	_	21620.10071	_	382.891399	137688.406851	_	_	
nim_01_10			_	_	_	66215.040678		327.374822	_	_	_	_
nim_01_11	_	_	_	_	_	_	_	622.210931	_	_	_	_
nim_01_12			_	_	_	_		532.105444	_	_	_	_
nim_01_13	_	_	_	_	_	_	_	641.369547	_	_	_	_
nim_01_14			_	_	_	_		905.842151	_	_	_	_
nim_01_15	_	_	_	_	_	_	_	1110.560059	_	_	_	_
nim_01_16	-		_	_	_	_		1243.463515	_	_	_	_
nim_01_17		ı	_	ı	_	_		1610.98619	_	_	_	_
nim_01_18	-		_	_	_	_		1699.635879	_	_	_	_
nim_01_19		I	_	ı	_	_		2064.899084	_	_	_	
nim_01_20	-		_	_	_	_		2631.465242	_	_	_	_

Table 4: Results on Nim 02, time in milliseconds.

name				Nike Bdd True First		Nike Bdd Random		Cynthia	Lydia	Lisa Symbolic	Lisa Explicit	
nim_02_01	86.975632	112.611648	105.373406	98.569137	119.114981	119.995565	114.925515	115.180326	22.998994	7.71421	0.335915	0.32857
nim_02_02	14861.324807	16186.670998	14325.332997	7333.083561	8301.186367	7004.188455	16339.154739	730.429379	291.899614	42.5965	1.10907	1.10246
nim_02_03	258217.922498	_	_	107711.86067	200600.7252	168324.776357	_	1018.461399	4443.044252	178.374	2.8325	2.90445
nim_02_04	_	_	_	_	_	_	_	5464.305582	73887.195858	287.6	6.57803	7.06112
nim_02_05		_	_	_	_	_	_	22790.095015	_	_	_	
nim_02_06	_	_	_	_	_	_	_	37507.865014	_	_	_	-
nim_02_07	_	_	_	_	_	_	-	23257.818323	_	_	_	
nim_02_08	_	_	_	_	_	_	_	169177.832518	_	_	_	-
nim_02_09	_	_	_	_	_	_	_	95835.707556	_	_	_	
nim_02_10	_	_	_	_	_	_	_	_	_	_	_	-

Table 5: Results on Nim 03, time in milliseconds.

name	Nike Hash True First	Nike Hash False First	Nike Hash Random		Nike Bdd False First		Nike Multithreaded	Cynthia	Lydia	Lisa Symbolic	Lisa Explicit	Lisa
nim_03_01	14589.428787	15583.749344	17541.842061	7563.240427	7376.988988	8799.891142	15761.988348	650.571523	270.715502	473.228	0.26237	0.27006
nim_03_02	_		_		_	_	_	12655.221579	42245.551844	3102.4	24.4585	8.01435
nim_03_03	_		_	_		_	_	_	_	_	_]

Table 6: Results on Nim 04, time in milliseconds.

name	Nike Hash True First	Nike Hash False First	Nike Hash Random	Nike Bdd True First	Nike Bdd False First	Nike Bdd Random		Cynthia	Lydia	Lisa Symbolic	Lisa Explicit	
nim_04_01	200248.683865	229673.2003	251716.519243	80051.226611	99057.523944	83007.538629	261215.876355	8614.624562	19574.724446	6523.22	6.79701	22.7605
nim_04_02	_	_	_	_	_	_	_	_		_	_	
nim_04_03	_	_	-	_	_	_	_	_	_	_	_	
nim_04_04	_	_	_	_	_	_	_	_	_	_	_	
nim_04_05	_	_	_	_	_	_	_	_		_	_	
nim_04_06	_		_		_	_		_	_	_	_	_
nim_04_07	_		_	_	_	_	_	_	_	_	_	_
nim_04_08	_		_	_	_	_	_	_		_	_	
nim_04_09	_		_		_	_		_	_	_	_	_
nim_04_10	_	_	_	_	_	_	_	_		_	_	-

Table 7: Results on Nim 05, time in milliseconds.

name	Nike Hash True First	Nike Hash False First	Nike Hash Random	Nike Bdd True First	Nike Bdd False First	Nike Bdd Random	Nike Multithreaded	Cynthia	Lydia	Lisa Symbolic	Lisa Explicit	Lisa
nim_05_01	_	_	_	_	_	_	_	220651.046985	_	_	_	— I
nim_05_02	_	_	_	_	_	_	_	_	_	_	_	_
nim_05_03	_	_		_	_	_	_	_	_	_	_	_
nim_05_04	_	_	_	_	_	_	_	_	_	_	_	_
nim_05_05	_	_		_	_	_	_	_	_	_	_	_
nim_05_06	_	_	_	_	_	_	_	_	_	_	_	_
nim_05_07	_	_	_	_	_	_	_	_	_	_	_	- 1
nim_05_08	_	_	_	_	_	_	_	_	_	_	_	-
nim_05_09	_	_	_	_	_	_	_	_	_	_	_	— I

Table 8: Results on Random Lydia Case 03 50, time in milliseconds.

name	Nike Hash True First				Nike Bdd False First		Nike Multithreaded	Cynthia	Lydia	Lisa Symbolic		Lisa
1	16.713829	17.150155	20.492264	17.892924	18.443531	19.430784	25.886465	14.689382	12.776132	0.06382	0.144459	0.151035
2	264.680185	114.455337	3557.0157	313.911392	84.343603	1209.118128	120.310362	257052.503168	359.320861	1.93298	1014.14	4.331
3	234.630113	128.765479	22201.139848	298.172512	96.743202	6647.968904	135.570123		2123.071477	3.285	6682.4	9.94998
4	19.079327	19.830259	25.699179	18.866273	19.797592	25.574912	22.010723	13.133271	7.249208	0.040258	0.030786	0.031127
5	52.336247	19.384262	100.87368	49.863463	20.542235	84.771026	22.809315	689.867092	12.085266	0.140104	0.314111	0.275143
6	1577.386535	2093.895391	-	725.614422	200.807375	1511.57062	2132.3953	_	8.397469	0.057513	0.02679	0.022097
7	16.018741	16.307278	16.355825	15.962757	15.742274	16.11696	17.791634	0.334175	6.456763	0.061564	0.037286	0.034532
8	18.729788	17.292283	21.160177	17.42736	16.338228	21.614487	19.61433	18.958183	8.408105	0.042382	0.041671	0.037531
9	643.679594	33.954107	446.159708	440.506309	24.064403	331.912445	37.463396	1446.110168	9.473982	0.108847	0.299497	0.223697
10	271.966483	125.269605	6986.377843	291.202488	88.268931	1212.15484	132.242892	_	405.910661	1.5725	1043.94	4.32516
11	16.356166	16.172018	16.024578	16.135849	15.641622	15.973239	18.363988	0.350353	6.698781	0.062039	0.043551	0.042436
12	17.644318	17.387841	21.174377	18.001583	16.112062	22.807826	19.799071	14.507595	7.888645	0.049974	0.038047	0.035527
13	458.727969	650.151788	29907.015123	245.595608	124.387906	832.017953	664.569816	194854.172797	7.462804	0.059772	0.022898	0.020817
14	16.357051	15.783832	16.127345	16.127328	16.171758	16.165932	17.972411	0.361341	6.051805	0.063003	0.035106	0.033882
15	15.077766	14.872916	16.035513	14.784308	15.072014	15.929674	18.103903	0.337413	6.078458	0.060975	0.03632	0.036488
16	14.832038	14.856293	14.985044	15.224145	15.43672	16.071333	17.977368	0.315692	6.061586	0.062107	0.039855	0.036139
17	190.618258	121.755879	9383.936116	250.605727	92.910674	2885.723867	129.325476	159589.187539	614.59472	26.9009	5348.79	19.5155
18	55.334547	18.848157	165.1421	45.913533	19.035935	38.694017	21.108721	104.673617	9.352371	0.044335	0.07384	0.058788
19	54.427956	18.188667	153.036554	45.203281	18.522585	37.837535	20.588738	140.255972	9.413107	0.058049	0.065438	0.057449
20	16.356937	15.976384	17.81288	15.462054	16.709166	17.513119	19.132442	0.669631	50.897121	0.269313	6.2213	5.67827
21	17.074823	15.546332	17.026238	15.215205	17.120348	16.684478	19.173544	0.689072	43.202003	0.248035	5.72242	5.48191
22	724.066042	225.894922	9607.277385	390.582355	162.926601	4208.671728	231.761959	18162.542336	208.620993	1.36026	7.8407	1.16876
23	16.670814	16.568445	16.375378	15.778166	15.935098	16.151078	17.966399	0.342892	6.250231	0.060198	0.043821	0.036132
24	1130.928125	35.791545	865.166314	701.890274	25.626445	571.691509	37.252717	2191.079127	14.486889	0.139222	1.00649	0.870784
25	1444.467959	1923.396813	45439.840468	474.863318	189.548111	787.300671	1949.683635	_	8.203597	0.048801	0.022684	0.021775
26	2404.261809	53.057997	1608.240944	1430.363825	32.974939	950.69129	55.344948	1807.668227	18.198376	0.19075	1.49014	1.33095
27	16.597258	15.653909	16.14442	16.231644	15.828257	16.152835	17.970229	0.334474	6.294527	0.059986	0.03996	0.035734
28	55.680205	17.353568	158.505392	44.872868	18.154151	34.895507	20.847353	105.016481	10.106468	0.042887	0.065826	0.059607
29	17.522887	15.841538	17.748955	15.741463	16.108436	16.981958	19.196889	0.769509	15.969278	0.237764	0.642442	0.573971
30	17.117795	17.075452	18.065027	16.628681	17.304774	17.937307	20.331448	1.155465	9.208742	0.030732	0.02721	0.024142
31	1902.780586	62.317975	1220.678367	1043.548058	49.56786	694.689226	66.300423	1692.896715	15.93553	0.282741	1.97019	1.83755
32	1576.045705	2026.958503	_	724.499705	153.352981	1507.332282	2067.653725		7.977131	0.055556	0.02419	0.023034
33	17.305131	18.800291	21.397722	17.852816	18.078376	21.178684	20.37338	14.411195	10.028272	0.052239	0.060712	0.049502
34	19.28371	17.723689	21.082703	18.26937	16.543205	20.983076	19.283711	27.988163	8.191364	0.046862	0.04448	0.038248
35	17.493864	18.623928	17.144722	16.675358	16.537226	17.749155	20.034379	1.088371	9.066229	0.029958	0.030354	0.03343
36	51.766919	20.608086	99.927493	48.562024	20.013443	84.912427	22.961859	683.649909	11.487724	0.140631	0.346283	0.267817
37	245.469889	135.929817	36008.074847	302.795444	99.122248	6783.819619	142.800676	05224 225655	2041.623783	2.45021	5084.13	5.07294
38	627.606506	114.970183	5609.496118	546.581704	85.3683	1212.832145	120.850876	85324.327072	542.216844	1.83944	1028.28	2.72172
39	16.477352	16.537701	16.103698	15.758982	15.666638	15.347946	18.063974	0.358671	6.32582	0.062576	0.038331	0.040518
40	218.775557	128.720692	16199.217323	268.852499	93.874143	3984.103628	134.270809	218541.788047	844.145195	1.77382	1820.05	5.68449
41	168.578158	127.149589	4213.349162	200.99304	93.129704	1880.764779	133.278853	72265.733766	455.314357	0.67818	317.863	1.65207
42	16.34758	16.364573	16.095463	15.934677	15.327764	16.075688	18.314594	0.366722	6.362349	0.060675	0.039911	0.035567
43	16.009279	15.007877	15.280716	14.554233	14.67194	16.143937	18.59881	0.300164	6.587226	0.06028	0.037458	0.036005
44	16.666632	18.749467	19.583271	16.371975	17.640385	21.214213	20.303502	14.702622	9.606057	0.050511	0.057788	0.052592
45	17.809862	17.518336	19.831975	17.816912	16.62885	19.481835	19.55468	26.557034	8.779915	0.042701	0.046153	0.037496
	16.471657	16.187371	16.351982	15.508155	16.045107	16.353617	18.925974	0.591926	42.797751		7.71272	7.37132
47	1082.606504	63.88079	806.591752	644.893042	47.786146	514.973699	65.520798	1417.136701	16.362788	0.246407	1.61334	1.57232
48	17.886467	17.558697 15.247747	16.986374	16.678409	16.920717	17.003458	19.298747	0.647124	45.319374	0.214015	5.75524	5.58755
49 50	16.540877 15.734072		15.57153 16.035176	16.127498 16.039607	15.87803	16.005635 15.479667	17.941164	0.278557 0.428451	6.589328	0.061237	0.038313 0.02272	0.034757
30	15.754072	16.636959	10.033170	10.039007	16.350442	13.4/900/	18.612241	0.428431	6.234186	0.020722	0.02272	0.021039

Table 9: Results on Random Lydia Case 04 50, time in milliseconds.

name		Nike Hash False First		Nike Bdd True First			Nike Multithreaded	Cynthia	Lydia	Lisa Symbolic		Lisa
1	16.870001	17.153821	17.18682	16.384968	17.227759	16.543762	19.17354	6886.058277	11.739812	0.328307	0.520087	0.516529
2	15.399163	15.196455	15.486768	16.118445	15.354612	15.305571	18.010372	0.384879	6.501435	0.058177	0.034233	0.032827
3	247.406245	18.096118	1644.213418	178.924989	18.780541	138.306082	20.774158	2303.136716	23.831855	0.089467	0.356991	0.337432
4	1773.638344	691.986975	_	1593.325115	495.672686	_	711.480355	_	156043.561906	83.2831	_	1869.97
5	3697.624058	578.107085	89662.888683	1848.740326	462.946393	31916.684263	587.466884	_	1902.637411	6.17162	495.238	10.5653
6	19.20774	18.906754	19.334721	18.794765	19.034083	18.790621	20.62917	1.393927	10.059809	0.034501	0.027884	0.026008
7	1033.160623	705.34598	_	1102.201835	500.411941	_	720.373232	_	196991.230935	79.4626	_	1836.46
8	16.276201	16.557357	15.570412	16.050833	15.857689	16.445607	18.30212	0.427595	6.801465	0.062123	0.041645	0.043245
9	16.220484	15.344821	16.726388	15.388823	14.90343	15.133476	17.488743	0.307166	6.335313	0.065033	0.037991	0.036245
10	528.952816	542.025474	115056.660334	661.978156	403.736946	9262.388932	553.574231	_	12009.676309	24.8063	_	129.708
11	4113.077586	4912.778258	_	1255.594826	501.361131	8738.39105	4948.390074	_	8.427913	0.101292	0.070586	0.023958
12	18.060112	19.582205	19.232682	18.712173	19.218014	20.761301	20.54302	80.191847	22.788498	0.083626	0.230281	0.209495
13	63.204606	19.646581	184.887076	51.204644	17.818737	51.350984	20.992928	66.253604	9.812948	0.061691	0.072654	0.059898
14	18.59421	19.17194	18.983517	18.617359	17.241058	17.911433	20.089896	1.615347	10.072841	0.035515	0.033486	0.025501
15	16.431986	17.879536	17.782248	15.871638	16.036575	16.999188	18.919838	1.322599	57.378305	1.33781	44.52	41.7204
16	1162.705726	1194.294394	_	1329.430143	691.836271	94842.901311	1217.434627	_	21501.88651	25.8822	_	410.237
17	269.829022	155.577164	18432.587722	312.423837	123.297704	10050.661301	159.901717	_	1417.155195	0.76009	616.448	1.55039
18	20.951444	20.832115	21.102809	21.138189	21.160877	21.594988	22.86222	1778.805749	10.187241	0.244391	0.345002	0.311715
19	26718.268166	33774.276741	_	6277.411501	1100.814974	14089.571064	_	_	8.971867	0.091563	0.024193	0.021914
20	6645.128291	610.843628	_	5575.774526	439.373057	_	619.993118	_	128234.709265	77.2975	_	1843.85
21	813.005043	585.334113	175082.184445	780.785159	419.634689	10393.307308	592.314906	_	8923.181014	44.582	_	213.586
22	41499.589367	438.825398	26221.993615	15704.163416	367.840986	10694.960992	443.137796	_	61.736103	1.37953	46.7087	47.8082
23	20265.716712	2155.098302	_	8052.62209	1329.331051	149141.397963	2171.736018	_	2381.60708	7.0781	441.055	11.5326
24	1443.519399	635.212743	_	1398.462387	456.11369	79449.528756	642.633105	_	25241.345964	72.8237	_	301.372
25	17.510523	17.345556	17.68764	17.017076	17.424828	17.2006	18.479083	0.642831	6.814329	0.031561	0.025388	0.023043
26	26442.212578	33376.556292	_	9237.860156	859.084715	26441.503646	33894.608053	_	8.69352	0.149138	0.025823	0.024636
27	23.420571	17.763076	34.999837	23.525474	18.395255	36.92474	19.386776	285.641275	11.818623	0.103162	0.122483	0.10628
28	245.715633	19.360676	1632.002209	180.74237	19.675706	138.855659	21.026316	1803.642676	20.473892	0.085041	0.370282	0.282473
29	12853.634445	2369.522389	_	5158.494929	1426.899595	186948.62404	2375.277667	_	5814.895464	17.8198	1668.06	28.5502
30	17.394228	17.155361	17.567925	17.377432	16.444314	17.969385	18.47071	0.677391	6.538339	0.029614	0.028862	0.023412
31	16.428081	16.555444	16.75394	14.817397	14.928218	16.095582	18.073823	0.35766	5.94707	0.069534	0.040131	0.033822
32	1389.531201	2482.372896	_	1478.682314	1345.482246	_	2526.51656	_	157837.988954	85.7016	_	2768.92
33	18.930979	19.433514	20.556808	19.492616	20.067001	20.728699	20.768037	78.942834	26.084775	0.080169	0.273666	0.219388
34	17.806737	23.800582	29.118223	19.591375	24.045317	28.318308	25.41602	72.058796	13.683566	0.063089	0.104555	0.089007
35	43632.699118	288.109294	29699.15258	19383.436399	199.104787	14087.576926	291.612039	_	103.261976	1.48659	55.8196	53.549
36	16.27677	16.394562	16.304074	16.396582	16.538878	15.832221	18.144872	0.416398	6.518815	0.06577	0.040485	0.0322
37	16.924209	15.82008	17.503772	16.962768	17.113509	16.672981	18.824079	15378.321264	10.891294	0.321595	0.706819	0.510498
38	17.115121	16.137143	16.539814	15.700243	16.514551	15.579854	18.972824	1.206223	19.45839	0.516172	1.33028	1.24466
39	854.180186	581.279795	94855.865723	942.913678	440.54094	30655.329388	597.542584		7129.672146	3.40026	_	23.4741
40	1019.26628	1000.59163	_	1181.002998	730.500061	_	1025.689427	_	136656.758395	86.7387	_	1901.53
41	7411.949775	9596.189369	_	2851.782378	745.681609	14062.726104	9696.939732	_	8.965806	0.161929	0.068553	0.029518
42	62313.335697	219.527225	39866.466445	29989.033676	102.97094	19846.589668	222.06792		132.329979	1.12276	40.5966	32.9678
43	1102.776587	700.368441	_	1149.92034	494.607613		725.440218		49492.006869	25.9512		175.126
44	2735.065293	597.388931	_	2653.892219	441.051312	72447.476077	617.076613	_	22126.671165	412.83	_	420.189
45	16.337958	16.572393	15.799223	15.690027	16.085439	16.515104	18.014188	0.387981	6.91398	0.056931	0.087155	0.03429
46	245.819861	18.612222	1674.154767	177.601241	17.744922	153.350328	21.046032	2256.588951	20.86646	0.08617	0.394199	0.289619
47	2606.001119	563.022806	119788.015925	2555.982148	437.743402	18093.501345	582.170434	_	4168.452764	11.7834		102.313
48	18725.787665	111.899406	17564.597023	9594.940835	57.954708	9157.838574	114.906748	_	92.187092	0.614829	13.2141	13.0344
49	18.731715	19.799915	19.142488	19.450474	19.377172	19.130106	21.210979	1.688165	9.751101	0.041184	0.029841	0.027085
50	23.651542	18.321266	36.24551	24.950433	19.040056	38.544705	20.051343	84.997919	11.695353	0.069393	0.072315	0.069581

Table 10: Results on Random Lydia Case 05 50, time in milliseconds.

2 5590,032495 5562,886644	name		Nike Hash False First	Nike Hash Random			Nike Bdd Random		Cynthia	Lydia	Lisa Symbolic	Lisa Explicit	
3 19.681307 19.744672 19.84728 19.39955 18.779845 19.399557 21.201815 1.897343 11.232399 0.041901 0.0072184 0.4 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.007503 0.0	1	17186.954282	2956.285242	_	5894.234357	1710.078046	_	2955.30058	_	21309.590105	78.1458	_	61.445
1302.535106 20075488	2										40.5712		2756.39
5 \$5573.333707 3757.329705 — \$2386.356.226 2344.961407 — 3817.34839 — — 1439.49 — 1 — 2557.955604 — 65784762 2475.11 — 2 2575.95604 — 65784762 2475.11 — 2 2 2025.41 9.801664 0.008533 0.07166 — 2 2 0.00833 0.07166 — 2 2 0.00853 0.07166 — 2 0.07166 0.00833 0.07166 0.07167 0.07166 0.07166 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.07167 0.071677 0.07167 0.07167 0.	3			19.845728									0.028203
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To		5573.333707	3757.327975	_			_	3817.344839	_			_	3940.64
S													209.235
9 20.312661 22.927794 64.443445 21.950302 22.727967 67.347209 22.988407 61.845556 22.771483 0.114032 0.254064 0. 4309.954455 12.704127 0.395275 0.072556 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.072575 0.07257		16.814876		16.986842	16.689582				2.025441				0.036585
10		_		_	_	1849.490522	278185.208134			600.227128			5905.99
11				64.443445									0.206482
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13				_			_	_	_	12.704127		0.072536	0.027598
14		1418.814216	3159.765087		1643.036592	1954.006579		2601.183561					2443.92
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$\begin{array}{cccccccccccccccccccccccccccccccccccc$	37	21031.281618	8841.655426	_	20069.762917	6513.826754	_	8935.08687	_	_	102.137	_	2100.7
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	38	2194.047751	37.467729	63045.095541	1423.494421	47.179014	11487.086893	39.11185	_	76.663057	1.25485	28.1663	27.782
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1 48 18 235069 17 583504 18 6094 18 584168 18 284128 18 179705 19 468825 2 442147 168 732547 10 075 1012 31 8													6858.53
		18.235069			18.584168	18.284128							862.443
		_			_								7540.64
50 19.71022 19.845304 20.27337 19.657116 19.781079 19.682149 20.862223 2.264566 12.563414 0.048344 0.033352 0.	50	19.71022	19.845304	20.27337	19.657116	19.781079	19.682149	20.862223	2.264566	12.563414	0.048344	0.033352	0.029265

Table 11: Results on Random Lydia Case 06 50, time in milliseconds.

name	Nike Hash True First	Nike Hash False First	Nike Hash Random	Nike Bdd True First	Nike Bdd False First	Nike Bdd Random		Cynthia	Lydia	Lisa Symbolic	Lisa Explicit	Lisa
1	17.725612	17.815749	18.306462	17.260368	16.949622	18.316431	26.258953	1.824316	74788.499671	128.161	_	1605.91
2	17.622506	18.725651	28.870486	20.297471	19.637225	29.361514	21.549324	88.152674	108.293412	0.449279	1.11059	0.61805
3	2647.044011	39.104455	147931.751387	1283.700043	50.225297	15786.606906	42.017331		112.983522	1.57557	48.2856	46.751
4	16.78076	16.583245	16.804801	16.658298	15.80621	16.467267	18.624064	2.675993	10.65112	0.043024	0.045095	0.047252
5	_	_	_	_	_	_	_	_	75795.185641	198.599	-	312.79
6	12320.366361	64.441768	_	5132.779359	42.093978	3864.07905	67.630661	91133.936828	25.545632	0.353424	0.384728	0.318895
7	_	_	_	_	32863.42443	_	_		18.455482	1.44071	0.030167	0.024532
8	17.82573	18.175483	17.733877	17.910561	17.758118	18.076	20.096125	12947.866661	41.300468	1.15366	14.6333	13.8457
9	20.053167	20.435898	84.134085	20.002887	19.924446	87.878398	22.500527	432.876722	582.385469	0.896769	12.7224	0.897712
10	17.716032	17.280368	17.479329	17.406261	17.582699	18.81597	21.096807	3.851121	2985.885631	555.273	_	277.605
11	_	_	_	141181.279957	8402.491324	_	_	_	13.053026	1.64984	0.074758	0.027474
12	17.024589	16.998167	16.840117	16.611187	16.979116	17.085917	19.135059	0.48344	10.563795	0.044445	0.061931	0.046672
13	17.040205	17.126015	18.244227	19.067354	16.74355	18.86702	20.539393	1.033106	56172.697453	72.7671	_	892.311
14	26301.516771	4032.275555	_	23596.600669	2386.960475	_	4174.430387	_	_	3158.18	_	
15	19834.802467	18286.26178	_	19721.813078	10996.921383	_	19076.639896	_	_	802.983	-	
16	24734.504829	18775.691775	_	23753.583476	11854.909836	_	19221.525103	_	_	6818.89	_	
17	16.6766	16.073141	16.66132	16.910015	15.913763	17.014416	18.730441	1.855938	11.207786	0.0757	0.098661	0.076674
18	_	63137.169839	_	_	24601.669398	_	64107.643242	_	_	476.795	-	692.795
19	113698.055349	17913.488071	_	110763.847018	10665.933706	_	18487.432555	_	_	9240.79	-	
20	19.316355	18.677881	18.85099	18.713745	18.340243	18.273598	20.884063	3.772515	2671.076192	438.715	_	485.7
21	7140.714042	20.763188	_	4890.0597	20.828187	3178.002565	23.034582	119017.441801	481.347471	0.948815	28.8825	1.0312
22	19.716807	19.342622	85.046277	20.624832	19.764781	86.692778	21.914121	413.545907	573.00698	0.799826	15.236	0.904199
23	60.401429	20.955882	289.653173	65.214642	22.400495	329.55547	24.78023	1663.157691	27.59101	0.227142	0.29925	0.234439
24	17448.336731	17950.574591	_	18453.006294	10811.445129	_	18804.099254	_	_	2960.7	_	1010.1
25	15800.07337	61.71774	_	8147.754581	74.657259	65916.391457	65.441964	_	379.027379	5.55059	622.332	12.179
26	20.08871	20.679686	20.142815	20.916778	20.563588	21.078182	22.385438	2.627018	13.940041	0.088197	0.03387	0.027611
27	_	179686.597171	_	_	80035.726928	_	_	_	_	_	_	1431.36
28	2866.200072	62.329039	283871.96806	1809.079596	72.992599	24161.619692	64.889624	_	287.736236	3.14671	263.849	8.40822
29	19.171152	19.505468	47.074791	20.48262	20.581259	48.704523	21.824145	37.203601	26.545113	0.271858	0.265133	0.182623
30	5840.081411	37.802951	_	3737.900743	29.260213	3220.039076	41.598124	86151.022195	464.287332	0.523643	9.86331	0.558945
31	17.692214	17.293052	17.869315	18.837028	18.073613	18.026609	20.912307	3.117526	1865.090784	190.66	_	288.638
32	15687.920867	60.255655	_	8155.123249	75.025749	87413.367931	64.013807	_	363.573356	6.09257	584.65	11.9831
33	14479.991594	15942.799789	_	14992.214685	9756.641969	_	16598.157156	_	_	640.662	_	2155.99
34	1503.76944	21.15171	_	1017.000229	20.726429	786.887448	22.632066	7619.817101	90.255739	0.478207	2.09661	1.91511
35	49.464049	18.113441	163.680663	52.076523	18.765431	195.186827	20.344538	12373.527089	22.395965	0.762474	1.21756	1.07333
36	185338.515399	25493.089778	_	172516.614662	16917.052234		26413.000282		_	22070.0	_	
37	116711.256208	17780.586724	_	111141.43535	10696.312535	_	18668.029405	_	_	3227.14	_	
38	7455.26956	115.523274	_	4742.474649	61.038613	4635.772466	125.081206	66214.901623	74.589504	0.310648	0.889523	0.825519
39	64716.590774	81279.694386		50584.270968	36672.849229		86197.115618		_	13047.1	_	
40	18.643652	18.7264	18.533985	18.687562	18.960498	18.534082	21.188701	3.204172	1152.111611	94.2117	_	71.3779
41	152140.416259	118311.629543	_	87395.480084	42197.762605	_	_	_	_	20398.7	_	
42		_		185133.314594	9858.934197				13.112195	0.54108	0.070434	0.074639
43	2209.962737	37.645791	36344.135408	1385.541474	48.208086	9607.154131	40.748249	_	78.137948	1.16236	28.3838	27.7359
44		2085.218596			1399.316105		2111.386651		4696.974627	33.363		98.6493
45	18.116922	17.628702	17.743739	18.203033	17.896056	17.510276	19.911393	0.977629	7.911422	0.043721	0.027849	0.024403
46	69705.083347	20110.527227	_	59295.14942	12239.06974		20880.078621		_	1271.97	_	
47	19388.081826	26454.657244	_	19933.131137	15256.891156	_	20528.079671		_	666.857	_	_
48	21.17218	20.680712	20.582413	19.765074	21.099256	20.606945	22.691593	2.555701	15.833586	0.055275	0.081228	0.029366
49	17.024565	18.186843	16.208681	16.057734	17.619484	16.304216	19.621447	0.963113	8.187546	0.049854	0.025115	0.023008
50	18.11862	18.765472	18.534884	16.789009	17.716776	18.277607	20.5402	3.287861	4724.58507	345.182	_	181.636

Table 12: Results on Random Lydia Case 07 50, time in milliseconds.

name	Nike Hash True First		Nike Hash Random			Nike Bdd Random		Cynthia	Lydia	Lisa Symbolic	Lisa Explicit	Lisa
1	_	139659.636414	_	272613.224302	86346.68118	_	150617.396927	-	_	6046.44	_	
2	108246.403146	115.779725	_	46391.418416	191.093623	_	118.8012	_	1876.379831	27.1607	12457.7	80.1553
3	_	_	_	-	-	_	_	_	_	_	_	
4	17.566906	17.394854	17.141297	17.420313	17.46057	16.627154	18.922813	0.912246	17.759666	0.055737	0.143472	0.120822
5	136.994026	23.104773	914.861403	172.446904	24.219817	1016.665293	25.182862	21372.884565	130.019039	2.96725	7.03019	6.27644
6	17.232201	16.426434	17.360178	16.669022	15.882919	16.582951	18.614869	0.845496	10.277482	0.034572	0.057241	0.04242
7	32592.043851	37890.665585	_	30436.587611	21635.183297	_	45652.719643	_	_	_	_	_ 1
8	120121.212446	89861.312352	_	96946.44598	47849.849233	_	91915.972515	_	_	_	_	_
9	105942.531586	178876.690535	_	103848.223766	87565.248963	_	182948.698773	_		12373.5	_	16807.4
10	21.200884	20.864971	22.245619	20.758841	20.544966	21.116246	23.171215	3.24482	17.557405	0.098368	0.083639	0.035535
11	_	249875.639164	_	_	116615.448359	_	254221.414281	_	_	_	_	
12	_	36928.321603	_	_	25765.916616	_	_	_	_	1128.02	_	9653.81
13	16.989145	16.824699	17.024381	16.969187	16.264646	16.289116	18.995765	1.168709	17.101061	0.059973	0.128092	0.073875
14	_	95894.416914	_	_	55972.2665	_	100907.636521	_	_	_	_	
15	16.807833	16.713155	17.251369	16.922354	17.056758	17.063217	19.486674	0.994828	18.291201	0.066545	0.07243	0.072435
16	20.6055	20.527607	20.942258	20.47675	18.910981	19.913015	23.520856	3.639858	15.416263	0.092292	0.039808	0.032357
17	184056.301042	_	_	166913.895133	184620.172847	_	_	_	_	10842.8	-	
18	22.177628	25.0118	159.328237	23.176467	25.839925	189.976448	27.005697	502.980908	106.019146	0.830984	1.28571	1.143
19	273492.273852	_	_	235780.516569	239713.780994	_	_	_	_	_	_	
20	_	_	_	_	20326.769993	_	_	_	14.128244	5.21136	0.029817	0.027678
21	18.620333	18.167771	17.649685	18.200941	18.186755	18.02476	19.765213	_	237.896288	5.49234	2075.74	12.0054
22	30017.818487	40.266265	_	20230.000809	29.234852	16018.464315	43.828668	_	2025.721988	1.17849	51.4027	1.85201
23	_	152553.071717	_	_	90432.83243	_	_	_	_	_	_	
24	165382.195993	241847.07017	_	152071.000286	131789.973055	_	_	_	_	_	-	
25	_	_	_	_	97293.702811	_	_	_	24.069194	4.84413	0.069058	0.070298
26	149.103448	22.626461	978.851695	169.141322	24.277867	1072.542207	24.648778	281818.943958	98.841766	11.2667	27.7896	21.3565
27	37780.398963	21.183765	_	26696.136747	21.040494	15053.008481	23.003475	_	2929.873912	2.11929	-	3.36781
28	109.002642	17.498203	805.936563	130.893395	18.289007	906.815831	20.347545	_	125.426948	8.47757	16.9098	15.2035
29	16.18018	16.539943	16.831302	16.653144	15.516199	16.687271	18.497197	0.529552	17.228671	0.059729	0.080399	0.06606
30	18.680234	19.297598	65.42806	20.464174	21.527321	69.480097	22.771787	2279.899643	4377.451111	3.40626	94.503	5.84106
31	112584.230469	106892.487048	_	106350.368801	59820.569176	_	116731.921405	_	_	_	_	_
32	18.847318	19.001098	19.276024	18.561686	19.131745	19.343208	20.862294	1.637654	_	1927.02	_	_
33	15.877677	16.633968	15.662549	16.940131	15.656215	15.739041	19.051578	0.459259	16.449256	0.075777	0.121778	0.131984
34	23.833475	52.303108	116.363368	25.416274	52.173101	122.693402	41.858172	547.925213	106.06356	0.449711	1.11023	0.512011
35	15.244248	16.859991	17.273988	16.428828	15.502607	17.134687	18.956044	0.483225	10.024851	0.055403	0.048495	0.041678
36	_	10779.514788	_	_	7474.839078	_		_	11350.283337	342.1	_	853.776
37	194143.982081		_	183772.059796	153911.64927	_	_			_		
38	21.850777	25.5672	434.369505	23.319772	26.536098	509.687074	27.391043	1216.057957	1632.068686	1.94115	32.1651	2.8346
39	16.423516	16.452341	17.551999	16.419512	17.4089	17.193939	19.85607	1.177408	8.748741	0.065532	0.026006	0.023087
40	16.777183	17.077404	18.00011	16.640976	16.291248	17.028004	20.153962		327.688167	6.02855	5257.02	18.6328
41	15.466287	16.464266	15.292817	15.355776	15.313759	15.403857	18.957689	0.839953	11.143646	0.045749	0.054575	0.040143
42	279656.987457	149758.509196	_	242456.032139	102462.012582	_	276128.94699	_	_	_	_	_
43	_	293629.571325	_	_	175758.39622	_	_			_	_	
44		-	- 10.127/2/	- 10 122207	- 10 (00 (12	-					_	-
45	19.497227	19.351264	19.127426	19.122297	19.698612	19.091178	21.683916	5.392415	7303.509533	3130.66		4358.56
46	19.911364	20.799284	64.815077	21.196554	22.354869	69.300221	23.282352	2053.324053	3969.177388	3.30501	93.8687	7.05162
47	248.647304	27.265209	1234.019359	284.942522	28.325648	1335.919013	29.433656	99227.115311	117.777574	5.98298	17.0413	23.9457
48			_							725.899		1316.68
49	31660.015362	44.988977	_	20357.347037	30.873643	18288.888469	46.644426	_	2437.966819	2.08067	106.275	3.98303
50	_		_		169708.337508	_	_				_	

Table 13: Results on Random Lydia Case 08 50, time in milliseconds.

1	name	Nike Hash True First	Nike Hash False First	Nike Hash Random	Nike Bdd True First	Nike Bdd False First	Nike Bdd Random	Nike Multithreaded	Cynthia	Lydia	Lisa Symbolic	Lisa Explicit	
3 18,689927 18,482602 19,206651 18,446774 18,401904 18,64012 19,007631 — 1004,314178 22,5193 3990.2	1		_	_	_	202624.173201	_	-	_	25.582577	32.5515	0.067548	0.033464
18,55694		_	_	_	_	_	_		_	_	_		
5 — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — —													217.157
6 — 102641739203 — — 16434.9 — 16434.9 — 7 7 35914243109 — 22503577 — 2256816775 32.73514 — 51.666327 — 265900157 — 11710.179313 135.937 — 8 — 252.03577 — 202652023917 434.751429 — 265.900157 — 11710.179313 135.937 — 10 — — — — — — 379.84188 — — 279.99448 — — — 97.99448 — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — —			19.312037			19.07326							
To		-	_	_	_	_	_	_	_	_		_	_
8 — 253,208577 — 262562,923917 434,731429 — 265,900.57 — 11710.179131 135,957 — 10 — — — — — — — — — — — — — — — — —		_		_	_		_	_	_	_		_	
Part	7	35914.243109	48.799137	_		32.73514	_		_			_	15.3771
10		_	253.203577	_	262562.923917	434.751429	_	265.900157	_	11710.179313	135.957	_	1561.16
11		-	_	_	_	_	_	_	_				_
12		_					_						0.033802
13		17.406469		16.994471	17.297509		16.974202		1.854803			0.180101	0.198227
15			264.909548					280.967496	_	12116.241854			19.454
15		-	_	_	_	280052.81727	_	_	_	_		_	_
16 22.056381 21.601903 21.402569 21.22219 22.003891 21.719739 24.221701 3.638146 15.804157 0.148472 0.051698 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.001598 17.						_			_				1076.92
17									_				108.042
18					21.22219				3.638146				0.053838
19													
127,679/147			22.902142		23.053399			25.651635		20.026471			0.041123
18.0636399			_		_		_			_			
22							_		_				621.849
23		18.063639	18.168886	17.9081	18.156082	17.669599	18.858741	21.200775	_	966.255249		35824.9	86.7208
25		-	_	_	_		_	_	_	_			2732.14
25			24.377995						_				100.557
26 1798733 18.778486 18.175267 18.286952 18.23803 17.757906 19.983488 — 224.443449 6.80783 18.782.6 27 — — — — — — — — — 224.443449 6.80783 18.782.6 29 — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — <td></td> <td>_</td> <td>251.231309</td> <td>_</td> <td>260724.012333</td> <td>434.448379</td> <td>_</td> <td>264.795461</td> <td>_</td> <td></td> <td></td> <td></td> <td>1552.31</td>		_	251.231309	_	260724.012333	434.448379	_	264.795461	_				1552.31
27									_				0.037917
28			18.778486	18.175267	18.286952	18.238803	17.757906	19.985848	_	224.443449	6.80783		20.5224
29 — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — — —			_		_				_				
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$		24.102854	23.940298	23.729757	23.767862		23.409177	25.537464	5.469836	18.634229	0.115413	0.084761	0.087624
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		_	_	_	_		_	_	_	_			
$\begin{array}{cccccccccccccccccccccccccccccccccccc$										39.666088		0.175426	0.194824
33 9.776704 18.94031 18.01242 19.382039 77.49408 19.067017 21.160141 6.98768 8.8580.0151348 — —				17.844302				21.080046	1.31361	_		_	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$												_	278.41
$\begin{array}{cccccccccccccccccccccccccccccccccccc$													
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$													0.045717
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$										56.317516		3.92686	5.65143
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$										_		_	
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$					17.512082			18.79189					0.244685
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$					_			_		44582.900961			_
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$										_			_
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$							22.828246						0.085425
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$							_						231.517
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$													196.46
45 168.083867 26.653953 2355.232076 221.061957 28.076017 2611.3152 29.997087 — 134.418919 3.88001 5.4512 46 19.025471 17.064875 17.67436 18.553497 16.69701 18.573641 20.507404 — 958.965537 17.1833 38537.4 47 16.767765 15.811001 17.559552 17.200257 15.951787 17.317494 19.166961 1.078338 30.813243 0.067606 0.1624			30.004244				2163.667734						28.6809
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$							_						0.048914
47 16.767765 15.811001 17.559552 17.200257 15.951787 17.317494 19.166961 1.078338 30.813243 0.067606 0.1624													7.00168
													187.228
			15.811001	17.559552	17.200257	15.951787	17.317494	19.166961		30.813243			0.201867
48	48	_				_	_		_	_	_	_	
49 18.029356 17.985733 16.849153 18.11485 17.858815 16.973439 20.561123 1.88034 11.12712 0.104645 0.080152													0.031448
50 262407.892568 — — 282131.53332 296839.320663 — — — — — — —	50	262407.892568			282131.53332	296839.320663				<u> </u>	_	_	

Table 14: Results on Random Lydia Case 09 50, time in milliseconds.

name	Nike Hash True First	Nike Hash False First	Nike Hash Random	Nike Bdd True First	Nike Bdd False First	Nike Bdd Random	Nike Multithreaded	Cynthia	Lydia	Lisa Symbolic	Lisa Explicit	Lisa
1	200.296323	201.567275	203.168077	212.315198	211.333889	215.085183	214.71067		3765.572701	97.1977		880.774
2	_	_	_	_	_	_	_	_	_	_	_	
3	20.147491	19.405688	20.195466	19.662369	20.110029	20.140943	21.846456	12.447289	_	_	_	
4	996.878624	44.910837	13744.3846	1099.670634	46.319641	12883.353099	48.160912	_	933.194199	95.7317	713.011	834.38
5	_	_	_	_	_	_	_	_		_	_	_
6	19.585303	20.233692	19.673646	19.668884	19.37875	19.736536	21.890737	11.056458		_	_	
7	_	_	_	_	_	_	_	_	_	_	_	_
8	534.117976	19.59044	6090.845023	406.786223	20.614786	5752.704324	21.771562	_	496.888634	96.56	514.965	608.349
9	_	278.570826	_	_	461.805236	_	288.673375	_	31019.403569	176.118	_	867.472
10	_	_	_	_	_	_	_	_	_	_	_	
11	_	_	_	_	_	_	_	_	_	_	_	
12	17.505689	17.298959	17.416763	17.737131	17.110917	17.481125	20.021202	3.166652	61.725406	0.112209	0.447661	0.585107
13	_	53.56902	_	_	33.707265	_	56.982615	_	117605.335016	43.5619	_	172.915
14	_	_	_	_	_	_	_	_	_	_	_	_
15	585.116591	20.224199	8285.270866	413.593697	20.641122	7365.119343	21.077476	_	457.507922	319.046	_	_
16	_	_		_	_	_	_	_	_	_	_	_
17	1891.30431	41.835165	14414.404324	2060.02855	43.648632	15363.806665	43.222086	_	954.950878	113.093	802.317	884.28
18		_		_	_	_	_	_	_	_	_	_
19	28.25844	28.170182	27.749755	27.96281	28.144196	26.161355	30.919007	9.480531	24.080528	0.184404	0.055062	0.042064
20	l	_	ı	_	_	_	_	_	304.409219	331.094	0.032945	0.036227
21	l	_	ı	_	_	_	_	_	23.66599	339.687	0.037214	0.039295
22	18.859243	18.522718	18.850804	18.777523	18.494124	18.576399	20.823638	2.285719	9.58564	0.124427	0.027258	0.032123
23		_		_	_	_	_	_	53.234065	400.021	0.048801	0.051911
24	28.554814	28.313811	28.691009	28.791152	28.162286	27.138076	30.939031	6.301981	23.056391	0.239977	0.057292	0.065249
25	19.031579	19.310545	19.865352	19.050093	17.786393	17.965267	21.807561	1.791023	_	_	_	
26	19.246743	19.813456	19.906902	19.714937	19.447442	18.30384	21.600346	13.655258	_	_	_	
27	_	_	_	_	_	_	_	_	22.157384	118.031	0.071023	0.078694
28					_							
29	22.449315	21.987618	22.034307	21.334802	21.942872	21.886558	25.115722	6.938389	19.870879	0.192848	0.04919	0.060071
30	_	_	_	_	_	_	_	_	_	_	_	_
31	_		_	_		_		_			_	
32	_	24.101913	_	_	23.606858	_	25.605592	_	172110.597835	47.0083	_	180.165
33												
34	28.186903	28.305976	28.754304	27.371607	27.312023	27.950146	30.38891	6.334617	23.750319	0.161832	0.077504	0.044852
35	19.590999	19.320211	19.716771	17.665698	18.970661	18.212797	22.366145	4.759862	24572.636922	_		
36 37				_	_	_	_			_	_	
38				_	_	_	_				_	
38	— 19.398852	— 19.715057	 19.769205	19.340182	19.507698	18.436303	22.102144	27.188393				
40		19./1505/	19.769205	19.340182	19.50/698		22.102144	27.188393				
40		_	_		_	_	_			_	_	
42	22.478374	23.033107	22.782828	22.048596	22.49234	22.597907	24.271406	4.383399	19.632279	0.219921	0.09619	0.097988
43	20.635724	19.882713	21.058818	20.240772	18.730647	18.643832	22.801462	10.594384	19.032279	0.219921	0.09619	0.097988
43	20.055724	195541.175723	21.038818	20.240772	164335.468253	10.043832	22.001402	10.394384				
44	29.1681	28.874478	28.119487	27.803505	27.504798	27.624774	30.376049	5.178641	20.292778	0.160278	0.079334	0.079631
46	29.1081	19.167374	19.337507	17.671985	19.254439	18.223237	21.474227	11.945624	20.292778	0.160278	0.079334	0.079631
46	20.120003	19.10/3/4	19.557507	17.0/1983	19.234439	18.223237	21.4/422/	11.943624				
48	18.682479	18.755441	18.338184	18.113817	18.177409	18.401453	20.14213		1953.194231	34.9219		195.364
48	10.002477	18./33441	16.336164	18.113817	18.177409	10.401433	20.14213		1733.174231	34.7217		173.304
50	28.971457	28.671703	28.522456	28.13169	28.164525	28.276661	31.169693	9.889272	25.313422	0.182945	0.089335	0.045606
30	20.7/143/	20.0/1/03	20.322430	20.13109	20.104323	40.4/0001	31.109093	2.009272	23.313422	0.102943	0.009333	0.04.3000

Table 15: Results on Random Lydia Case 10 50, time in milliseconds.

name	Nike Hash True First	Nike Hash False First	Nike Hash Random	Nike Bdd True First	Nike Bdd False First	Nike Bdd Random	Nike Multithreaded	Cynthia	Lydia	Lisa Symbolic	Lisa Explicit	Lisa
1	_		_	_		_	_		28.782413	60.3576	0.032948	0.037117
2	_		_	_		_	_	_	_	_	_	
3	17.575102	17.352167	18.173289	17.371955	17.395569	17.545897	18.723553	1.080734	140.346973	0.200886	0.597075	0.572767
4		574,387805		_	981.787471		587.057097		157430,510276	860,009		1093.0
5	_	_	_	_	_	_	_		_		_	
6	17.371103	17.750082	17.536003	17.546889	17.228279	17.089149	18,940858	1.191698	141.895564	0.197331	0.64155	0.526382
7		297.350363	_		565,279784	-	303,154461		83451.112641	1111.48		5069.74
- 8	_		_	_	_	_			83.362532	488.51	0.047216	0.03603
9	_	_	_	_	_	_	_	_	_	_	_	
10	_	_	_	_		_	_	_	40.052831	318.29	0.075553	0.073298
11	_		_	_		_			-			
12	_	1123.95505	_	_	1626,926109	_	1212,909402		_	3797.13	_	4292.7
13	19.307176	19.935293	19.468371	19.577817	19.89629	19.67229	21.614557	_	15128.326275	408.815	_	3086.72
14	15.811408	16.624685	17.482837	17.035327	16,789336	16.855076	19.581005	1.075849	61.180518	0.108772	0.393716	0.290431
15	-	- 10.024003	- 17.402037	- 17.055527	-	10.055070	17.361003		- 01.100310	0.100772	- 0.373710	0.270431
16			_									
17	29.30735	28.891086	29.233792	28.217818	29.205045	28.277628	30,944918	9.76887	23,631755	0.36434	0.090895	0.084076
18		20.071000	-			20.277020	30.74710	7.70007	25.051755	0.50454	0.070075	0.004070
19			_									=
20					204447.016053							-=
21	18.978805	18,65948	18.837451	19.749085	19.421608	19.001093	22.077104	2.944238	13.788441	0.220771	0.075605	0.070925
22	-	10.05740	10.057451	17.747003	- 17.421000	17.001073	- 22.077104		15.766441	0.220771	0.075005	0.070723
23			_									$\pm \pm \pm$
24			_									+=
25	17.664698	17.350628	17.699025	17.754208	17.580507	17.478857	19,709357	3.24919	134.277958	0.213936	0.682873	0.57274
26	17.004070	- 17.330020	17.077023	-	- 17.360307	17.470037	17.707337	J.24717	-	0.215950	0.002073	0.57274
27	24.372136	34,904099	672,729441	26,048133	37.891423	860,133638	37.678796	1111.262669	1553,191567	7,20715	38,7803	20.181
28	26,699376	27.639418	28.873281	28.219889	28.538878	28.073293	29.626727	15.57836	28.346627	0.404512	0.061239	0.052158
29	20.077370	448.395892	20.073201	20.217007	305,627611	20.073273	461.884847	13.37636	3966,068165	15.3239	0.001237	5.54832
30	23.244622	36.147881	1875,881298	34.498614	37.227489	2214.888375	37.617141	3530.297388	9380.365713	34.1356		77,4551
31	25.244022	30.147661	1073.001290	J4.490014 —	31.221409	- 2214.000373	37.017141		9380.303713	34.1330		- 17.4331
32												$\pm \pm \pm$
33	17.644231	17.478486	17.28789	18.434666	17.967924	17.541657	18.737701	0.62762	136,946041	0.194661	0.660158	0.613405
34	24.387423	87.029666	2528.426838	27.372095	90.742544	2743.069545	42.39416	2609.39982	2625.937534	9,70728	49.1341	5.2198
35	24.367423	67.029000	2326.420636	21.312093 —	90.742344	2743.009343	42.39410	2009.39962			49.1341	J.2196
36	29.159523	29.940538	29.882961	29.138067	29,477853	29.222763	31.853127	11.379259	28.369612	0.321665	0.052205	0.044892
37	29.139323	29.940338	29.882901	29.138007	29.477833	29.222/03	31.833127	11.379239	28.309012	0.321003	0.032203	0.044892
38			_				_					+=+
39	28.799718	28.241571	28.454633	28.426142	28.372775	27.383608	30.347658	4.752875	22.102583	0.292842	0.110732	0.10539
40	28.799718	20.2413/1	20.434033	20.420142	28.372773	27.383008	30.34/038	4./328/3	22.102383	0.292842	0.110732	0.10539
40	26.032707	34.998464	1643,707461	36,937454	36,946626	1970.217552	36.719967	5361.711451	9763,86672	43,0906		13,4229
42	20.032707	34.998404	1043.707401	30.937434	30.940020	1970.217332	30./1990/	5301./11431	39.595451	309.962	0.080362	0.032016
43	19.525821	19.194809	19.173425	19.089618	19.224351	19.192651	21.406796	3.642171	15.30179	0.212786	0.026099	0.032016
43	19.525821 580,790637	19.194809	19.173425	376.334587	20.902793	19.192651	21.406/96	3.6421/1	607.365575	218.259	0.026099	978.357
44											186.18	
	3165.431081	67.384064	33401.568292	1823.355478	68.233522	28171.919469	73.998536		165.097198	40.1551		172.881
46	_	_	_	_	_	_	_		_	_	_	
47			_		_	_	_		_		_	
48	_	_	_		_	_	_		_		_	
49	_	-	_			_		_			_	
50	_	296.521874	_	_	623.837349	_	302.797427	_	75010.002967	473.546	_	3315.42

Table 16: Results on Random Syft 01, 0-100, time in milliseconds.

name	Nike Hash True First	Nike Hash False First	Nike Hash Random	Nike Bdd True First	Nike Bdd False First	Nike Bdd Random	Nike Multithreaded	Cynthia	Lydia	Lisa Symbolic	Lisa Explicit	Lisa
1 2	17.838381 15.555838	18.010678 16.936421	19.426528 16.358218	18.434495 16.154483	18.272431 15.942102	19.153742 17.039143	25.453386 18.64216	1.480109 0.433352	17.149557 17.302952	0.06058 0.21697	0.097848	0.041566
3	244.892236	252.21823	2774.826025	264.237455	273.860434	2827.775795	256.829823	7029.127958	10.39073	_	0.022478	0.018531
5	17.890429 2304.336286	18.123882 2557.382003	18.386884	18.493321 2695.759816	18.205205 554.392568	18.900738 267737.691448	19.865162 2574.013279	0.95174	11.366788 94.161289	0.043558 205.777	0.055002 3.52906	0.040489 2.99827
6	19.385058	19.853257	18.833662	19.287574	19.506592	19.331106	21.038914	1.37929	14.260233	0.048421	0.048696	0.048428
7 8	16.689495 15.624526	17.907299 15.633984	18.143165 16.042865	18.205655 16.168236	17.339884 16.1247	17.51406 16.46547	19.608336 18.422168	0.808236 0.374489	73.956006 16.366283	35.799 0.182094	5.08427 0.627471	4.73567 0.567531
9	17.984099	17.476691	16.748291	17.076929	17.97599	17.106557	19.494134	0.855414	10.610905	0.042498	0.036051	0.034236
10	17.685524 389.619713	18.434985 419.762999	18.692184 60576.314704	18.5878 420.830747	17.938472	18.103472 14209.226413	20.628276	1.252084	14.802912	0.040851	0.042319	0.037315
11	19.070878	18.864848	18.31963	19.247821	130.066422 18.830747	19.113381	423.536608 20.321897	1.204464	25.077844 13.288654	10.5695 0.043428	0.421491 0.043071	0.411797 0.045563
13	15.887511	16.77877	17.107754	16.62774	16.516723	16.034154	18.624028	0.498387	17.666278	0.213673	0.102817	0.107286
14	339.821205 162.272237	364.239667 174.798238	44226.770913 11789.731216	358.522842 177.251406	122.971479 74.224155	8039.982239 2729.808089	367.73303 177.15959		27.976605 20.627745	3.80797 1.75585	0.503232 0.228625	0.467393
16	1509.966477	1566.454966	27261.589853	1682.550258	1717.016302	27560.277917	1581.280398	103131.79842	12.818765	_	0.019117	0.018583
17	142.819737 838.29836	151.45346 894.617486	8151.451692 221379.839928	155.414205 965.46771	71.099953 241.680447	2011.102901 41075.694593	153.354157 898.638368		22.114329 38.109586	0.882753 156.856	0.223118 1.01648	0.18435 0.963573
19	17.270588	16.967485	17.321624	17.511575	17.354024	16.7567	18.494921	0.569946	17.003998	0.208543	0.088764	0.10037
20	386.317438 17.747976	418.668603 18.208437	60513.798071 17.610393	417.569434 18.272474	130.361392 18.511557	14205.189526 18.094666	421.642649 19.536769	0.918224	25.719567 72.920621	10.1365 36.3237	0.412505 4.99377	0.374022 5.60264
22	15.316318	16.186033	16.229343	17.030148	17.366439	16.348987	18.304633	0.345069	13.934593	0.078271	0.13289	0.128495
23 24	603.218039 184.382973	627.781188 228.445676	9601.708496 11820.075855	693.869988 197.647765	734.398143 81.761266	9851.581664 2477.502089	633.240728 230.802229	53268.810636	11.831575 20.082156	0.250827	0.019162	0.018439
25	1088.027511	1345.104983	_	1297.532657	283.541843	50718.754348	1343.744655		37.39476	1.57995	1.36921	1.33312
26 27	19.106695 439.359316	18.892473 549.218957	19.907648 61480.890203	19.044579 535.928432	19.745137 144.645399	19.869472 12165.196185	20.909851 555.43626	1.534108	16.588936 25.370698	0.042317 0.401692	0.038912 0.384919	0.043676 0.359069
28	65.34019	68.060989	1446.174353	77.126	47.911932	437.316258	71.310846		18.448045	0.301191	0.384919	0.090017
29	19.510086	19.480615	19.626307	20.114163	20.207296	19.883162	21.058823	1.517884	14.749464		0.039173	0.037379
30 31	17.796464 834.704614	17.141718 892.352369	18.067132 219925.925031	18.230111 958.480101	18.835673 240.512728	18.470463 40921.902029	20.229483 900.103927	1.077217	11.108248 37.909149		0.041413 1.02738	0.040371 0.973671
32	18.853431	18.441649	18.816021	18.324635	18.355627	18.93115	19.582102	1.121247	10.856368	0.046129	0.046183	0.041159
33 34	18.51626 72.833878	19.210881 76.776238	18.349824 2097,753697	19.086112 84.571508	19.282884 48.041133	19.357208 50.076369	20.895474 79.561967	1.513182	15.973199 15.674648	0.041817	0.038651	0.041744
35	19.516778	18.712961	18.999099	19.222748	19.384858	19.205386	20.308106	1.38979	12.717289	0.043439	0.041494	0.039623
36 37	2082.916478 19.461929	2203.328206 19.4699	 19.806604	2448.639765 20.128936	527.584372 19.791491	188829.191301 19.925405	2215.713089 21.238381	1.58849	63.698237 15.597709	96.7323 0.041249	4.55131 0.038553	4.25849 0.040421
38	19.274954	18.53945	19.018333	19.367378	19.018674	18.803317	21.387779	1.672004	19.34519	0.041249	0.044483	0.042277
39 40	604.462492 18.561429	630.736384 18.489886	9661.670611 18.236152	693.966054 18.464858	735.466325 18.564716	9784.947528 18.605955	632.084144	60819.085273	11.673504 10.700197	0.043309	0.023862 0.046731	0.019667
41	445.460579	550.610109	61408.85439	535.94689	144.539823	12163.77802	554.318357	1.000484	24.984857	0.404265	0.401735	0.35505
42	17.86007	17.721834	17.624715	17.223047	17.144118	17.04507	19.088906	0.735273	26.381654	2.94813	0.333768	0.329457
43	338.704793 19.862606	362.050383 19.481509	42850.212669 19.116644	358.159441 19.429932	122.117459 19.585253	8075.993002 19.875229	365.77127 20.796584	1.505084	27.308999 16.363736	4.08317 0.049731	0.500809 0.039396	0.42975 0.037756
45	16.050377	16.30501	16.773092	17.196538	17.557337 18.677201	17.54545	19.086706	0.44466	31.430007	11.7493	44.6026	41.2842
46 47	18.95409 17.329796	18.887318 17.588465	18.211898 16.165224	19.110623 17.781723	18.67/201	18.93475 17.693352	20.459382 19.121568	1.230969 0.752094	13.449608 40.004619	0.053191 8.86861	0.041114 0.699018	0.042503 0.635636
48	16.502577	17.549346	17.206256	17.193872	18.173447	18.720152	19.948513	0.989553	11.253373	0.056921	0.043817	0.039984
49 50	183.970155 19.082125	227.830665 18.9206	11713.627335 18.521306	196.482371 19.159651	81.388342 19.112681	2469.984018 19.330766	229.619755 20.721196	1.358353	20.147378 14.450093	0.260683	0.25392 0.044314	0.233146
51	16.538293	17.257886	16.406874	17.783555	18.020055	17.469827	19.15471	0.82261	71.808384	35.4888	4.98909	5.00492
52 53	17.312163 17.110113	16.306766 15.910061	15.854163 15.543221	17.608147 17.343677	17.153367 16.879322	16.688082 16.289783	19.074556 18.895444	0.499486 0.543965	30.719126 20.937185	11.6318 0.665605	44.1242 0.156675	41.7962 0.142058
54	183.72581	227.190041	11730.799413	197.584271	82.114315	2479.801962	229.936294	_	20.480717	0.26582	0.246579	0.192936
55 56	246.399503 73.822753	254.620197 84.853201	2765.464936 2102.386923	265.754738 84.824374	274.804509 49.913332	2812.997654 50.415233	257.039386 79.55685	7670.893788	9.965514 17.025365	0.520329	0.019834 0.102664	0.019059 0.076228
57	839.843242	898.444533	220098.657839	960.799852	244.150235	40901.131864	899.936556	_	38.897168	160.437	1.02752	0.940999
58 59	143.203853	152.306944 18.506917	8137.994862 18.454695	156.47147 18.036329	71.193879	2011.781255 18.507305	153.649471 19.575336	1.013787	21.452164 9.699644	0.919024	0.219583	0.199535
60	18.257701 18.120745	18.169974	18.223305	17.531822	18.319724 18.193501	17.825478	19.699619	0.929932	10.428169	0.038116 0.037448	0.03706 0.036146	0.033189
61	18.910568	19.246255	19.798143	19.928485	20.21575	19.526309	21.427354	1.627314	17.904303	0.04214	0.03965	0.040634
62	1505.899065 50.167838	1565.904292 50.997964	27180.572077 148.79575	1680.162522 52.846748	1725.600163 54.396983	27552.374465 152.980537	1570.65331 52,906594	89501.220672 733.876396	13.684823 7.743211		0.0203 0.02767	0.019172 0.018136
64	19.147819	19.097725	18.813736	18.732769	18.982399	18.93032	20.633226	1.30917	13.604488	0.047091	0.043339	0.045745
65	2620.841221 18.994852	167566.582198 19.104061	18.948748	3028.11548 19.068567	1880.302314 18.972374	19.473389	5048.219751 19.981251	1.226957	85.099962 12.64131	6.49458 0.053758	8.61049 0.048452	5.42297 0.041614
67	18.393297	18.058215	18.129538	17.610861	18.071889	17.873825	19.031524	0.807879	72.120237	36.137	5.09362	4.76134
68 69	961.745988 18.30881	1027.746258 18.052403	 18.013414	1088.914084 18.289102	255.982329 17.627037	61833.197998 17.977935	1035.550623 19.958002	0.967749	39.158085 9.92455	46.6199 0.036971	0.68693 0.036612	0.640986 0.042474
70	17.916782	16.500189	16.507784	17.905199	16.806537	18.269319	19.456554	0.806608	71.834252	35.899	5.32392	4.86028
71	19.046806 1502.339493	17.802542 1564.010598	18.302599 27314.216053	18.808982 1667.897116	19.222108 1725.231331	19.309349 27563.656516	20.739749 1568.589682	1.346071 98144.675877	16.225406 13.186243	0.041273	0.04123 0.01958	0.042496 0.018976
73	606.297548	627.991612	9612.548223	693.454067	735.187176	9888.086702	634.277586	60587.899753	11.310017	_	0.023115	0.018529
74 75	17.655822 184.522382	17.504637 227.593475	17.444252 11803.12315	17.502487 196.25699	18.092495 82.423162	17.869764 2477.132978	19.044753 231.544012	0.525863	30.375586		46.3648 0.242487	42.6693 0.207454
76	19.463433	19.48375	19.221506	19.595326	19.839377	19.0083	20.769505	1.525629	16.514527	0.261122	0.044215	0.037979
77 78	50.141944 2078.973517	49.994043 2217.587265	148.296536	53.31466 2447.113452	54.153682 527.898237	153.796406 188859.364436	52.398876 2221.348443	747.516586	7.671221 66.347634	96.1493	0.020452 4.78902	0.022182 3.93807
79	19.091119	19.034207	19.05833	19.088223	19.400005	19.427604	20.547832	1.3619	14.337009	0.047325	0.03983	0.039225
80 81	102.561338 17.405454	106.062828 16.489675	419.58354 17.525211	119.290861	122.961028 17.387875	468.459137 17.288714	110.163705 18.73548	1183.393015 0.439646	8.976944 15.283343	0.183134	0.019682 0.618921	0.019126
81	837.853067	892.040404	219590.691425	964.613796	241.934844	40910.250965	901.849547		39.34125	155.688	1.02472	0.9828
83	17.615493	17.199498	17.403029	17.590183	17.702883	17.461639	18.642304	0.680928	27.330104	2.92566	0.320324	0.29777
84 85	16.301263 18.161215	15.645244 18.255417	16.600874 18.157552	15.99343 18.322022	17.288325 18.886528	17.349964 19.512379	18.876741 20.937977	0.427344 1.382395	15.539014 16.10217	0.188435 0.043902	0.664727 0.039958	0.611289
86	19.457944	18.05302	19.000915	18.971998	19.698684	19.791431	20.935581	1.382326	15.086646		0.039027	0.040592
87 88	1506.606513 19.808824	1555.174862 19.181858	27527.160239 19.923596	1679.4498 19.450722	1723.15849 19.421092	27563.307637 19.643954	1565.448034 21.443542	89213.142732 1.512323	12.905669 15.462491	0.042461	0.019657 0.041897	0.01938 0.037847
89	604.978695	627.629519	9651.121389	690.163286	737.020465	9802.548125	633.111709	57348.48895	11.456716	_	0.020084	0.019037
90 91	82.677023 338.843202	100.053102 362.55532	2245.079272 43035.217554	93.529206 359.000421	53.657448 121.700379	527.130957 8051.625901	101.720539 368.199601		16.556631 27.993134	0.161916 4.09917	0.122032 0.530752	0.093962 0.453141
92	104.373122	107.174957	415.909708	118.962367	135.158076	469.384344	109.52915	1278.514058	8.922729	_	0.019022	0.022135
93 94	19.548517 18.761154	20.217582 18.208567	20.132645 17.80263	20.112914 19.75555	20.301001 19.270346	20.488955 19.046696	21.116389 20.442227	1.751711 1.305112	18.265656 14.109473		0.04187 0.040265	0.03708 0.039094
95	15.770447	16.177787	15.473282	17.110182	17.179447	16.543033	18.190152	0.414422	12.951078	0.041900	0.141479	0.126151
96 97	602.710772 1510.081798	636.027282 1576.592584	9621.318732 27252.38667	692.283353 1682.321784	733.020054 1727.332303	9784.595758 27597.779842	632.597816 1569.984876	59057.55237 95869.609498	12.283027 13.114178	_	0.01879 0.018764	0.018215 0.018383
98	18.445672	18.643773	19.098869	18.470905	19.002688	18.833405	20.313615	1.139242	12.335054	0.047052	0.042133	0.042254
99	17.976526 49.081453	18.02166	18.304801	18.088995	19.862373	19.217505	20.705746	1.286753	13.239812	0.047424	0.040735	0.042211
100	49.061455	49.36695	147.572494	51.854593	54.235075	153.448182	52.920622	739.336432	7.872234		0.019015	0.017899

Table 17: Results on Random Syft 01, 100-200, time in milliseconds.

name	Nike Hash True First	Nike Hash False First	Nike Hash Random	Nike Bdd True First	Nike Bdd False First	Nike Bdd Random	Nike Multithreaded	Cynthia	Lydia	Lisa Symbolic	Lisa Explicit	Lisa
101	17.049827 17.298718	17.433849	18.03419	18.127264	18.324177	18.168057	19.728269	0.986675	10.005363	0.036104	0.035689	0.037083
102	2619.760211	18.766137 165036.284525	17.739139	18.916295 3028.209367	19.015619 1865.938059	18.320205	20.296427 5049.075983	1.240988	14.055802 83.840387	0.042816 6.97416	0.043886 5.87934	0.040517 5.43837
104	73.593391	79.033897	2107.287044	85.097798	50.440105	51.304254	79.462928	_	16.982128	0.517877	0.09886	0.08593
105 106	18.612943 65.523752	19.336494 68.227214	18.767024 1445.416127	19.363399 75.811361	19.432526 47.489396	19.680179 432.719049	20.691308 70.144778	1.296773	14.172291 18.532368	0.046593 0.284118	0.041691 0.118855	0.042389 0.091792
107	2312.880279	2561.363222	_	2707.34949	561.11436	267230.115431	2567.199951		91.060229	204.388	3.63981	2.78289
108	19.228815	19.273509	19.015467	18.813943	19.040968	18.982281	20.168209	1.325333	14.2508 10.688592	0.040745	0.042506	0.038822 0.041547
109 110	18.191138 17.075558	17.171185 16.153034	17.944441 16.125885	17.861194 16.96995	17.245369 15.831912	18.323573 17.237933	19.687574 18.985689	0.985249 0.651945	26.424967	0.044652 2.88086	0.043006 0.328286	0.041547
111	16.475236	15.851799	15.937535	16.144981	16.828532	17.193215	18.395748	0.470689	17.348462	0.20178	0.087101	0.096783
112	961.805872 836.393634	1030.509355 897.450764		1087.279899 973.172627	256.139186 242.547964	61774.304495 41010.22362	1036.706261 901.911416		38.495731 38.093461	48.2833 165.723	0.667742 1.05906	0.60487 1.00214
114	17.903042	17.376601	17.524113	18.065467	17.334913	17.915165	19.152192	0.582949	55.164097	81.0875	496.651	431.563
115	17.336133	18.46162	17.12966	17.965182	18.220361	18.703912	19.469365	0.912812	11.405093	0.039521	0.037495	0.035331
116	17.926726 81.993654	18.697924 99.75528	17.557031 2247.15703	17.982384 94.154393	17.588386 53.518616	18.796433 526.68507	20.268995 101.215964	1.007876	11.634695 17.034054	0.042792 0.136738	0.045134 0.136725	0.039451 0.094062
118	17.904476	18.072066	18.60132	17.92315	17.758764	18.014484	18.892824	0.892585	72.128759	36.1074	5.12779	4.69636
119	18.546549 2616.430744	18.173002 165659.558079	18.975551	17.696253 3032.682309	18.082317 1864.786895	18.686461	20.671183 5048.086822	1.32996	12.978533 84.586588	0.050307 6.57214	0.041817 6.27278	0.044363 5.50561
121	143.162109	152.412643	8163.639682	154.882487	70.7082	2010.470887	154.221092		21.789841	0.902902	0.221344	0.186799
122	162.83131	174.764351	11794.062719	175.997141	74.491817	2716.81782 153.818662	177.26857	 750.945521	20.237198	1.77054	0.227776	0.165493
123 124	50.554178 141.638446	51.771589 151.524804	149.785442 8160.402169	52.698737 154.722122	54.196897 70.978785	2012.356471	53.431863 153.274867	/50.945521	7.749675 21.524826	0.877752	0.019322 0.212744	0.019137 0.166639
125	142.250875	151.505442	8135.390537	155.731783	71.63575	2008.169135	153.721356	_	21.474958	0.904654	0.253286	0.168762
126 127	18.416535 1501.18688	18.716484 1557.830044	17.95453 27243.768001	18.092977 1689.245414	19.01304 1724.667831	18.527257 27646.003929	20.191816 1570.038191	1.178828 96964.366333	12.828639 13.095918	0.045443	0.042092 0.01923	0.039808 0.020617
128	17.246936	17.251308	16.70335	17.281655	17.408798	17.154768	18.846095	0.464704	19.496119	0.675386	4.13573	3.95502
129	142.126394	150.086775	8214.800724	155.180186	70.99405	2010.861762	153.902913		21.788289	0.938474	0.23945	0.185604
130 131	18.921524 17.30866	18.761039 18.444962	18.931694 17.229147	19.372089 18.021001	19.568875 18.326418	19.48001 18.560179	20.656468 20.107929	1.521507 1.056809	16.554805 12.109954	0.041834 0.047175	0.042671 0.041227	0.044902 0.042688
132	15.808345	16.948881	15.894809	17.049724	17.120662	17.223184	18.437962	0.429364	19.137191	0.705644	4.03995	3.95124
133 134	102.415604 16.473551	105.41542 16.100327	414.020237 16.999268	118.778795 16.907759	121.366985 16.951787	468.856094 16.987527	108.640728 18.588778	1230.855029 0.41822	8.844848 13.278457	 0.072454	0.019673 0.126165	0.019613 0.126844
134	18.26968	17.835976	18.050291	19.648198	19.243136	18.861713	21.112436	1.47577	15.012387	0.072434	0.05269	0.126844
136	1090.193084	1336.835469	_	1300.957231	283.772941	51055.869399	1349.533714	_	37.438313	1.525	1.3733	1.33393
137	388.883085 17.783078	419.860456 17.940587	61299.162265 18.284163	419.146507 18.037334	130.511058 17.891922	14177.342512 17.913619	420.775537 19.531929	0.844803	24.538467 39.02818	11.0081 8.71848	0.439017 0.69163	0.389265 0.657243
139	2072.199444	2209.599996	18.284103	2439.312296	527.381485	188965.360267	2217.582599	-	65.272774	100.966	4.95618	4.33511
140	73.357582	78.066923	2109.85134	85.859598	49.04168	51.184071	79.189733		16.641512	0.523635	0.124714	0.086369
141	142.994988 16.876042	151.095591 16.603056	8121.305127 16.447427	155.754349 17.158831	70.624344	2013.047596 17.122958	153.414963 18.957769	0.425541	21.759242	0.927517 0.081902	0.241768	0.194222 0.12083
143	161.810373	173.263724	11840.219764	177.345836	73.845034	2714.31589	176.401874		20.805143	2.12439	0.234915	0.190368
144	17.40213	16.889225	17.400468	17.18751	17.066334	17.368074	18.900851	0.490555	15.179824	0.187329 0.046933	0.652716	0.59615
145	17.852346 72.624244	17.394884 76.152939	18.246801 2104.101698	18.712281 84.029182	18.169162 47.912493	17.854484 49.47727	20.293833 79.602207	1.131709	12.933088 16.943957	0.046933	0.04213 0.103704	0.039902
147	18.689413	18.762857	18.348438	19.192667	18.914205	18.779789	20.615641	1.321913	13.098592	0.045356	0.042463	0.039116
148 149	81.525827 16.693482	98.67698 17.169654	2258.803304 17.300941	93.408889 17.413589	54.147093 17.335327	526.082397 17.270656	101.607884 19.086355	0.642621	16.856412 20.425433	0.13624 0.669621	0.144917 0.194365	0.090797 0.146484
150	160.668546	196.770013	11787.07908	176.270706	74.91965	2725.03771	176.697807	0.042021	20.190396	1.79935	0.239056	0.19918
151	66.251373	68.341872	1439.551773	77.902299	47.740292	434.973714	70.121649		18.539992	0.283094	0.125074	0.09196
152 153	1508.308007 104.637981	1564.24334 107.177594	27336.69078 415.073675	1686.352648 118.847985	1725.248978 121.736216	27586.158247 469.221888	1579.542306 108.281701	99055.161097 1213.421391	13.580415 8.483275		0.020858 0.021798	0.018186 0.017956
154	339.570795	363.274258	42922.429458	359.292667	123.374049	8063.546408	364.452313	_	27.289818	3.97908	0.501185	0.424913
155	105.042617	107.521001	415.906355	119.158334	121.876736	470.729234	108.913491	1316.542701	8.610729	_	0.028584	0.022264
156 157	17.933981 836.969657	18.064185 898.515052	18.09483 219790.26635	17.930192 961.958593	17.756939 242.30628	18.123562 40921.218721	19.109874 899.93889	0.784609	39.981719 39.772038	8.6912 163.843	0.711645 1.16158	0.643574 0.965945
158	338.704365	364.058626	42964.730095	361.28814	122.270944	8057.530878	366.939687	_	27.272456	3.91956	0.502449	0.44223
159 160	17.516647 19.109855	17.419048 17.747136	17.644756 19.142663	17.542356 18.900899	17.249692 19.18449	17.556693 19.056741	19.17458 20.444737	0.514601 1.29768	20.707745 13.084834	0.689205 0.044615	4.11512 0.043512	4.03541 0.042227
161	1087.403229	1339.3061	_	1294.463932	282.830294	51504.275299	1341.651858		37.998088	1.52365	1.38804	1.34081
162	20.114953	19.245995	19.738411	19.688225	19.71485	19.941714	21.280325	4.884849	20.247985	0.041138	0.053858	0.039091
163	18.470795 2303.107059	16.916333 2569.830704	17.697835	18.592915 2698.231928	18.171507 555.546033	18.523736 266530.757214	19.930127 2590.474596	1.549751	10.561949 92.460747	0.042247 206.926	0.042154 3.28639	0.040625 2.76926
165	82.520475	100.469157	2298.673846	94.269132	53.174663	528.126835	101.826492		17.230081	0.145147	0.133508	0.1065
166	185.478937 50.448367	229.261928 52.319976	11717.08544 148.182128	198.03131 54.214064	81.448979 53.747115	2469.893004 153.755788	229.934383 52.741924	749.080697	20.777103 8.182141	0.257728	0.237387	0.201827 0.018103
167 168	19.625469	19.240399	19.382382	19.342213	19.30636	19.78001	20.440304	1.916867	16.592541	0.043392	0.042177	0.037985
169	16.707475	15.509862	15.632176	17.053583	16.65465	17.364209	18.666517	0.98569	17.461429	0.208465	0.112827	0.079871
170 171	340.129698 82.481795	360.173194 99.69026	42958.022029 2239.959415	359.883132 93.715477	121.78242 53.975823	8060.429527 527.569547	364.840667 101.157251		27.805213 17.265727	4.17558 0.136207	0.537934 0.127679	0.461241 0.096821
172	184.358928	227.507826	11712.999167	198.195237	83.249126	2469.801471	230.230958		20.678141	0.260429	0.233421	0.212675
173 174	837.394282 19.412765	891.94248 19.183451	220858.587341 20.091084	962.596283 19.61017	241.443375 19.232746	40796.453667 19.377023	902.478936 21.053249	2.12853	39.826348 16.55714	155.483 0.046326	0.997468 0.039768	0.933004 0.039402
175	50.479159	51.022524	148.508604	53.24126	53.829158	153.07597	52.788633	736.424247	7.325467	_	0.019316	0.022577
176	388.593269	437.939648	60426.285056	415.968985	129.587573	14274.914953	424.13897	_	25.528255	10.8248	0.450645	0.395375
177 178	66.286201 50.464998	68.335665 51.146232	1439.313654 149.800248	76.384899 52.873137	47.44872 53.740762	441.979698 155.355589	70.042264 52.726979	733.725795	18.63157 7.976308	0.278638	0.110293 0.019225	0.086084
179	18.812763	18.821958	19.07792	18.277836	19.073556	19.314379	20.236734	1.105995	11.760035	0.047853	0.041439	0.040529
180	73.118469 1099.988816	76.556849 1339.541999	2104.54184	84.507777 1298.959203	49.066682 283.552827	50.751809 50620.243775	79.304373		16.297316	0.50533 1.45529	0.092028	0.086307
181 182	17.420909	1339.541999	17.726554	1298.959203 17.610638	283.552827 17.738725	50620.243775 18.137089	1343.42771 19.04473	3.555107	37.726474 40.488224	1.45529 8.57744	0.685537	0.635251
183	18.831564	19.533312	19.226732	18.411536	19.481751	19.077939	20.563975	1.912364	15.282442	0.043248	0.041442	0.042017
184 185	16.693324 16.838626	17.924859 18.30742	18.009435 16.687492	17.046748 16.48327	17.760019 17.76081	18.162627 17.966784	19.838211 19.283392	1.329779	10.485753 9.570745	0.045017 0.037852	0.042191 0.036121	0.042057 0.034796
186	16.371669	17.262753	15.996938	17.003435	16.603681	17.277025	18.749722	1.024019	31.635335	11.7023	44.4207	43.3477
187	18.162474	19.247236	17.226007	17.618565	18.978193	18.617761	20.291237	1.262775	14.517983	0.043319	0.042594	0.040045
188 189	17.299222 17.098631	18.078718 17.764284	16.694931 16.863465	17.142624 17.282719	17.78969 17.833119	17.929119 18.188274	20.13849 19.624317	1.060398 1.447021	12.71177	0.045191 0.037247	0.04575 0.037597	0.043304
190	102.844583	107.376728	414.799815	118.721518	120.616705	468.485152	109.217321	1440.151349	8.720145	_	0.019693	0.018689
191 192	19.724249 64.484267	19.838913 68.220799	20.058389	20.0024	19.863295 45.623076	20.464915 434.176451	21.605493 69.476025	1.98714	17.898014	0.041986 0.293911	0.043475	0.037677 0.087047
193	18.445927	18.858582	1443.427617 18.311312	75.848896 18.687885	45.623076 18.644803	18.59349	20.553768	1.159279	18.138358 12.275127	0.293911	0.096765 0.041793	0.087047
194	140.927293	151.180504	8148.473772	155.612571	69.646114	2004.405937	154.311214		21.749533	0.895042	0.244078	0.180151
195 196	390.055238 19.492123	418.518051 19.044938	60698.175006 19.140407	419.564038 18.81328	131.394795 19.052504	14563.523603 19.167014	421.942604 20.646346	1.707934	24.951592 12.919456	10.0451 0.042345	0.421613	0.408385 0.048326
197	18.414884	17.43707	17.63608	17.511803	17.810723	18.696841	20.215207	1.503153	12.797254	0.042343	0.041406	0.048326
198	16.746141	16.559429	16.252501	16.506082	17.868703	17.284427	19.03703	0.671854	41.107514	8.81092	0.699691	0.67508
199 200	18.226898 17.356273	17.821209 16.895382	17.84567 16.933841	18.906024 17.920577	19.126668 18.614833	18.456682 17.561487	20.579462 20.043188	1.785686 0.999272	16.670018 12.787913	0.040645 0.042083	0.041672 0.044345	0.038189 0.03922

Table 18: Results on Random Syft 02, 0-100, time in milliseconds.

name 1	Nike Hash True First 1504.973108	Nike Hash False First 5157.85633	Nike Hash Random	Nike Bdd True First 1857.615553	Nike Bdd False First 2446.271323	Nike Bdd Random 6742.374297	Nike Multithreaded 2886.465606	Cynthia	Lydia 4590.170819	Lisa Symbolic 21.8974	Lisa Explicit 978.013	Lisa 7.64967
2	18.706711	18.533534	19.349636	18.803158 999.373529	19.292196 276.591712	19.238666	20.782447	1.245319	14.055715	0.022093	0.023939	0.021903
4	3552.730691 4775.026745	290.086476 977.8761	=	3626.136501	249.937242	15301.785696 250056.665951	291.288737 987.554438	66763.036325	14.90648 163.610671	0.076225 93.8458	0.078319 13.697	0.062949
5	2450.454876	2829.232249	_	2654.521757	1876.844986	_	2835.214667	_	321.614877	_	397.263	347.974
7	9297.348399 18.558617	1830.678317 19.291644	19.592553	2201.321798 19.768541	1737.504453 19.282277	24281.761385 19.088439	1844.30975 21.151468	— 1.419	20.38892 12.99837	0.039756 0.035211	0.034423 0.032893	0.034081 0.028164
8	647.184126	724.587044	19.392333	403.818041	251.998173	55634.419844	731.882461		170.913881	22.4828	72.3822	66.4217
9	86.591293	206.334595	9057.499966	95.894753	166.545235	5576.509296	153.467425	_	120.325054	21.2469	13.884	13.8187
10 11	10681.127172 6232.394258	11508.697939 793.684201	_	11586.290259 1334.331733	2169.267205 889.277276	6970.327383	11616.413402 802.275172	_	24.931001 20.162265	0.029979	0.019879	0.023657 0.027779
12	120.501293	39.509624	3030.497785	105.571956	37.771401	600.520208	41.770665	178109.056765	19.04953	0.294271	0.219959	0.163034
13	16438.349097	2877.949597		3996.236484	2524.975001	275583.60457	2885.456476		44.592512	0.566023	0.107322	0.091596
14	21.72036 4074.917305	28.729516 17218.998067	63.564985	22.849808 1166.417746	28.273522 991.690724	59.178203 4385.690539	31.236353 7665.608828	6878.638779	9.829246 17.052352	0.158144 0.042633	0.074229 0.032727	0.084331
16	10535.661628	11344.875092	_	11561.475574	2079.996579	_	11501.856079	_	16.129658	_	0.019693	0.019956
17	26.551993	100.839968	602.193323	27.823097	100.819801	511.44433	45.638522	418.903229	63.302181	36.0567	293.692	258.126
18	404.126927 10389.196961	141.9924 11229.82228	2239.744404	195.287627 11477.037008	73.121931	1571.616317	144.290289 11361.660461	967.398508	7.798195 445.725844		0.020437 139.492	0.024088 128.213
20	8642.807414	9167.815582	=	9522.203496	2008.533157		8741.1303		14.929145	_	0.021445	0.020482
21	187.094327	199.639336	7264.601276	131.095429 18.921174	89.311697 19.257784	2416.974799	200.613347	_	24.694945	0.886062	0.177933	0.146722
22	18.924151 18.98905	19.000528 18.400137	18.574103 19.293014	18.921174	19.257784	18.815346 19.313683	20.424527 20.953118	1.337612 1.37052	339.39851 14.08606	3.13836 0.055303	0.34577 0.03327	0.324545 0.035561
24	108.354634	113.142386	1419.414927	123.127695	75.171342	1034.848817	116.133575	4458.441239	8.434413		0.019833	0.018403
25 26	2432.074252 1519.416103	4089.532827 1584.411542	61863.592531	2701.373821 893.667088	2020.822758 272.29408	 14673.139792	4149.733783 1600.753265		277.728663 10.462261		338.434 0.02477	303.588 0.062023
27	17.230536	17.124773	17.458637	17.00102	16.876577	16.818185	18.823343	0.420772	9.359446	0.076324	0.130935	0.062023
28	1024.592862	1101.013751	136546.488286	665.1213	347.874298	30140.703774	1106.010372	_	28.375347	10.2657	0.658548	0.575248
29 30	5249.935978 2971.49795	5760.815287 1824.321655		5829.483975 2254.604179	1053.684258 491.149902	 79669.837418	5785.626175 1839.001199		4486.779718 132.323575	5.48546	42.5111 28.8763	74.2423 26.7994
31	9304.898339	9875.69759	-	10253.752576	3989.189179	_	10056.280016	_	15.186167	_	0.020551	0.020091
32 33	19.248901	19.303022	19.216811	19.028952	19.456821	19.919151	21.134376	1.463963	15.381085	0.05454	0.041853	0.040218
33	18.841562 159.455997	19.642667 61.016805	18.683661 542.977231	19.923757 94.955849	19.157135 41.482128	20.178438 488.256295	21.505402 64.536128	1.5154 16525.022981	17.769491 6.452843	0.034067	0.031674 0.020778	0.030004 0.021335
35	18.513988	17.55893	18.766487	18.681309	18.482083	19.148755	20.465321	1.055855	25.52176	1.93097	4.39936	4.13041
36 37	1322.007939 19444.556071	511.235385 33208.941125	_	521.862967 4285.478699	274.964506 3000.032166	24815.806648 55877.869266	515.264016 33894.047594		19.9039 20.10736	0.598744	0.12225 0.035709	0.102774
38	1166.596019	1253.555684		1281.193365	284.96169	34162.225074	1262.033541		106.942367	8.16926	2.55561	2.46503
39	20.474829	20.606662	19.532546	20.017287	20.206729	20.365065	21.709426 21.516486	1.640538	14.6635	0.034797	0.02434	0.023653
40	20.383671 21.409509	20.325921 24.482057	20.084979 111.855449	19.494384 21.432505	19.014032 25.606779	19.658419 82.033509	21.516486 27.280313	1.594364 225.306216	20.013454 46.981821	0.056009 1.2478	0.030512 9.43219	0.031589 9.35792
42	6969.947326	1322.411911	-	1493.134562	1436.008585	4998.30372	1340.290285	-	18.897928	0.037135	0.04114	0.035312
43	2784.55414	621.307346	-	819.098998	505.064143	31306.872391	631.90935	_	19.174882	0.190449	0.063286	0.062209
44 45	904.714361 6234.460796	1005.214738 6847.201473		1032.801646 6991.655589	233.994698 1242.04586	71645.452769	1003.578073 6958.9953	_	317.381621 4810.02683	95.5719 311.977	2.60936 46.5761	2.74642 44.2941
46	1049.039503	395.772375	137478.244692	386.776732	255.787234	4275.473317	402.326423	_	13.257913	_	0.022126	0.021029
47 48	117.913823	135.912274 7584.857998	6963.115274	131.075676 8022.879379	99.223301 8268.005696	3838.904704	140.051575	_	18.230485 12.76014	3.67986	1.13069	0.978477
48	7193.98618 21709.370539	110653.482037		19189 453175	4007.617853		7812.158916 41944.736449		10000,403112	66.4859	0.02024	0.018588 58.6544
50	48.295809	27.669747	562.411484	39.290156	28.51009	53.068544	30.386979	394.740534	10.080901	0.028552	0.060121	0.024461
51 52	16667.285203 3955.6497	4340.890991 958.850776	_	4837.970497 1009.192279	2587.736722 976.760532	— 3227.148247	4441.300195 978.527533		29.838471 15.63058	10.656 0.042461	0.43725 0.03357	0.401334
53	18.61114	18.879499	19.033662	18.953912	19.155658	19.028724	21.197601		10.342269	0.139157	0.03337	0.030233
54	17.494366	16.01538	16.71926	17.64128	16.92803	17.626395	19.689766	0.61638	10.238338	0.449211	0.352726	0.316135
55 56	18.20183 18284.708516	18.262187 19134 33934	18.201022	18.666407 20271.461628	17.727441 20439.294565	18.831151	20.415424 19610.911741	0.88687	22.452138 15.318891	0.876173	0.189905 0.021259	0.169749
57	1204.253097	256.597478	_	352.911412	250.047634	3828.321192	260.909678	=	13.012331	0.056238	0.031704	0.032352
58 59	3878.942162	4492.442517	_	2191.933232	1187.205825		4577.414072		2782.164848	394.597		29.2764
60	13603.906262 18691.111057	8850.114969 22483.012946		6878.292901 19969.556227	1932.926927 3337.307838		9005.543826 22447.026553		1141.847714 391.444578	95.9632	184.311	38.7778 68.8754
61	19.185424	18.225312	18.922194	19.184921	18.867766	19.719237	20.99999	1.245065	10.523151	0.027256	0.07191	0.024729
62	17.612252 2009.408461	18.186858 2140.679113	17.535461 197397.750008	18.199539 2294,759698	17.892125 539.831269	17.911882 43133.142434	20.337714 2175.441184	0.97924	1677.207654 12.678589	931.331	0.022118	60.8032 0.020863
64	128.606121	117.431946	2553.95682	130.317207	118.927534	1990.773653	120.246206	3718.285793	167.700893	41.0649	235.953	212.784
65	2583.61898	2241.621427	297094.040307	1135.772469	727.025187	35792.928971	2267.764591		12.878018	_	0.021423	0.020742
66	449.32368 1209.291928	146.366566 475.085841	107918.606157	196.85044 461.911902	128.033587 292.960166	2351.508069 11885.811729	150.281915 482.884799		11.531659 17.744852	0.060111 0.11685	0.031927 0.065564	0.031314
68	33.380586	29.908496	93.044121	31.202259	28.580185	83.582502	32.179876	172.232818	22.365919	0.301464	1.01638	0.980094
69 70	20.967313 367.492826	20.772257 171.206615	20.331724 1642.108847	19.727171 391.287344	19.956186 170.549052	20.469147 1297.513347	22.340343 173.918609	1.669579 33458 901054	18.086534 117.252065	0.054305 489.027	0.049434 3481.1	0.038313 3257.81
71	24.99341	126.121817	903.129466	26.070249	127.063131	599.086324	41.825819	8607.4523	442.945008	92.4947	8756.87	8207.41
72	225.629862	229.347425	2029.810203	185.267201	177.936091	1764.299924	235.169514	3038.423848	8.960939	50.9325	0.020733	0.024909
73 74	90.271649 19.635722	345.549383 19.582577	18935.034787 18.804487	101.865673 18.817287	298.060082 19.013054	10525.537704 19.933917	168.097165 21.64452	1.291582	396.946236 17.694893	50.9325 0.11648	95.1075 0.086697	88.5057 0.077285
75	777.593488	850.007288	71693.806024	797.497498	870.664316	72271.360916	865.543295	28850.313122	11.838017	_	0.020589	0.022398
76 77	200.468891 124.568559	90.427614 79.204374	26706.79078 9205.566516	117.358515 93.563207	77.43714 63.153803	1199.468193 517.667698	93.83898 82.90211	2302 659393	10.286667 10.453178	0.065938	0.043595	0.039314 0.061305
78	239.68773	83.19051	7901.846934	144.312656	66.86581	1112.989934	87.473142	21337.836906	11.012287	0.147095	0.087841	0.081264
79	18.627963	18.457442	18.352323	18.731774	18.49713	18.731527	20.697632	0.991003	11.619935	0.050706	0.038443	0.033486
80 81	19.049643 356.635406	20.166132 375.867005	19.18098 13528.037915	19.755055 374.745769	19.693606 149.993626	19.653264 3193.757443	21.934615 382.055253	1.418644	15.003794 9.699199	0.052287	0.036515 0.022196	0.038543 0.025043
82	23746.746214	6399.217954	-	5135.413935	1430.660711	144253.553327	6485.921791		18.442181	0.080087	0.080569	0.065623
83 84	19.429648 15931.778242	19.535482 5907.625065	19.370947	19.1612 5265.857592	19.221848 2547.234509	19.181263	21.42699 6002.649927	1.259022	13.012719 358.081501	0.023214 25.2855	0.022405	0.024159
85	3550.203409	3862.667402		4110.276795	968.848053	237490.484923	3863.361022		12.71882		0.020995	0.019676
86	17.426406	16.925029	16.810167	17.292758	17.669078	17.290109	19.602863	0.477387	11.102065	0.082534	0.273026	0.166964
87 88	34.715151 220.159545	28.307099 222.199615	72.006696 5433.40993	34.322875 222.003631	28.83422 221.235334	94.973141 5422.083831	30.633266 225.869362	429.933907 1816.188841	33.173695 10.842513	3.05685	2.20391 0.022756	2.18218 0.018413
89	17.837425	18.053809	18.048761	17.699905	17.800165	18.618625	19.702445	0.747664	8.619019	0.049015	0.038805	0.036929
90	108.382286	146.428219	1559.755128	62.094148	70.229878	431.975927	151.219893	23802.570888	14.852793	0.438277	0.133108	0.123532
91 92	11863.633416 23629.802256	670.161033 7321.933132	=	1071.22681 7063.506575	372.299212 7028.318803	5891.816224 39253.955018	677.600063 7401.736602		15.115988 24.578779	0.070214 0.081757	0.050211 0.053515	0.044162 0.047798
93	70.43492	73.848192	1106.648256	72.390541	71.77538	500.713685	75.743672	5808.641036	24.768374	9.90021	0.990539	0.962736
94	137.392352	327.15854 4663.97851	7024.158072	150.682286	343.767785	7146.513298	263.673748	26836.05506	9.788042	<u> </u>	0.02116	0.019072
95 96	4335.797672 18.693188	4663.97851 18.98534	18.901924	4878.208593 19.274475	976.523467 18.956925	— 19.176934	4761.433108 21.186712	1.545231	1556.641373 12.1075	0.029937	45.2737 0.026583	40.3999 0.024163
97	59.444051	56.814887	2770.254471	62.258289	49.475093	720.415206	60.562269	58108.463046	29.122142	0.38621	1.79193	1.80976
98	19.101489 17.962762	19.332099 16.856812	20.014669 17.149568	19.978005 18.312306	19.740154 17.994335	19.961741 17.928682	22.258343 20.359847	1.888736 1.207551	16.533036 9.143653	0.085834 0.027502	0.035732 0.025445	0.031881 0.034946
100	9146.47612		-	7072.342539	5795.497969		10862.566981	-	272.586767	63.7672	70.1691	12.3616
_												

Table 19: Results on Random Syft 02, 100-200, time in milliseconds.

name 101	Nike Hash True First 1893.295514	Nike Hash False First 2124.460514	Nike Hash Random	Nike Bdd True First 1938.579287	Nike Bdd False First 1702.496663	Nike Bdd Random	Nike Multithreaded 2154.451071	Cynthia	Lydia 434.622776	Lisa Symbolic	Lisa Explicit 655.528	Lisa 107.261
102	2319.958785	846.097249	_	844.271099	518.399692	22340.772101	858.199308	145879.742948	12.540078	_	0.022875	0.024112
103	144.770494 18.659551	165.784182 18.373764	7679.685127 18.109879	158.743126 18.437595	116.606741 18.390078	361.039836 18.653903	170.732243 20.269547	1.430386	97.028037 10.908449	1.5045 0.083266	2.49803 0.045452	2.38788
104	133.218373	165.405762	12514.192894	97.025729	69.989218	605.606859	174.44256	1.430360	10.511282	0.083200	0.05796	0.056922
106	62.570635	59.888824	790.981212	62.905215	61.995424	586.848967	63.477016	1159.876483	161.391046	30.2802	10.8114	10.4937
107	603.904043 18581.952243	641.253886 19053.028961	110485.987951	621.13678 3894.69085	621.855499 3144.082299	73897.325208 45178.40042	653.651782 19617.251982		330.434515 32.155439	352.153 0.051518	261.918 0.047105	243.038 0.02895
109	322.742314	107.464257	7343.486179	210.92186	66.714149	2192.387368	111.058221		20.780582	0.892174	2.55266	2.3162
110	2793.674467	2956.476709	_	2824.535447	2911.305814		2977.935352		27283.088914	_	_	200.262
111	17.556391 1660.138427	17.290686 2055.670734	17.371601	17.469615 1048.220752	17.183872 569.571937	17.307855 256801.197538	19.304667 2088.175957	1.135934	11.546653 582.059454	0.259431 1203.95	0.156717 161.263	0.139262 152.637
113	1163.112365	1245.85179		1285.179322	285.133541	34237.344325	1262.631791		107.896886	10.7745	2.54548	2.69736
114	750.029753	2289.063798	-	581.518801	365.847412	5402.651219	1392.136485		14.414567	0.175487	0.141569	0.119784
115 116	10693.369505 506.128836	11509.979758 541.053207	167453.375152	11783.815718 596.657327	2188.126635 150.629919	8429.15418	11760.873203 547.011365		3115.907412 51.472661	2,58593	120.647 0.801641	113.506 0.766391
117	19.061023	18.958967	18.761046	18.958723	19.101531	19.219031	21.083585	1.765207	23.796874	0.302163	0.117473	0.088349
118	93.104075 440.807987	89.11147	2122.936073 247211.907434	83.873066 473.511263	78.478125	1155.189164 93787.413506	91.956726 850.329553	19237.218082	9.286089 185.092912	429.215	0.020131 316.074	0.018569 282.526
120	324.450883	1146.292145 358.766301	247211.907434	344.09409	782.72827 119.91857	9926.409959	364.107634		10.601809	428.215	0.021203	0.021725
121	1557.17222	8690.244926	_	1439.946105	671.588515	91520.197268	2917.338481	_	307.63509	6.04039	230.78	190.964
122	18.827312 13418.081894	18.810114 14313.49923	19.200876	19.299457	19.828795 2469.992358	19.647516	21.707486 14573 282937	2.047421	13.474204	0.024283	0.025784	0.027236
123	238.518254	620.763738	76932.764954	253.04159	253.365045	5072.954847	453.689307		61.503684	1.1293	5.35618	5.09353
125	36671.70772	1081.049377		2467.468681	273.853646	2180.573976	1095.083289		12.752069	0.045941	0.025633	0.02692
126 127	2520.031135 56.579959	690.181101 68.609626	169350.219546 1592.897634	1078.599959 68.230954	203.2541 51.139625	39768.687156 287.31449	705.183819 72.27534		62.970359 10.616078	13.9433 0.117838	4.14191 0.199226	3.94596 0.19051
128	453.144634	1008.103438	-	220.731603	200.590131	3566.068463	849.761536		14.049378	0.079409	0.055745	0.051642
129	20.297997 256.486378	19.860686	19.95314 7650,730453	20.391722 272.87958	19.822262 118.010589	20.797076 4985.0397	22.357116 277.945204	1.858983	17.976851 9.351083	0.026479	0.025392 0.019071	0.02748 0.019738
131	17.331404	271.106166 17.947864	18.013265	18.04269	17.672756	18.326432	20.013773	0.729705	90.912479	7.00272	1129.04	1034.04
132	22.203293	52.546093	488.437332	23.135442	53.199206	383.165014	37.240201	1103.248408	111.502757	119.236	1347.79	1230.21
133 134	16.269576 1119.069705	16.639573 1247.872149	18.414655 43739.047134	17.505682 772.38457	17.197829 936.716453	17.987799 30018.712714	20.19382 1273.590533	0.617601	67.064782 12.844641	3.69534	13.4343 0.020405	13.2136 0.019785
135	19.964301	19.735497	19.872711	19.948527	19.955943	19.882377	22.599307	1.932033	19.600965	0.072705	0.020403	0.019783
136	17.400066	17.030299	17.538979	17.573989	16.636702	17.462557	20.244655	0.721784	7.962425	0.046583	0.032631	0.031587
137 138	17.799578 18.575722	18.420587 19.066193	18.425099 20.447542	19.299427 20.013841	18.424741 19.845466	18.509158 19.672203	21.970846 22.66037	1.340391 1.855618	13.545084 22.133657	0.056421 0.024905	0.033062 0.025523	0.031675 0.023365
139	87.12556	77.929919	2439.087484	71.782341	53.294797	348.220088	83.522583	4539.820639	7.857572	_	0.026101	0.019873
140	18.961644	19.70638	19.433043	19.157042	18.773367	19.389279	21.875079	1.369682	11.947425	0.023506	0.02474	0.022579
141	18.968232 1562.276252	18.444068 8663,909709	19.496264	19.3366 1433.28004	18.567722 671.100111	19.06394 91408.481569	21.630268 2935.517799	2.068988	14.70138 306.6649	0.057739 5.9713	0.027245 212.462	0.026235 201.513
143	17.482322	16.894645	17.950643	17.572241	17.678651	17.94416	19.45001	0.629095	12.643728	0.774173	0.602218	0.548826
144	3871.608361	4073.848668	255529.746128	4367.329742 8091.42799	1623.740803	215816.2112	4143.724794	_	13.393991		0.023676	0.019465
145 146	61508.307891 2003.651185	8000.421511 1269.266757	44344.314239	8091.42799 1016.759551	7382.412823 924.47249	48618.943092 19068.79487	8090.019175 1286.483198		25.067239 12.708032	0.08741	0.067437 0.020151	0.063397 0.019289
147	87.305802	65.581928	395.954988	68.381499	51.224319	436.571172	68.109885	209.369222	8.38179	_	0.019722	0.022764
148	18.037622 19.355999	17.597687 18.033032	18.569963 18.41511	18.22432 19.291566	17.698549 18.756131	18.206054 19.960798	19.893386 21.148663	1.134664 1.251684	16.526436 12.877941	0.274908 0.029778	0.2003 0.026794	0.158469 0.027145
150	84.448715	151.407813	6765.250901	72.912806	86.831925	393.757766	153.496304	1.231084	10.503384	0.063149	0.026794	0.027143
151	3744.658726	20333.524252	_	3442.480905	1097.100708	189495.823578	7110.047102		737.181534	12.5258	475.563	435.339
152 153	18.214688 18.247536	16.585916 19.12657	18.326859 20.083726	18.037068 19.565331	17.972869 19.288319	17.904444 19.279591	20.340294 22.033812	0.935692 1.54521	487.791834 15.669933	82.6521 0.024932	66.8504 0.027162	62.373 0.022971
154	18.498561	18.096996	18.721186	19.328503	19.770436	19.670747	22.23537	1.264265	27.532433	0.286333	0.107379	0.091185
155 156	7252.810102 572.087686	8798.484896 173.114973	167899.776234	7844.155042 215.627096	1428.113067 151.007894	1709.729615	9011.163913 176.949038	286015.364551	906.072538	14.2613 0.054649	206.812 0.033825	187.362 0.027348
157	83.248256	30.76489	2237.874494	47.885102	32.802423	141.470102	33.680896	521.916687	9.352752	0.037447	0.033823	0.027348
158	6248.167087	799.736758	_	1325.532016	887.849494	6931.900882	806.873732		19.320009	0.035002	0.030806	0.028527
159 160	16.54009 218.054669	17.795498 225.395863	18.033105 2668.750154	17.884388 234.490695	17.685597 240.020209	17.735938 2750.609021	20.174523 229.060529	0.849426 5984.972326	10.709011 8.560967	0.10109	0.075234 0.024088	0.067039 0.019312
161	1887.905482	2035.753627	2008.730134	2128.192337	456.154257	195742.146204	2069.21078	J964.972320 —	13.140964	-	0.024088	0.019312
162	24.474929	69.743711	765.730148	25.664107	70.889679	375.92149	41.153659	9538.621593	274.186257	74.8452	1497.73	1390.83
163 164	18.205906 12985.777093	19.013974 6792.482676	19.789232	19.788377 4022.689273	19.402011 6775.120583	19.433696 23654.671747	21.504058 11111.188488	259603.395033	15.882312 20.814716	0.124762 0.057976	0.062841 0.043975	0.059927 0.037036
165	18.106679	17.860624	18.069532	18.250189	18.249112	18.228034	20.05165	1.046052	9.807512	0.025262	0.032629	0.03871
166 167	1534.249197 16955.528934	1785.505537 2960.858761	_	1001.252131 3986.209745	530.842378 2784.731247	185399.937362 119864.028568	1820.219424 3012.407971		354.835038 30.405663	69.24 0.197832	157.558 0.060413	6.3675 0.053287
168	61.263992	63.062745	670.791093	63.904099	64.84201	676.518251	64.897966	415.492053	8.327135	0.197832	0.000413	0.033287
169	769.874747	3663.990336		590.316632	385.80413	11133.915241	1438.971334		14.377549	0.170903	0.14449	0.131732
170 171	2447.596788 20.318521	2416.167282 19.825925	20.041818	2862.114346 20.470964	543.992728 19.706759	 19.895546	2460.62894 21.944788	1.598868	444.626651 15.590935	398.9 0.026156	37.3955 0.025404	34.4995 0.024914
172	6861.531362	1240.031394	_	1684.859559	1235.016231	11432.234105	1249.445473	_	19.002806	0.032032	0.028518	0.025343
173	19.431865	18.964024	18.872808	19.249141	18.954118 3434.8358	19.393496 26361.705929	21.095446	1.207846	11.060395	0.05889	0.037824	0.034852
174 175	8399.467604 20.39012	136368.306472 20.01375	20.179135	1961.254819 20.389824	3434.8358 20.442884	26361.705929	16036.95932 22.256898	2.010696	14.863648 19.306095	0.023035 0.051426	0.022007 0.030485	0.028874
176	444.448675	114.269532	43006.827247	327.36741	57.510683	2848.599313	118.04581		41.036203	0.268135	0.445849	0.473477
177	24644.011233 1083.085537	23109.386453 247.223854	236945.023807	14749.645029 328.248064	5733.108809 252.994388	1991.111028	23663.261367 252.978785	39455.456817	494.981389 12.78484	2.13438 0.018993	1.91645 0.021347	1.86911 0.021523
178 179	4087.141365	247.223854 4402.065801	230943.023807	4570.853776	937.371562	1991.111028	4482.277197		12.78484	0.018993	0.021347	0.021523
180	17.717758	17.129116	17.801177	18.286782	17.740305	18.121657	20.204427	0.942595	9.063687	0.057409	0.042091	0.049349
181 182	94.312492 58.909461	34.419263 63.53549	3067.786161 1459.339026	64.632634 70.30898	44.526318 58.693066	80.147739 764.847473	38.403303 67.321623	7300.489236	10.361032 21.335163	0.038387 0.937392	0.032492 0.254591	0.033308
183	5438.985266	6933.124619	_	5869.082228	1584.711857	_	7044.187287		1084.008903	89.3043	_	72.804
184	17.974956	17.604699	18.225361	18.205567	18.102789	18.138763	20.220323	0.963797	142.248974	98.6547	119.5	117.382
185 186	2599.872649 18.235893	2239.054616 18.956267	298560.364325 18.582173	1130.590665 18.908974	725.099306 19.113273	35827.873954 19.231068	2269.801569 20.859973	1.192543	12.26315 16.301141	0.109756	0.021574 0.096187	0.024855 0.070894
187	8034.055522	8413.509611		9016.949259	9104.148836		8528.469025		14.185462	_	0.021335	0.018832
188	15720.015718 7010.763393	17017.987534 4993.441765	_	16562.387396 6423.034665	2777.074031 950.719154	_	17330.890842 5088 930808		430.484482 106.509693	219.924 8.20707	53.9162	22.4331 49.5487
190	104.354625	61.522434	2522.214944	82.739685	51.480849	1244.5166	65.2019	1146.297857	81.225863	0.591436	15.7432	15.1563
191	19.43745	19.907392	33.883081	20.556387	20.051552	28.364187	22.116688	38.911868	14.276463	0.094043	0.520541	0.46681
192 193	25.850773 546.188391	245.703502 221.932079	2318.133847 105716.732423	36.623975 248.376202	247.091989 143.962472	543.416613 7360.092713	46.35037 226.720461		191.854669 17.369051	58.7659 0.23062	1561.92 0.067343	1416.25 0.066995
194	126.383501	128.379448	216.356056	94.48065	86.522107	232.209295	131.78043	1292.598908	8.42389	_	0.020408	0.019688
195	23038.51963	 17795.923146	-	4953.251996	5683.807077	65565.887905	43784.778239		21.28359	0.037978	0.049457	0.03369
196 197	16972.804761 17.914756	17795.923146 18.417526	 18.413838	18572.343079 18.285834	19182.642253 18.071416	18.397896	18079.836417 20.025909	1.008716	13.89295 8.511284	0.027657	0.021158 0.023506	0.023478 0.028131
198	5436.900779	5841.854009	_	5832.70619	1122.046241	229762.731348	5874.823302	_	14.345949		0.020461	0.02347
199 200	46.73356 18294.477602	51.007011 10913.063188	362.852413	49.985269 5894.223411	52.384179 3385.880089	369.307416	51.902771 17562.290062	270.988981	7.759925 43.436186	23.8899	0.019915 0.990356	0.018336 0.85296
200	10274.477002	10913.003188	_	3074.223411	2202.080009		17302.290002		43.430180	23.8899	0.770330	0.65290

Table 20: Results on Random Syft 03, 0-100, time in milliseconds.

name 1	5188.103402	Nike Hash False First 132263.301164	Nike Hash Random	4180.54409	2711.475735	Nike Bdd Random	5342.515073	Cynthia —	Lydia 78.270212	Lisa Symbolic 1.10837	6.9235	4.49524
3	105948.080231 19.265656	1316.554382 19.662589	20.12297	25574.821837 19.936581	1300.172417 19.238229	 19.713098	1346.357127 21.89371	1.448557	25.187672 14.246965	0.220906 0.063966	0.450101 0.029014	0.396162 0.033395
4	233,067626	243 093066	42490.74027	171.539432	186.165276	1894.872473	254.627278	1.448337	13.381828	0.159445	0.029014	0.033393
5	45.987631	43.572294	43.56121	49.200354	47.383417	47.982572	47.897064	351.33871	19.11144	3.26319	5.61274	5.38125
6	16225.575144	1317.145448		3527.678918	1404.144196	48471.777664	1347.228569		26.177785	0.066827	0.043084	0.039006
7 8	491.301194 7187.974353	227.206716 7621.506997	157146.942522	204.606569 7726.176755	88.506694 1308.297586	2392.068684	234.019052 7819.265315		12.294267 21002.995631	0.061251 384.041	0.043303	0.031415 48.5037
9	3903.415906	902.45203	246099.290463	3714.069421	935,838864	205175.529418	925,958384		12.551581	504.041	0.106661	0.019967
10	1926.266914	544.98582	_	1058.920526	213.272974	60194.582035	558.747681	_	703.588207	100.435	513.279	7.60559
11	32.393772	133.87675	280.365328	40.486832	136.123275	397.773856	58.533279	7877.729223	68.959669	19.7827	134.174	116.071
12	114.601265 16.742854	70.563451 16.833951	3965.29635 17.318593	86.676466 17.446383	61.789695 17.290594	286.836891 17.136917	75.978006 19.634112	1.048952	9.056456 26.806175	0.04561 0.415625	0.032771	0.032238 2.8255
14	447.88612	125.286317	36818.560445	227.610468	92.651685	2963.69477	130.201464	-	11.229178	- 0.115025	0.021606	0.021899
15	81.702213	81.709404	3025.26317	94.550918	93.438311	3234.99572	86.08585	6896.689925	8.971957	_	0.021226	0.020501
16 17	64.675298 24253.162615	566.998004 17633.511367	40483.808778	68.587705 10457.292991	566.764283 4109.395691	6033.465967	119.185958 18424.064685		155.860764 39605.754749	11.3891	514.987	472.484 160.528
18	27398.615095	17681.888495		19440.468703	3136.588642		18420.072258		11285.037872			385.615
19	705.310967	295.721426	156372.035116	327.783939	193.463556	8838.871509	305.038122	201334.030296	24.243047	0.176193	0.389631	0.343872
20 21	866.869609 24262.949926	611.527261 8077.107961	613.204937	795.321798 6088.529978	687.746504 4524.733224	690.685853 152505.712774	684.251288 8258.635133		14.652677 16.404068	0.099089 0.064872	0.108866 0.046853	0.095907 0.040966
22	2875.969403	494.564016		979.418292	362.99482	35349.615704	504.60767		17.919814	0.193951	0.040833	0.106673
22	10741.172878	1552.87021	_	7590.420448	1486.210677	261019.946385	1597.041116	_	52.981284	5.96844	16.823	16.8125
24	13908.973493	13857.768371		3265.783669	2490.041992 4545.995774	110726.813524	14270.917986		19.209188	0.104807	0.037953	0.035551
25 26	5612.124865 39.774385	5305.731519 215.008261	913.700459	4719.55815 38.919523	4545.995774 212.273371	4563.167434 1063.564356	5923.171722 71.141653	3142.028738	33.272102 7.895257	0.533558	2.07766 0.021943	1.97717 0.023455
27	17.795033	19.068347	19.2772	18.484254	19.329324	18.94861	21.425516	1.28562	13.199203	0.024995	0.028315	0.021239
28	9100.124189	9704.634548	_	9950.295623	2285.476192	_	9941.550457	_	13.397989		0.020976	0.031773
29 30	2760.819133 3060.53097	2297.352538 2555.164525	=	1429.892457 2772.268379	730.632321 2154.349232	54783.663963 73832.980579	2317.226833 2569.791781		13.521183	0.065866 4.29509	0.056464 8.67329	0.05303 8.69821
31	2020.181293	2352.85466	135202.107443	786.750043	326.430818	20733.380992	2387.500471	_	10.000203	_	0.022614	0.021994
32	19.803336	19.197516	20.183863	20.468526	19.831914	20.63374	22.093122	1.786628	18.549058	0.059556	0.031073	0.029407
33	4652.762127 6567.251089	2603.244519 6873.185586		2139.477858 7303.03139	810.064417 7529.98848	239104.291019	2633.56519 12791.006652		32.436064 11.010109	13.3393	1.07155 0.02082	1.02289 0.019449
35	4119.774704	397.144603		1553.697113	7529.98848 232.885011	45887.214993	411.379643		16.465219	0.424391	0.02082	0.019449
36	19.042594	19.426719	19.867453	18.976419	18.939021	18.821977	21.95617	1.221579	12.062694	0.064642	0.048923	0.040546
37 38	3218.148149 4879.705248	1218.677647 3490.119883	_	1180.694413 3567.224364	660.817335 825.315336	37267.271377	1256.084589 3556.242988		13.236037 206.140868	0.212089	0.045813 31.4975	0.048694 27.4378
39	36303.328962	1091.72555		9623.64872	1069.543032	70164.18722	1104.826282		19.621199	0.089789	0.104019	0.087405
40	4562.60434	241.539438	_	1801.074614	236.30825	16042.723269	247.878623	_	14.469067	0.029166	0.025176	0.029019
41	221773.718104	7078.61951	 1746.975225	14176.314477 62.059114	3698.945173 165.235624	98760.140956	7212.100181 121.011161	12007 08172	42.673872 1321.364731	1.84769	2.77968 3703.43	2.77672 46.9985
42	65.379993 61.527722	167.209798 54.972558	2502.287694	56.048218	51.495449	872.805805 1140.92919	60.411041	12096.081652 44715.099255	272.426668	916.47 13.3003	454.471	411.131
44	27165.733126	29062.051653	_	13683.054313	1878.534726	_	29871.317978	_	20.500766	_	0.019967	0.023826
45 46	19.323011 402.990242	18.654872 454.808077	19.546097 56934.84436	19.608846 255.705959	19.940917 224.441692	19.52465 2464.46435	21.714395 466.787074	1.53815	13.688054 13.114165	0.024977 0.128325	0.024285 0.149283	0.02218 0.147463
47	6780.714196	372.255027	J0934.84430 —	2001.630947	286.217683	25498.996278	379.575062		19.753121	0.128323	0.149283	0.147463
48	135.101681	1613.400395	30795.964209	145.276406	1623.841671	30680.33695	255.584035	96851.282852	11.295299	_	0.020674	0.023578
49 50	1010.01531 9732.122356	1087.331265 10061.941908		1120.87349 9593.962119	278.545162 7575.22732	35226.800143	1105.788643 10267.276829		47.237391 173.201179	28.7316 1086.84	24.2151 381.213	22.2475 347.662
51	637,908698	355.712314		354.041482	152.812443	13570,890697	364.546338		13.351662	0.945877	0.189279	0.133011
52	24.440258	96.73444	215.016986	26.32711	104.313116	311.267674	41.935894	9436.841663	51.309029	39.0554	86.1684	76.6603
53 54	198.500023	543.029971 606.422317	11433.113397	134.198393	506.69816 480.214534	6871.229211 8338.786801	378.280379 624.047366	67583.400448	10.797168	0.207999	0.020078	0.020173
55	1250.476569 18.049369	18.688721	110769.319036 18.77427	635.366011 18.874233	18.576223	18.356268	21.124026	0.980078	14.561647 12.778696	0.207999	0.167659 0.067998	0.168371
56	84.763583	535.363913	22048.299234	96.921594	499.972761	9976.324943	157.913056		9.286211	_	0.019421	0.01884
57 58	47888.024204 3881.882266	81430.305778 1938.577524	_	11184.993533 4435.591229	3379.033103 436.737585	84800.256956	84147.607543 1962.721492		16.969797	0.037823	0.027888	0.024028 0.019012
59	343.231263	64.045197	33586.574231	226.162763	52.662726	3252,43086	67.015235		142.127575	1,29371	23.2817	20.7253
60	94.758951	200.561972	2056.784792	72.991676	193.159744	1807.325752	179.4764	21426.041358	371.509626	35.7963	4491.22	66.3832
61	315.45533	200.185702	37376.402384	185.659254	134.465823	3847.411924	205.645399		26.94032	0.195494	0.967774	0.84598
62 63	10838.82929 7437.622306	5923.060286 8931.001651		8065.893551 4143.007686	2875.983905 2924.589396		6096.108593 9183.824954		16.111869 16.149021		0.026684	0.019309 0.019494
64	17.69416	17.747718	18.037804	17.554874	18.146544	17.930544	20.171984	0.748267	8.241555	0.033825	0.034825	0.032
65	5221.899229	2296.56443 17.497496	17.59718	2357.674355	1300.725739 17.432247	17.708103	2353.89615 19.669398	0.767388	175.713085	2.77468 20.946	11.1913 1331.99	11.114 1247.94
66 67	17.467616 17.230968	16.981399	18.229106	17.789206 18.77413	17.751682	18.362813	21.313296	1.175862	200.458165 94.081073	14.9712	6.27967	6.18562
68	15.748373	16.39222	18.045609	18.224088	16.975071	17.081986	19.884748	0.710574	7282.464025	1810.88	_	813.171
69 70	15.852497 1986 320347	17.099387 2113.515868	16.438122 94045.844991	18.087967 1907.165409	16.787283 1993.169058	16.935605 43813.452633	19.749176 2168.562643	1584.58411	66.445364 13524.615386	117.613	1128.4	1012.46
71	1986.320347 2775.754809	3051.914163	94043.844991 —	1542.566243	662.097241	43813.452633 274024.692977	2168.562643 3113.052237		201.422725	199.602	7.34033	313.815 6.71268
72	682.356981	1834.489056	_	280.223395	1700.785809	90997.001993	1317.514092		53.808895	23.5293	22.3276	19.3326
73	12017.490909 26855.21214	11184.417809 6841.211334	_	3961.200307	2595.917843 2660.699542		11460.266073		13.028386	_	0.022536	0.02326
74 75	26855.21214 48.150176	6841.211334 744.326413	22204.1389	9669.875691 42.227493	2660.699542 752.523359	17744.960884	6962.592823 87.518116		12.462586 3398.932213	5110.98	0.020765	0.01996
76	1100.851875	401.085573	39706.968675	1076.035798	398,591663	45369.654329	405.811727	113652.264577	592.931196	206.699	4077.9	75.8544
77	17316.924829 1899.706821	11222.430886	_	6517.707014	2233.736514	20374.45049	11533.41836		1352.34515 30.685097	-	230.144	37.3085
78 79	1899.706821 19.716765	492.607377 19.353361	19.279231	1030.001657 19.464262	346.556582 19.589282	19.386486	503.839595 21.595342	1.346945	30.685097	0.25436 0.396668	0.642067 0.199439	0.574638 0.170212
80	17.724154	15.964294	17.837401	16.899656	17.834614	16.992366	19.886882	0.726234	8.551355	0.027568	0.028015	0.026941
81 82	79.45386 1606.982268	60.723339 1365.041351	2631.107916	81.972893 1106.655029	64.890423 476.102552	2369.413961 41050.080994	66.065193 1357.06199	694.808335	9.315012 811.354642	— 16.8427	0.022854 439.128	0.021067 408.152
82	43915.974405	10550.386214		12003.900307	4470.507564	410.00.080994	11244.468648		2574.257109	37.0065	439.128 14.1866	13.5071
84	4354.173859	2322.799714	_	1655.704684	722.744187	94082.871443	2368.684344		23.924779	2.01954	1.15394	1.16925
85 86	1978.647246 12467.581593	362.457297 2923.257919		830.36373 4160.083648	310.203616 2815.948213	17596.240346 107405.874382	371.821398 2952.479219	108475.565513	12.544578	0.064957	0.040562	0.038264 0.241168
87	28.207428	62.908588	105.86551	31.288094	60.461353	107403.874382	50.599684	1572.032877	65.231726	8.01234	188.203	163.495
88	4122.279012	4798.178722	_	2945.158012	1243.657471	_	4880.537416	_	14.315506	_	0.020144	0.019897
89 90	19.228092 20582.032218	18.606449 13156.245401	18.847573	19.658036 7829.198582	19.103798 3739.45358	19.464135	21.601989 13499.610877	1.307729	12.178001 1426.590005	0.035302	0.027536	0.022438 32.3332
91	42.21637	195.660654	2034.876615	36.467509	187.380017	1515.646013	74.482944	3415.514159	28.488278	5.6953	7.63679	7.43229
92	6902.830781	2954.760333		2435.903581	617.082745	_	3026.054143		320.349189	7.87659	0.670694	0.653867
93 94	2352.061205 53.457665	678.986815 56.063513		1953.155772 49.557852	575.68895 51.166836	239981.392441 355.454469	698.452804 58.374138	1254.429242	616.280426 15.777084	297.877 0.466024	0.226092	96.8386 0.2019
95	26.16463	24.116394	227.070036	27.778917	26.066628	61.044051	27.775256	359.673758	60.25719	1.469	5.0309	4.93839
96	527.046429	1950.064476	32022.874137	527.358873	1958.215973	8889.282213	1014.525626		9470.276692	_	_	820.594
97 98	518.340369 9314.932917	327.47001 3533.488929	10483.415883	406.639017 2932.104508	183.659189 1628.060468	7189.665346	331.926341 3574.106978	21812.749276	10.033403	5.6222	0.067819	0.019266
99	28.899465	32.493796	198.937913	29.80466	34.06762	76.21039	35.504701	6320.540737	133.386275	0.697653	136.849	126.866
100	1518.781361	4658.010297	179855.565164	488.149134	1686.29256	82781.842496	2981.330071		10.819517		0.020573	0.019856

Table 21: Results on Random Syft 03, 100-200, time in milliseconds.

Dec. 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975 1975	name 101	Nike Hash True First 371.12851	Nike Hash False First 147.818981	Nike Hash Random 10690.126604	Nike Bdd True First 397.076257	Nike Bdd False First 138.739578	Nike Bdd Random 2279.263585	Nike Multithreaded 152.011757	Cynthia 80864.237136	Lydia 3575.094001	Lisa Symbolic 461.358	Lisa Explicit	Lisa 1177.9
December Phi-2002 Phi-2002 Phi-2002 Phi-2002 Phi-2003 Phi-2003	102	63.73732	97.00888		57.05748	85.436514		100.213576		9.482275	_		0.01983
Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec Dec			3496.971662				— 1941 166494	3557.506868			0.242074		
1.00				- -							0.343074		
ST 12000	106	36.962905	27.474348			24.850223	255.308462			20.487993		0.212219	0.193576
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10 10 10 10 10 10 10 10				_			32586.529517	7220.548149				0.463357	
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1460 1461 1461 1461 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462 1462	144	27966.927295	16861.847786	_	12854.555852	5903.250913	-	19063.56082	_	634.916272	6.193	50.6783	42.1672
148 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1985 1	145				41.678434	92.25376			907.498676	22.018499		12.2191	
149 189 1815 110,538904 200,5189018 214,44767 60,39811 260,113,0165 112,707175 — 33,59905 31,1267 142,128 1387275 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 12				54266.895673			3348.472722					1.61968	
150 20.56632	148	199.185154	110.539894	20025.186918	214.44767	60.39831	2679.136205	112.707175	_	33.399005		1.43285	1.38725
152 1802-044 18.22-881 1.27585 1.83509 18.4522-841 1.27585 1.83509 18.4522-841 1.27585 1.83509 18.4522-841 1.27585 1.83509 1.84522-841 1.27585 1.83509 1.84522-841 1.27585 1.83509 1.84522-841 1.27585 1.83509 1.84522-841 1.27585 1.83509 1.84522-841 1.27585 1.83509 1.84522-841 1.27585 1.83509 1.84522-841 1.27585 1.83509 1.84522-841 1.27585 1.285809 1.84522-841 1.285809 1.84522-841 1.285809 1.84522-841 1.285809 1.84522-841 1.285809 1.84522-841 1.285809 1.84522-841 1.285809 1.84522-841 1.285809 1.84522-841 1.285809 1.84522-841 1.285809 1.84522-841 1.285809 1.84522-841 1.285809 1.84522-841 1.285809 1.84522-841 1.285809 1.84522-841 1.285809 1.84522-841 1.285809 1.84522-841 1.285809 1.84522-841 1.285809 1.84522-841 1.285809 1.84522-841 1.285809 1.84522-841 1.285809 1.84522-841 1.285809 1.84522-841 1.285809 1.84522-841 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809 1.285809			5666.422156		10352.512364				1 012514	69131.784099	- 0.049526	- 0.074967	
ST ST ST ST ST ST ST ST				19.333106			189227.524203	536,417356	1.812314				
155 365,14922 124,073365 18,991,998 199,259999 179,45254 7425,020326 695,14022 98,74381 204,037 296,418 234,697 155 585,414928 140,047099 94,953,4596 336,56296 101,974762 2325,560686 140,04709 140,047099 75,757,7023 140,047099 75,757,7023 140,047099 75,757,7023 140,047099 75,757,7023 140,047099 75,757,7023 140,047099 75,757,7023 140,047099 75,757,7023 140,047099 75,757,7023 140,047099 75,757,7023 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 140,047099 .	152	18.032614	18.282481	17.275853				20.506335	1.091015		0.627372	0.424098	0.391162
155 368.341932 1240.67365				29039.802759									
158 17.41466 17.518719	155			_	333.557052	920.786965	6103.260232			7675.398026	1027.06	_	101.225
158 17.441466				94595.34596					_				
159 100.910337				17 313773					0.694132				
161 666-75599	159	100.910337	42.393191		84.755976	40.833939	734.446088	47.970135		12.980888		0.098455	0.071453
103 913.814206 6454.43888 2223.107347 777.826248 148.94283 7133.038098 656.655932 84490.064136 8.186335 0.0193786 0.0193786 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937187 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937187 0.01937186 0.01937186 0.01937186 0.01937186 0.01937187 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186 0.01937186				-							-		
164 349-569452 2168-20208				23223 107347	380.384973 777.826248	148 94283		656,655932	84490.064136		0.152966		
166 \$537,019507 \$197,711397 \$4907,2294703 \$391,506359 \$110,371257 \$406,1841204 \$202,635943 \$70832,857751 \$10,399112 \$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$	163	91.418574	93.621776		86.432444	63.955365	844.896116	98.880156		18.092836		0.281016	0.248638
166 3307.018527 2428.334425				0407 204702					70922 957751		13.4962		
167				_					_		0.091524		
199		18.87278							1.452607		0.024848		
171 909,9797625 651,866637	168		352.84631 777.684129	3082.24085	245.633471		5384.436642 8352,529165			10.216231		0.020298	0.022176
172	170	2283.619554	2654.85618		1878.878117	1928.761682	-	2706.283598		4009.203172		_	75.0224
173	171			51580 175200							0.510611	0.84711	0.718293
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$		1214.716419				327.359516			277482.718818		 	0.02263	0.021151
176 20.136186 19.820758 19.4811 19.87877 20.088255 19.622621 21.46986 1.6742 15.089687 0.032774 0.066218 0.022463 177 105.338604 1007.530688	174	8308.346052	115358.000891		9027.655561	9871.660201	_	16115.743133		1444.195722		- "	16.5491
177 1057.338604 1007.530688	175			19.4811	1149.689732		96252.392235	1942.763208	1 6742			0.066218	0.023463
179									1.0742				
180 17.966472 17.532438 17.435862 18.101091 18.54871 18.1131 19.755559 0.980232 3668.39919 54.003	178		1639.65251		1745.783243			1655.170856	_		_		
181 129402128									0.980232		540.03	0.021462	
183 32,497706 27,461618 140,107789 33,696268 26,153255 76,3018 29,743684 3367,019401 10,043979 0,123385 0,050397 0,046963 340,185766 148664,832981 222,174508 3371,934319 10,1480,204841 62,2593886 — 3787,8794585 — — — 3065938 188 232,133 185 431,282186 186,27514 71,090,213294 215,245429 188,232133 413,28566 192,07789 — 10,8325791 — 0,066988 0,21588 186,2751,147056 1942,240746 — 3063,020308 639,808915 188,232133 413,28566 192,07789 — 10,8325791 — 0,066988 0,21588 187,241649 1912,626247 — 2217,712769 1061,514424 111192,686651 1942,066927 — 19,696347 0,147109 0,078575 0,056677 188 720,102182 363,324605 — 45,7474788 309,614133 1289,1638109 371,169831 — 13,105237 0,06451 0,056503 189, 189,00683538 988,190865 — 6527,663867 1998,008414 — 30,800,84358 988,190865 — 6527,663867 1998,008414 — 1,048,108,108,108,108,108,108,108,108,108,10		1294.02128		_	556.86533	849.099404	7058.788527		_	11.209379		0.033598	0.036905
$\begin{array}{cccccccccccccccccccccccccccccccccccc$													
185					222,174508				3307.019401		0.123383	0.030397	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$		431.282186	186.27514		215.245429	188.232123		192,07789		10.826791		0.060988	0.021568
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	186					057.000715	111102 686651					1.70754	
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$					549.774788	309.614133					0.128527		
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	189	18900.688358	9881.900865	_	6527.663867	1998.020841	_	9982.326585		72.819883	23.8983	7.43551	6.97946
$\begin{array}{cccccccccccccccccccccccccccccccccccc$			20.265614	20.430125				21.685294	1.804504				
$\begin{array}{cccccccccccccccccccccccccccccccccccc$		19.406391	18.744142	19.445815	19.243925	19.452849		20.927578	1.381499				
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	193	48920.088553	12352.967347		10796.347611	2291.139035	=	15126.18692		18.43698	_	0.035251	0.020561
$\begin{array}{cccccccccccccccccccccccccccccccccccc$					930.129987		112386.813926	430.179153	282002 270551		43.7145		
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$			161.41972					168.074547		18.852657			
199 759.929632 811.403639 102393.696475 480.015293 252.271533 8381.812769 821.27574 — 14.560449 0.950335 0.208877 0.181454		1620.975323	264.668199	_	682.444183				_		0.028636		
				102393.696475									
					43.700189								

Table 22: Results on Random Syft 04, 0-100, time in milliseconds.

name	Nike Hash True First	Nike Hash False First	Nike Hash Random	Nike Bdd True First	Nike Bdd False First	Nike Bdd Random	Nike Multithreaded	Cynthia	Lydia	Lisa Symbolic	Lisa Explicit	Lisa
1	256.495355	228.735753	128248.419483	199.741663	100.188716	13191.074464	242.473378	-	109.559054	1.8342	10.2948	9.92636
2	3161.904989 19.457204	3587.597951 19.707575	19,127515	1952.863484 19.056863	1678.634163 19.722886	149269.331504 18.932257	3659.930257 21.901975	1.387975	12.385282 83.047175	3.64832	0.020014	0.020004 3.26698
4	3902.566501	1866.096556	32343.601131	1948.857015	876.066626	32705.814231	1909.859299	-	11.884163	_	0.022698	0.021129
5	705.616097 11681.395936	532.830888 3889.592045		673.623614 4164.122781	478.865033 2355.545719	25498.68394 91223.570167	547.91626 3948.020875		4302.309411 15.180614	57.2941 0.217421	872.108 0.101268	11.7207 0.091401
7	43428.89856	1123.216954		15303.335216	655.681661	187814.222779	1150.745076		29.932109	0.855873	5.44999	5.41465
8	3510.226511 18561.571596	1814.892139 8167.49774	_	2410.134011 7213.115722	765.912107 4559.685007	128993.539209	1855.342362 8359.002735	_	296.416071 402.907789	0.63778 4.46692	92.2801 26.8029	74.0444 24.6481
10	585.236351	1988.598172		372.986438	1831.247827	124177.598864	1112.388545	 	14076.898843	4.40092	_	1360.38
11	21640.838058	902.873441		6492.992931 262.583102	830.341252	259001.958349	920.898578	_	67.312154	3.21831	7.35578 0.226485	7.18099
12	295.844514 6352.708638	221.549517 6748.363224	12177.859371	262.583102 1751.695497	99.31047 754.30253	1453.648612 116688.418925	228.791538 6955.648292		12.336179 11.317853	0.212305	0.226485	0.225774
14	2574.308415	1773.096374 13619.237179	72112.663309	1523.058589 5633.517883	555.534069 3699.746185	9062.721652	1834.375203	_	721.031266	34.2325	2161.5 785.108	4.16693 698.9
15 16	10322.630248 14495.248018	8576.237713		5768.296393	3753.506401	=	11697.118573 8804.322921		616.120478 14.921571	15.5687	0.025993	0.022366
17	1956.611661	1062.997874	_	824.412763	300.761052	8041.792541	1095.078238	_	12.60841	0.178765	0.054848	0.046648
18 19	3746.779149 372.854129	2551.553243 274.242047	62019.57828	2857.928176 385.769709	1756.860521 208.606032	10605,713224	2616.422615 283.226702		3922.65084 407.519899	2700.85 57.1511	103,476	697.298 94.7214
20	1400.936239	198.248605	73464.11795	472.555019	174.086033	3069.904629	203.854643	_	15.597123	0.11146	0.110365	0.101934
21	30400.741307 9522.441231	20266.915803 4400.986333		16211.537936 6458.327	5266.879901 1828.521081		20997.093072 4486.620658		59796.939283 13.489721		0.021084	0.019722
23	12703.189616	12107.173942	_	3836.640378	2267.930922	=	12461.349779	_	14.055154	_	0.022507	0.019342
24 25	160.714576 350.910966	1508.611907 63.260544	124037.011351 22656.068219	91.442445 243.806173	1329.384027 52.13708	12307.857626 8423.256812	304.078415 67.643118	234238.035983	51.709584 435.350972	72.1763 3.90005	391.734 57.3607	346.541 50.417
26	2505.830794	722.947396	48866.713518	873.849846	166.4548	24614.807536	745.100593	_	11.070343	_	0.021353	0.019105
27 28	1636.772441 304.959573	644.900088 543.91237	14582.610336 81822.763637	746.852707 229.164734	259.846449 313.441292	12090.767569 14323.294289	663.58866 558.487444	=	10.146193 29.427712	13.6312	0.019392 3.43246	0.018707 3.25401
29	7677.310215	12596.668777	_	2359.326042	2186.87236	20943.986241	12968.542619	_	19.109384	0.033943	0.032876	0.029709
30 31	143.941429 860.214332	54.865952 770.480282	7136.127188 117185.893365	141.328147 601.157138	63.112399 580.05095	870.313319 6245.646097	58.907722 808.821711	24285.520015 93714.009806	29.686698 16.656594	0.97207 0.136608	1.08895 0.305278	1.05647 0.313502
32	1471.845552	1739.417779	_	1175.59146	417.570732	43762.387614	1782.069893	_	141.928365	4.27725	62.2051	57.4999
33 34	298.715068 852.671306	280.87808 714.270012	37889.869564 77764.99257	143.153432 431.040956	188.803014 196.837018	2922.442182 10588.834775	293.651912 741.642606	36027.322857	1708.614743 9.808593	15.0415	0.05907	93.9733 0.019135
35	46058.192306	30690.358397		27850.263061	6065.580722	_	31814.569792		688.584368	82.9573	_	48.59
36 37	5484.581035 16931.698984	7140.802782 1790.258144	=	2255.000559 6050.406511	1427.846766 598.931518	195607.312091	7897.744248 1828.047155		324.53987 63.159424	98.2595 23.9887	148.026 8.57339	135.819 7.70389
38	40345.575684	9202.835253	_	15039.814426	2678.669851	_	9484.966396	_	3296.565088	132.1	8.37339	53.0641
39 40	2879.586744 60.175214	5412.29202 426.054357	8967.771182	1639.393811 71.579514	4336.744073 398.883474	2532.802191	5574.991559 110.475079		13.869611 1689.829928	543.099	0.060323	0.068849 6485.26
41	426.874011	154.399056	26707.047181	357.395106	125.839356	4584.21553	162.042943	 	484.756028	168.391	2453.41	2261.6
42	70652.006535	8372.793931	_	21208.310973	2283.442405	 56234.434852	8630.894312		8018.198688	245.895	4.27502	679.983
43	5021.898899 607.24779	892.610116 4642.907021	274646.230552	2839.426622 538.947618	788.385476 3405.275986	86817.403557	927.367487 1213.247581	 -	27.726577 31373.785395	0.973701	4.2/502	4.04907
45	4952.530003 6465.946323	2303.093205	_	2467.303284	1513.383947	52880.788487	2371.354774	_	15.492841	0.030227	0.062212	0.069998
46 47	6465.946323 2436.00031	548.042094 2130.565639	=	1597.937487 1192.156932	506.199746 557.530247	55339.282936 19431.194507	1013.060679 2183.858709		16.107588 37.692532	1.11006	0.020959 1.42625	0.019752 1.30975
48	79.036104	768.193419	9541.763589	74.286927	748.072364	2902.755375	148.348182	_	18788.201758	1751.92	_	1809.09
49 50	27381.184986 762.964759	511.748195 423.347105	58229.903646	9288.784952 511.450268	476.1844 256.099827	176797.189924 11618.117981	526.054291 434.829255		24.575731 349.564814	0.304025 97.242	2.46142 234.48	2.55773 213.993
51	43.706607	226.918651	7783.561492	46.299016	223.818392	4618.506187	79.127728	55016.039077	1688.090983	1571.06	-	2348.04
52 53	545.826607 946.242001	500.27075 419.77742	-	511.168613 930.913037	414.167775 413.644407	22813.65781 55675.772157	516.856115 473.783316		9913.266696 932.905653	771.968 43.2638	862,296	1610.24
54	6555.3822	1457.664121	_	2655.179329	472.482355	13928.472909	1495.156012	_	27.370011	0.609869	0.50988	0.456074
55 56	140.651708 430.501594	1465.500849 225.202707	152301.491613 91809.110176	109.608593 296.174438	1427.273021 98.816914	6968.853126 9377.732536	262.72065 234.799755		51.138669 87.575815	13.2605 2.63244	415.987 16.6731	377.611 16.03
57	38154.530475	25440.648478	-	16033.612467	8534.386244	_	32385.001589		19071.241342	2.03211	_	6044.77
58 59	5109.817409 184408.901908	837.204068 40206.413429	_	2428.23398 46665.475949	279.790756 2443.656735	27454.829734	847.448008 42077.545701	_	12.728151	28.9616	0.038354 0.764322	0.022364 0.728475
60	6715.265969	6959.030972	_	3257.053981	1671.037286	243674.719491	7239.651222	_	14.465581	_	0.045812	0.022241
61	2560.977406 2552.273132	1299.134751 5514.672002		829.632247 2377.052485	479.715517 2588.776135	10564.607628	1333.706828 4809.073492		14.983162 48615.857948	0.075569	0.067469	0.06202 457.687
63	7819.656088	6641.566114	=	3412.835924	3002.412461	_	6798.407953		29.09049	2.58196	0.195	0.168749
64	2175.131773 30423.272681	3612.740913 5847.340013	_	2491.675728 11729.797207	1801.647233 4135.154099	216020.807147	4200.061125 6610.407073		11.803082 17.161422	0.054715	0.021967 0.03508	0.023848
66	7097.194417	1780.262877		2904.985253	1585.81584	171454.921804	1821.08538		47.891555	0.323858	5.98375	5.73763
67	2730.294757 9745.759136	1223.137942 6650.22017	_	1399.426156 2308.611278	639.481356 1804.573706	46745.533797 41319.615054	1265.041093 6820.157108		23.647681 36.769315	0.28867 1.21578	0.929683 0.529795	0.856437
69	453.318253	54.098758	60108.426852	226.929137	54.630291	2541.226408	58.260422		13.57836	0.152947	0.329793	0.12667
70 71	4285.216788 17.283198	5049.521886 17.206609	17.029712	2692.228791 17.090817	3930.374141 17.127856	217646.817005 17.198905	5124.318812 19.168461	8.75706	685.244732 10.575735	1315.17 0.190278	1217.24 0.321406	101.909 0.284155
72	11212.168875	1303.901702	_	9520.056718	292.374888	_	1322.855742	8./3/06	19.160316		0.023603	0.019499
73 74	1386.94293 204851.994436	295.546689 19811.027245	107516.962618	795.900041 76490.358871	112.069802 16930.429067	5078.152987	302.410659 20188.475496		37.886986 26.540738	1.01797 0.366387	1.78337	1.71344
75	3381.850549	1370.90748	=	1191.193427	325.645417	98339.386391	1389.529018		33.088125	0.366387	0.275834	0.224149
76 77	104561.884928 235.94869	16400.806487 47.353858	48553.07593	25305.131301 144.615259	4030.088795	1184.956861	16648.207507	32271.993448	14.872364	2.55769	0.02058	0.019101 4.4437
78	33915.497321	47.353858 9462.343289	48553.07593	9312.549724	58.088661 2951.415314	155513.91555	52.018616 9636.084007	32271.993448	30.051636 17.709029	0.133449	4.65556 0.084604	0.073914
79	1221.910316 3305.613687	2544.376499 2189.603846	_	673.720617	2028.617143	129982.634572	2328.588344 2188.353421	-	92.66271	26.0946	14.4444	12.4518
80 81	62.811193	243.902846	2339.657754	3186.055867 58.573291	2033.903077 140.103834	239635.48747 860.517883	2188.353421 111.936005	9358.553223	3835.46044 169.568629	160.704 22.2561	1484.4 720.871	1374.71 626.504
82	551.413718	296.919927	174077.065101	525.470298	167.627414	9430.046591	310.607107	_	39.268418	0.575279	12.8384	12.5712
83 84	558.602058 48224.117965	536.865052 3820.645545	229394.12745	271.487824 15680.196648	242.513973 3700.021568	1490.105477	552.987154 3891.608266	_	11.441811 25.204569	0.046025 0.334451	0.036557 0.684068	0.035531 0.62731
85	14598.407206	1041.678326	17001 200770	5010.65728	477.902041	242043.499279	1059.298599	-	17.145407	0.303169	0.296968	0.274118
86 87	339.776482 35770.532875	56.448837	17081.309678	209.665483 13658.329907	56.605324 33374.408478	839.454358	59.619826 67324.646632	2341.302251	10.501215 28.401828	0.039226	0.04962 1.93538	0.04825 1.82864
88	117735.213	4690.061556	 15549.848762	40618.332006	1459.910054	_	4785.71739	_	11.627206		0.019927	0.018203
89 90	253.798826 501.407582	548.703197 296.428026	15549.848762 284394.055261	177.591971 578.872189	303.750312 141.135517	758.180857 24621.677224	463.273446 303.959284	_	23.933821 181.681383	0.192361 4.7421	0.66018 520.218	0.613637 484.833
91	9619.504757	2166.989565	_	4087.726677	1311.891118	49623.231015	2193.163477	_	15.143075	0.039694	0.026211	0.027755
	23464.466904	6824.843367 10783.938121	=	10160.221937 12499.787349	1853.120632 4533.769446		6816.20311 10899.066962		84.802205 14.402145	0.68981	0.842845 0.022718	0.795024 0.018492
92 93	25895,790943				2101.149577	263802.946589	2231.349286		31.912914	7.67057	1.24115	1.23357
93 94	18435.027887	2204.622579	_	15518.824543	2101.11/2011	*****						
93 94 95	18435.027887 557.80243	2204.622579 204.012645	46249.636139 10008.486475	543.086807	208.257887	31339.989397	208.022781 242.555626	69479.127892	13663.433513 5980.444998	361.839 1780.23		153.594 356.269
93 94 95 96 97	18435.027887 557.80243 218.430251 2351.318509	2204.622579 204.012645 235.452514 339.792965	10008.486475	543.086807 236.493684 1125.268508	208.257887 236.320827 192.915219	31339.989397 3244.6971 38489.248804	242.555626 348.018991	=	5980.444998 16.312196	1780.23 0.265708	0.115217	356.269 0.091023
93 94 95 96 97 98	18435.027887 557.80243 218.430251 2351.318509 17.181187	2204.622579 204.012645 235.452514 339.792965 18.202233	10008.486475 — 17.281317	543.086807 236.493684 1125.268508 17.567556	208.257887 236.320827 192.915219 17.697807	31339.989397 3244.6971 38489.248804 17.730045	242.555626 348.018991 20.120973	923.791519	5980.444998 16.312196 34.412129	1780.23 0.265708 2.69854	0.115217 2.42289	356.269 0.091023 2.15574
93 94 95 96 97	18435.027887 557.80243 218.430251 2351.318509	2204.622579 204.012645 235.452514 339.792965	10008.486475	543.086807 236.493684 1125.268508	208.257887 236.320827 192.915219	31339.989397 3244.6971 38489.248804	242.555626 348.018991	=	5980.444998 16.312196	1780.23 0.265708	0.115217	356.269 0.091023

Table 23: Results on Random Syft 04, 100-200, time in milliseconds.

name 101	Nike Hash True First 295.002645	Nike Hash False First 261.686271	Nike Hash Random 30830.986106	Nike Bdd True First 242.378586	Nike Bdd False First 123.063882	Nike Bdd Random 2462.101056	Nike Multithreaded 266.229504	Cynthia	Lydia 12.177656	Lisa Symbolic 0.090917	Lisa Explicit 0.111282	Lisa 0.101919
102	1942.392116	3524.821693	_	1339.39268	2501.494184	79674.19967	3554.085578		40.152494	0.74228	1.00443	0.96298
103 104	25135.384243 23207.335679	978.008038 2252.594011		8649.644533 8433.401777	436.282311 2147.376905	136539.597599 149511.378653	1000.435108 2280.106977		12.680067 37.502715	0.076829 0.734245	0.086768 1.03674	0.088021 1.02668
105	63682.554619	3183.390487	_	26685.771334	1057.304424	_	3239.980873	_	60.325145	1.85618	85.7931	81.7416
106	1528.021637 18.541823	879.138803 18.994679	19.118518	1445.727308 19.186762	783.596915 19.22695	53950.231467 19.266799	888.384367 21.059284	1.312632	22661.341436 19.04481	0.16584	0.357022	241.9 0.288947
108	24262.05354	7697.267922	-	4972.409866	1848.635115	-	7799.256021		130.895069	74.1143	547.103	68.8497
109	197203.706206 50.082337	56351.121265	24006 002542	39786.930291 58.419485	12419.175767		58086.636578	_	26.63248	0.517648	0.976711	0.871435
110	50.082337 1579.76613	264.174597 462.323063	24886.083543 97875.190785	58.419485 1218.169889	259.100972 164.567686	7363.12572 39998.376153	89.49381 467.729562		6482.320884 11.485207	382.08	0.048157	364.915 0.019753
112	167099.02908	2136.910782	_	42013.970832	2089.409793	_	2161.005926	_	25.909877	0.135875	0.269614	0.207768
113 114	84.956232 6091.849202	525.652097 1495.339359	18389.070589	96.238876 2414.540173	509.640311 1416.604272	6145.618071 173931.383106	150.830328 1505.355092		7738.505539 16.324846	418.437 0.084881	0.084213	642.242 0.064998
115	16915.802909	4140.352726	_	7877.185978	2575.813298	_	4177.237597	_	41.450981	0.459932	1.11997	1.13353
116 117	17.282493 117702.942111	18.61944 25177.54123	18.196442	18.475435 29501.158199	18.543628 11644.742782	18.409714	20.466597 25653.310888	1.020007	86.88797 44.421799	19.731 2.93585	11.8289 0.243729	11.5422 0.22557
118	602.014842	146.318755	53125.708309	430.626298	57.9498	2347.611035	149.803422		35.454966	0.565157	0.509263	0.467137
119 120	17079.444674 18.955499	1471.369008 19.537727	19.270884	6223.601892 19.598377	1080.840964 19.670142	19.379838	1490.670282 21.320693	1.401701	15.86605 17.147802	0.115703	0.020507 0.069775	0.019178 0.060203
120	9265.312985	7965.752086	19.270004	5409.57241	2310.343264	294592.742179	8042.481043	- 1.401701	13.023112	0.115705	0.020921	0.000203
122	2703.009424 139572.133038	1360.21951 6218.677511	_	1058.544336 39699.311122	705.511888 2320.879234	51046.116116	1379.470458 6302.122724		9.980574	4.26201	0.022256	0.019012
123	319.48953	3717.73629		389.061058	3527.580257		593.813405		116.145501	4.26201	5.21081	4.90183
125	17424.2287	1549.973828	_	8546.897067	368.290509	130224.355003	1568.977772		220.092785	4.71063	90.6397	74.0987
126 127	52571.47372 60.518512	11580.625944 2070.657135	61085.816963	18090.31358 64.483211	2704.415433 2035.799845	21565.161707	11684.770171 110.86543		9545.561496 699.502149	532.105 878.982		79.2619 1898.56
128	22910.905951	9094.130882	_	9186.557544	4124.879185		9235.317173	_	13.530057	0.037198	0.07001	0.032894
129 130	24787.021745 5623.727709	21629.558546 2561.621739	=	12100.52466 6002.697221	4071.295051 588.69449	=	21024.230335 2609.144744		17.493794 16.204276	0.092462	0.057589	0.054558 0.026659
131	4790.6067	5206.654275	_	3393.613734	1287.471214	_	5296.01174	_	13.40788	_	0.021512	0.020052
132	3992.133373 184.303817	2440.945546 496.893772	43217.242535	3730.590643 170.88474	2390.775487 487.007179	144271.035437 15470.87304	2481.310835 341.12779		363.458704 11.856997	20.9587	153.353 0.020322	147.208 0.020416
134	12352.057701	3655.752288	-	3920.05494	2325.938333	_	3684.270456	_	214.382606	30.5838	183.033	11.0918
135 136	6289.708245 256.211707	2639.103669 1139.232271	98479.552039	3410.144308 206.094718	1298.161607 1089.726006	250821.632004 14802.157888	2664.743298 475.369726	_	218.009215 47.811135	1.98704 36.3718	69.7875 52.1515	1.23422 50.2812
137	19.453933	19.707749	18.934758	19.458831	19.642882	19.978092	21.997288		15.367699	0.141069	0.073359	0.072122
138	16815.550814	4720.687999	_	8638.758685	2178.328893		4783.394774	_	5854.59995	0.103692	0.089409	405.688 0.085838
139	35498.115175 16821.691221	1493.044072 2953.515292	=	11895.014781 6587.715603	1171.86572 1881.061169	198266.956883	1503.638438 2982.6445		14.278959 16.223891	0.103692	0.089409	0.085838
141	6550.288913	630.648611	=	2091.073347	696.161092	48084.631618	635.830667	_	18.945387	0.042142	0.031366	0.02829
142	4046.17785 116810.158866	4790.711061 15652.762767	=	2203.784237 46349.989841	1668.798315 3405.663127		4861.442726 21549.940115		37112.983704 21.381831	355.542 0.164899	0.705026	75.8374 0.615957
144	1093.643638	428.606985	_	503.74094	385.914467	27755.736725	432.951567	_	10.696694	_	0.020671	0.02306
145 146	19.147668 596.687497	19.645787 2048.512342	18.817636 143970.172238	19.300472 434.075953	18.998961 1773.402605	19.244106 83009.675406	21.087269 1132.012702	1.334178	62.627937 12.856968	3.16025	2.4306 0.025382	2.3327 0.019254
147	476.092004	205.49364	-	275.264535	201.328699	23646.78278	208.918333	64373.087406	463.148487	1030.89	_	825.419
148 149	8267.73296 12703.085285	1408.27176 12786.142046	_	6938.954457 11695.831044	398.970241 2301.338661	133585.942119	1414.349205 12939.697435		121.640037 4152.334142	5.94517 350.136	40.3145	33.6573 321.677
150	674.479855	1415.253534	24592.167741	465.828788	1141.648771	21754.378169	1311.809388	33846.066146	10.316114	330.130	0.05971	0.020556
151	2181.17635 3422.222921	983.572895 2065.500407	158225.9424	1030.917766 2203.477228	732.197414 861.6786	132545.847861 264097.323057	994.385964 2075.385528	_	10.342336 108.333895	6.05827	0.020053 96.3105	0.021989 88.792
153	11051.781937	2995.061018	=	4889.097496	689.779356	213956.809484	3020.871961		93.19003	40.855	92.1418	81.679
154	7350.8738	5994.397241	61097.354375	2046.313593	1625.285211	111954.872938 29008.702219	6072.812831	_	43.464869 10.042678	14.386	1.80358	1.70131
155 156	630.878605 4777.601307	1434.256944 2663.464851	61097.354375	260.58163 3770.119118	422.529703 2480.609088	92888.409152	1189.232885 2700.78867		64.062402	35.3638	0.021167 114.989	0.019553 118.627
157	8799.21745	2949.890227	_	3958.354953	908.512862		2985.894889	_	2371.337117	582.804	_	173.435
158 159	8651.899577 30700.123624	4760.178225 6792.93122	_	5735.078816 10832.374287	1465.182022 1332.208031		4812.289519 10713.482818		9035.162744 11.959961	474.513	0.060955	93.0846 0.022265
160	4187.306799	609.765441	_	4151.230371	626.478276	_	621.404598	_	13.217071	_	0.019735	0.019924
161	35752.029033 476.434784	2397.738167 173.974362	 196415.212529	10501.438415 222.569046	965.398373 168.717822	7793.698766	2401.850493 176.004768		20.017663	0.210468	0.322652 0.022035	0.255714 0.025584
163	20.472289	19.199831	20.124682	20.6493	20.662631	19.763718	22.713233	1.71419	15.810154	0.033012	0.026127	0.022262
164 165	28738.439163 1293.896615	17327.06059 542.767309		10136.34161 820.345445	2808.211991 344.933072	 16399.697217	17779.765329 557.907149		90.975572 67.882841	112.078 0.695871	153.292 10.2986	119.955 9.79484
166	18.797875	19.170747	18.969773	18.820475	19.015777	18.372774	21.391502		12.666223	0.135254	0.065085	0.055151
167 168	761.724429 103981.828138	745.632744 71002.675576	_	705.302424 31920.826801	654.222243 10766.765169	137453.073077	751.55452 74539.621223		11.578137 11423.539253		0.022109	0.018187 229.065
169	46748.251531	19936.433818	=	10142.618523	8682.639277	=	26039.632139		45.373596	17.7569	9.07006	9.12449
170 171	3195.758935 4390.479444	2119.029385 908.110932	_	1698.806984 2083.821806	839.399202 263.951424	101475.763322 48843.569094	2152.517056 917.1012		10.409174 19.328179	3.91127	0.021295 0.795724	0.020485 0.759036
172	3018.587193	447.562838	=	2781.182951	428.230118	180800.522092	467.056332		1620.941125	3449.99	_	222.775
173 174	4323.845551 2554.051742	3451.304938 5907.767032	-	3102.469169 1196.621783	2505.969239 2576.038959	139990.650503	3525.395448 4876.77493	-	43.282675 1363.115145	1.68053 94.4761	3.08216 905.789	2.91662 829.57
174	2471.758755	4327.499158		1831.212644	1943.785709	196991.401568	4378.646977		180.603681	90.8907	77.7662	69.1643
176	19.865848 6500 979661	18.839598	19.596072	20.103318	19.53977	19.467566	21.53432	1.300119	13.695123	0.028363	0.028682	0.026498
177 178	6500.979661 561.295307	1259.912319 543.481012	_	5443.895723 500.704613	1084.504709 422.251382	17648.330945	1276.67141 550.065898		5150.220849 66.562657	193.904 3.82842	14.4919	95.3437 14.4371
179	12227.884017	7500.89873	_	8040.709637	2493.761636	_	7716.080484		720.919641	18.2298	151.109	132.967
180	305.329109 1311.134414	536.691927 667.147396	15664.405887	290.869207 876.064164	531.529132 348.303538	10415.753021 16812.1785	559.664875 698.838055	18703.744824	2955.029202 42.77211	206.975 2.49336	9.97563	55.1586 9.60647
182	234119.38395	24920.780063	_	56795.741359	8125.502434	_	25875.488425	_	566.940447	13.7887	58.7461	47.4498
183 184	3216.729419 977.71116	319.68414 870.500028		924.007274 565.985504	314.526397 320.484067	10860.947504 12470.763103	331.851185 916.142455		18.558792 15.33436	0.303399	0.367643 0.267633	0.2938 0.262873
185	2611.133769	558.086736		696.441045	329.767034	13745.176184	583.152713		17.656473	0.566485	0.210732	0.220126
186 187	3551.764252 11883.240069	4414.804474 5535.203745	_	2291.027571 3764.475909	2921.029929 1277.508867		4519.85677 5764.441676		1657.784013 1333.579374	15.1741 55.1555	504.296	465.859 81.4687
188	16031.468044	14109.903349		6342.15473	1425.955311	298194.309857	14654.467736		11.278159	_	0.065107	0.020588
189	24202.08847	4518.47586	_	8748.074767	3083.013263 191.922243	176310.665213	4629.304288	-	16.560549	0.0487	0.033035	0.028518
190 191	401.430445 17.99	332.571845 18.33202	18.343717	410.565524 17.765818	17.791808	22563.057961 18.420414	348.102298 21.365875	6327.938278	19.624248 630.189379	0.132543 381.79	0.269362 4020.12	0.238565 80.2074
192	18.322788	17.849942	17.71427	19.024363	18.497113	19.554474	22.529594	1.286493	13.532845	0.04602	0.038673	0.037435
193 194	274.703485 1477.115521	243.461927 447.143557	72269.990289	190.072043 488.422108	223.093316 288.533923	20793.015464 3198.066257	254.149432 461.351907	168353.322414	15917.123513 13.522819	7151.25 0.048428	0.035336	783.317 0.028617
195	1052.286855	685.423775		722.774317	426.093266	97064.527392	711.688533		1644.659012	249.529	1693.39	32.9728
196 197	2643.864153 52433.734468	83.84095 6750.484987	=	696.859054 13315.076	95.896096 5586.49299	4229.511334	155.505308 6931.634893	281490.192442	14.915795 30.371204	0.053033 0.393057	0.058248 0.265987	0.052904 0.214521
198	318.52136	467.072126	34942.91639	334.422027	259.692389	5388.592068	489.753125		95.885999	0.821162	56.2739	52.4707
199 200	126182.092378 3548.378746	10526.250212 4265.277558	_	19141.218811 2214.36371	9799.531847 1013.606915		11037.944727 4423.322452		82.854819 13.532977	0.532961	12.5162 0.019796	12.151 0.024898
200	2270.270740	7200.21100		2217.30371	1015.000915		7723.322432		10.034911		0.017/70	J.U27070

Table 24: Results on Random Syft 05, 0-100, time in milliseconds.

name	Nike Hash True First 58700.330788	Nike Hash False First 2990.400872	Nike Hash Random	Nike Bdd True First 20294.760652	Nike Bdd False First 2017.257092	Nike Bdd Random	Nike Multithreaded 3045.018323	Cynthia	Lydia 73.348249	Lisa Symbolic 4.43764	Lisa Explicit 36.4456	Lisa 33.1644
2	141128.69629	137284.051836	_	28655.121064	27220.550187	_	139290.802305	_	17.210375	0.169509	0.080361	0.069687
3	8940.169389	3308.628316	_	4689.274945	2791.597485	188405.001144	3311.865263		35.006535	0.731498 858.889	2.36933	2.20971
5	7816.447644 2482.345045	767.415549 169.243278	_	5432.115451 2411.419836	590.001574 167.680277	284741.627653 74869.149956	771.415557 172.670223		1414.800526 28740.409431	693.476	=	220.26 1802.5
6	1229.462051	824.254725	_	1252.748591	594.600642	_	828.221929		10742.37776	45.1448	_	53.5212
7 8	422.816407 290.270328	259.31367 354.605701	79747.567677	390.160987 237.964082	251.17055 320.252766	34541.595055 75835.495815	260.90415 356.524559		9.664667 2630.081081	_	0.061738	0.019271 749.62
9	290.270328 908.579959	603 950842	147091.400727	237.964082 589.570175	243.312028	/5835.495815 5298.841251	556.524559 607.968146		14.228571	0.231575	0.437286	0.42008
10	2776.014956	3377.356946	-	1400.294562	3215.573188	66568.461546	3400.852308	_	11.540968	- 0.251575	0.020551	0.020436
11	4561.561287 1206.188263	4906.646676	-	3352.378531	1803.425981		4924.511546	_	12.086678	-	0.023772	0.022296
12	22060.570647	216.460045 1518.665733		705.984161 14760.616557	179.511497 1044.758461	29802.935194	219.615799 1520.955629		9.986439 8.961653		0.021042 0.020674	0.020071
14	19586.732912	3224.752069	_	10985.168243	1553.940856	_	3236.041756	_	9.599222	_	0.019806	0.018413
15	174.860352	918.163914	_	163.747455	543.292246	28674.405703	315.386866		1346.481302	74.7925	2965.7	51.4804
16 17	122368.949913 1008.058108	18059.210094 318.849241	=	55478.308181 601.284426	2931.429951 298.682834	66858.256916	18195.075795 322.750051		632.596444 3973.69759	3.33325	1050.69	4.04155 1505.81
18	27305.527748	16680.791168	_	13809.879371	2068.116533	_	16783.145669	_	159.252598	1.77571	38.5818	35.2867
19	1127.899574 28004.995636	1013.192438 6012.750736		484.389554 15441.358207	985.910701 4247.583707	35242.964355	1015.414729 6028.904249		12.971369 616.88824	36.0997	0.022197 2924.81	0.024832 38.1516
21	46995.20179	15958.9032		18143.878689	5002.276841		16015.867739		10.256214	30.0997	0.021404	0.020474
22	41939.801868	56589.627643	_	11846.930374	8095.387802	_	45843.177392		4054.44576	19.9354	_	28.678
23 24	2276.962163 2382.965078	2407.516481 150.289695	_	2042.815485 1312.397557	1881.321586 86.161235	 35881.13416	2423.523242 152.018178		27181.838151 11.552534	_	0.049887	2432.9 0.023302
25	342.579796	1055.256108	32919.480535	150.057803	652.567809	7475.080215	628.757361		278.981324	194.144	-	609.615
26	2548.49366	1057.666482	_	2046.095145	653.284112		1062.23481		11.026902		0.021623	0.02014
27 28	5681.003327 22779.023815	8478.06195 15780.579909		2722.518862 16747.897381	1533.487194 9719.848465	21023.226816	8490.91359 15798.1331		16.870401 12084.753991	0.644369 11259.2	0.208556	0.197683 18164.3
29	323.438963	188.702875	31309.826172	273.155515	114.311822	8315.587015	192.307801	20092.519	9.016868		0.058624	0.020551
30	8111.839713	1089.346128	_	4508.981958	336.23335	167490.471467	1094.754183		12.799015	_	0.021452	0.019478
31	30220.744632 36026.550087	10772.380292 2923.667522	=	8550.208048 18535.184301	2107.530857 1593.114583	74724.852915	10796.916829 2934.939404		14.168532 52.028249	2.20089	0.021149 5.32894	0.019517 5.17455
32	5457.047566	4144.309633	-	4144.972211	861.48506	245790.614812	4201.145213	_	404.246266	17.512	82.7551	69.3767
34	10278.205226	4312.48224	_	5566.168166	2269.719957	211960.171427	4324.788415		14.785487	0.032269	0.027274	0.026882
35 36	29795.082667 10331.827851	16260.560115 10601.895384	168702.048019	12501.806856 6129.331877	4632.845408 5865.042462	133478.318231 139313.537573	16331.157336 10607.595991		42.417759 11.474357	0.204222	0.020245	2.39425 0.019813
37	2725.911541	1275.001065	_	1501.958759	1043.543016	198886.785053	1267.759559	_	194.62376	78.4146	858.345	769.508
38	151.14027 10768.331761	101.48364 597.169816	6203.264951	143.364133 4553.003204	101.895832 299.064568	619.672523 108546.654545	103.271318 607.762678	4055.895728	792.038779 198.036013	276.011	4817.98 1334.12	4416.24 1245.71
40	46887.543055	50794.434161		29139.970488	2859.884197	108340.034343	51436.611373		13.233128	5.5938	0.021302	0.021823
41	8627.047396	7349.92334	_	8468.252463	4245.584072	_	7372.088139	_	82575.408922	_	_	_
42	32694.169314 66221.166189	1346.249937 17787.337552	_	11079.105089 27106.468983	1258.003165 2060.675577	130516.550047	1357.925349 17878.23406		21.493095 15.449197	0.188134	0.448735 0.02166	0.320219 0.020349
44	82040.188355	5049.051541	=	24891.550338	1920.190858		5049.454603		116.725539	9.78349	167.529	141.7
45	111589.322432	19715.695244	_	31259.874217	6252.870173	_	19766.3226		231.713301	28.738	75.8915	69.0689
46 47	6877.275047 1685.500136	5198.476979 367.722837		4232.935669 1291.805795	2350.083289 130.009063	=	5186.10696 371.84889		5718.881089 11.072001	234.362	0.020869	156.146 0.019589
48	38201.483738	8684.741989	_	14298.603306	3356.14556	_	8818.640246		19.443872	2.81047	0.445213	0.422222
49	30446.621776	16071.431927	_	21110.714254	6824.289215	_	16158.411535		55.073562	1.66613	10.1282	9.56761
50 51	808.702679 79870.284468	2004.775718 27039.497935		648.176473 28341.504227	2000.257277 3875.765594	147505.587691	1508.653032 27216.39657		2814.492087 23298.760913	428.082		3254.15 447.735
52	_	4297.204216	_	142763.813753	975.165527	_	4316.300418		1903.440879	54.5587	2696.27	15.8142
53 54	2293.419618 6391.245161	1687.627417 7280.390148	_	2291.491187 3870.921949	1686.368274 1695.947631	166153.53834 265493.15171	1688.38159 7280.450564		19366.810394 13.973014	0.214685	0.103811	0.07674
55	41890.690649	299.62048		17169.560463	182.764561	125783.221333	303,983505		48.177516	0.286914	5.05796	4.92432
56	70538.594124	3083.870253		29113.213469	1135.339266	_	2959.924875		11.553241	_	0.020626	0.019988
57 58	19.96096 1052.283541	19.663134 897.001044	20.167354 171692.45186	20.38119 854.883303	20.184889 500.141605	20.398332 13833.436406	21.745433 909.509701		14.614414	0.061915	0.040828	0.042583
59	12103.469956	1626.941118	- 171092.45100	6486.263538	854.672909	-	1629.526773		198.944376	2.70413	50.5322	44.1135
60	1877.445495	2835.500481	-	1535.463864	2368.999583	-	2838.625823	_	10659.146149	246.904	_	87.2884
62	1207.253726 715.052257	323.799285 269.464349	62809.999408	1061.680873 479.872075	324.814942 188.08073	47826.042231 23295.21443	327.053373 270.982204		2891.166817 136.24147	873.302 17.505	570.453	244.018 29.0511
63	135318.842367	26403.236274	-	45417.539051	6533.789692	_	26712.683863	_	13.587084	-	0.021591	0.020909
64	39346.063752 2230.870848	2485.955963 1136.039995		19287.34551 1790.012536	554.709275 1075.328145	4209.106976	2510.027457 1152.868329		15337.764082	0.387254	0.249575	1889.33 0.250466
66	405.04787	979.864949		280.006363	661.224271	46935.080583	746.973118		333.008792	10.624	27.3626	23.2703
67	23563.631679	4462.102163		11394.36493	1336.849044		4458.088495		31654.511342			1642.34
68	19.137556 2623.459003	18.61372 4672.141306	19.375038	19.856665 1523.907467	19.357889 3074.266612	19.261383	21.283478 4694.932329		24.087823 13.129133	2.2532	1.07976 0.022448	1.02903 0.020783
70	10252.129892	1638.215931		4715.949896	681.31875	161997.663676	1645.666907		41.683465	1.77815	4.3974	4.213
71 72	55.854341 81469.948613	193.831575 7076.204303	744.138934	56.344255 13385.017603	194.410901 890.253417	3257.806619	101.70087 7083.404944	2445.032522	166.292418 11.163133	224.294	2328.29 0.024193	2065.11 0.020281
73	104.099392	70.194601	25659.842229	97.542763	63.839856	12905.379983	72.775513	27915.052305	2311.45297	12.8508	0.024173	21.3147
74	6333.82123	522.351215	_	4436.80528	263.386138	_	525.805495		5849.638932	187.999		31.954
75 76	1109.924664 154827.791405	235.5938 7583.734721	149051.428826	776.70092 57633.900832	130.340633 2578.551598	50609.526081	237.660171 7628.31978	283769.02714	9.74164 100.489029	2.89343	0.054111 34.7436	0.02058 28.9774
77	9524.166996	7761.014994		6596.999382	2833.230246		7750.048458		_	2.09343	_	_
78	1896.166383	934.774299	26081.540162	1755.502308 3858.527317	893.230147	10234.218341	936.172934		11.129078	_	0.021221	0.020332
79 80	9711.013564 11414.292399	8928.415015 6420.406263		3858.52/317 5584.70324	942.80562 552.449801	52950.984201	8971.000315 6457.433405		9.902823 11.581165		0.027898 0.026891	0.023044
81	104248.924017	8062.036524		16204.706095	4233.852955		8076.96556		33.713198	0.9188	6.36559	6.51653
82 83	16148.503649 151.502919	17401.431254 499.841963	21824.110788	8825.756909 117.074323	3174.721273 477.12128	1436.756718	17578.514428 275.028057		12.773708 214.83311	7.75776	0.027597 82.5587	0.021661 60.3383
83	24408.673719	5268.732659	21024.110/88	7321.066317	2323.373755	1430.730718	7795.132989		64.041727	16.4526	82.5587 11.1158	10.283
85	19449.705986	12608.035344	_	10157.237636	3441.836509	_	12666.349474		11.732479		0.021678	0.019837
86 87	268582.842546 1124.932541	15272.160856 129.495996		108132.628358 834.041661	4497.444776 104.129539		15422.023341 132.871182	 230702.111015	 585.90562	34.5555	 4974.22	31.297
88	11720.92758	7731.704982		3676.198361	1315.636344	24909.893721	7816.531022		11.072075	_	0.021727	0.024843
89	12659.242716	3399.049935	_	7470.936161	2301.451173		3414.104743	_	2577.376869	33.3131	5864.11	16.8167
90 91	1012.743374	2232.924155 315.167288	 14020.324527	602.362741 499.082727	2006.712506 243.183486	32616.846822 6282.169072	1865.147023 319.193611	 19157.683312	752.755136 8.968402	166.417	5937.47 0.020456	34.0897
92	7055.653164	8030.383992	- 14020.324321 	2830.56065	3112.085804	_	8088.065967		428.099606	2643.19	_	20.4715
93	18875.080678	8229.263249		6349.615722	772.757983	119278.488206	8295.266474	_	59.92052	1.61087	3.65878	3.52094
94 95	346.627805	294.045201 96202.068731	32388.947096	191.77103 63470.438626	258.930113 14190.586011	3273.747398	296.816973 96779.071536		63.038296 45.458503	1.97943 15.3124	11.4597 4.55942	10.5733 4.67501
96	19.412523	18.813308	18.623944	18.770261	19.151119	18.584323	20.592042	1.250781	14.220639	0.514663	1.26755	1.13969
97	2854.924009	1104.945418	_	1265.8904 5932.684528	386.342752	77247.25626	1111.444406		152.817674	31.71	1465.48	20.6349
98 99	16408.669515 18.836146	1585.576443 18.599859	18.832898	5932.684528 19.545638	833.946243 18.894813	200281.461663 19.039171	1594.466049 20.743523	118576.973242	11.369562 25.291991	1.10615	0.022176 2.90432	0.027706 2.73659
100	3470.298417	460.761485		2153.914767	309.9182	219792.501808	462.929537	_	1749.585741	171.877	_	98.1923

Table 25: Results on Random Syft 05, 100-200, time in milliseconds.

name 101	Nike Hash True First 11698.55439	Nike Hash False First 3417.715229	Nike Hash Random	Nike Bdd True First 5215.458081	Nike Bdd False First 680.807943	Nike Bdd Random	Nike Multithreaded 3413,549859	Cynthia	Lydia 39.664408	Lisa Symbolic 24.8839	Lisa Explicit 48.0834	Lisa 46.7791
102	38812.320531	3398.762652	_	19117.586499	1162.067416	_	3408.450807		30244.842227	_	_	1947.48
103 104	89455.335706 11103.102123	27094.714908 5989.265511	_	43400.077024 4251.804433	22596.117104 2166.598487	187442.459665	43730.816842 6022.333877		842.856736 11.986854	6.19327	218.777 0.021689	3.72073 0.02161
104	20286.139818	1345.61415	_	8148.018682	403.962658	98424.359682	1352.164198		12.967107	_	0.021439	0.02181
106	16699.783977	3311.536535	_	7725.362959	1126.600651	_	3305.053633	_	12.411959	_	0.023527	0.023249
107	213347.76552 37379.861511	138242.852168 24242.199284		76715.798005 10768.730384	18652.59465 4317.157695	_	140503.700835 24370.222851		57.010477 12.340275	11.235	2.03394 0.021646	1.87405 0.019075
109	34919.590209	4893.927256		20414.760103	1196.280984		4888.337402		6251.418735	718.626	_	975.2
110	127274.712997	9584.722123	_	26055.946656	1832.638488	=	9646.546104 14319.039852	_	49.856221	9.85105	15.3067	12.8829
111	62654.81867 204897.717379	14268.550994 34275.668705	_	20673.665349 51318.292112	8868.764681 6179.441947		34469.069728		11.76393 13.111383		0.021315 0.021454	0.019446 0.022389
113	29276.232097	14951.892498	-	13130.224497	2563.746633	_	15001.396985	_	23.829805	0.313981	0.485369	0.409485
114	260459.395871	117222.342695 19435.472377	_	50601.462334	25731.154384 5419.186899	_	117992.747588 19479.941008	_	16.87594 713.907361	0.239269 27.0144	0.138055	0.110339 250.435
116	8016.252009	2411.984107	=	4337.650503	608.95524	44479.36879	2438.980802		45.906513	1.30291	1.76374	1.67993
117	5415.794338	3477.177237	_	3454.673287	2810.833085	41365.508755	3481.801287	_	12.337808	_	0.027947	0.020899
118 119	926.798734 19633.063539	2273.529582 3043.205176		472.592308 15429.878608	813.44719 2104.207168	17064.674642	1724.392599 3048.920054		25.760802 62.440265	0.129766 17.9433	0.434462 42.0292	0.413395 39.8836
120	123890.115259	_		32624.539743	35559.895736		227395.141141		90.290839	3.89388	154.391	147.117
121	17.976393 2926.261851	17.907602 1272.765583	18.308356	17.737155 1264.353596	18.581091 504.32085	19.105432 171047.37503	19.634738 1277.563604	6906.797893	24.465386 12.647077	4.05426	7.05405 0.023142	6.68111 0.019967
123	132.561924	285.801252		117.642364	158.19171	6562.748673	238.077212		83.530345	3.69884	6.15247	5.98438
124	13895.74016	584.947226	_	5972.004586	491.614701	_	585.971491		1268.93645	226.73	-	1312.14
125 126	81.62161 25670.968441	135.043226 17045.18735	2388.90184	75.919923 10840.184125	114.479745 4767.733409	1145.143475	133.497193 17133.738198	6584.834142	64.261245 55.300621	4.51852 7.30955	102.304 32.1783	83.5576 28.4759
127	503.846829	761.476555		365.026304	746.949403	25572.128439	763.743618		143.529892	34.2626	284.185	241.682
128	65282.368326	8528.73778	_	19085.431186	5533.682852	_	8585.816843		16.615518	0.220529	0.186843	0.132243
129 130	3475.584441 1920.651763	1718.890178 1459.035194	=	2687.41861 1266.38669	716.856508 304.361094	14510.288623	1724.621994 1464.738436		1919.866972 229.873673	28.4374 3.16496	62.3088	23.2328 53.1857
131	28803.177623	3716.207829		16040.519504	2745.926607	_	3721.415704		28.516968	0.171525	0.810644	0.729634
132	6982.127929 11533.961689	277.659596 7729.390851	29245.751748	3670.645915 5599.319222	155.755668 1317.024384	19338.778853	280.850886 7715.224484	22745.665849	8.188213 55.164555	121.757	0.024829 3.78245	0.021838 3.56273
134	76477.77149	9232.000625		33942.513257	2553.410682		11283.147045		_		_	
135 136	149913.475332 1362.274579	14103.879815 1453.398868	82153.226339	56214.754959 901.293772	3637.763005 359.559811	23581.888578	14208.966005 1454.297187		16.744235 9.43073		0.027078 0.020274	0.06088 0.021511
136	5899.774576	3637.136383	- 02133.220339	3628.040538	1237.998927	105026.109279	3655.057386		9.43073 25.381909	0.191452	1.0759	1.03524
138	103261.647691	156607.756849	_	25240.347092	20111.775331		157546.349265		30.135673	1.77365	5.16541	6.00157
139 140	5811.175079 2744.107213	669.831736 1494.222127	238569.468982	2631.543265 1937.572979	131.628467 470.751153	 41614.311706	673.132339 1877.682649		255.973672 11.636562	59.4978	19.1027 0.020711	14.3506 0.019766
141	316.306748	1760.538315	-	324.764556	1553.863509	_	581.364619	_	53492.903899	_	_	
142	19087.74132 1366.040111	7617.216223 911.647681	276449.945679	7985.135655 1036.713112	2816.079963 289.520913	19940.278611	11329.124253 920.078497		94.613364 322.674031	2.35625 26.0385	4.3742 25.6122	4.3198 19.834
143	123.620257	48.776211	4578.112921	103.044823	49.222351	889.450646	50.936869	18719.814589	58.012759	7.69925	29.0828	25.2248
145	10220.163485	3579.304633	=	4518.959823	1892.739915 2029.480115	195178.361891	3591.859873		14.449028	_	0.020237	0.020199
146 147	431.186375 2722.173031	2229.712044 3470.05217	=	303.54938 1330.082958	2819.898872	79279.112411	790.264722 3474.962189		17189.157839 1001.312386	36.4871	6482.91	2680.2 35.3994
148	5722.641439	1428.404252	_	3392.129186	528.613186		2681.881427		3031.561392	131.535	_	14.4495
149 150	1718.389401 12234.922362	966.2694 2556.248908		867.117448 6021.087076	651.375984 1168.666278	29844.867283 227890.684195	977.570001 2555.77573		51.408694 64.510353	0.243787 1.5043	11.2596 7.13668	10.9109 6.99642
151	_	297111.445057	_	114382.469674	68331.242136	-	-	_	6710.435967	112.676	_	168.637
152 153	193418.650774 18.500025	98753.904601 18.143742	18.230962	95226.26362 18.673249	18840.126101 18.729936	18.859515	99796.94703 20.583184	0.955184	746.283156 24.226776	16.5005 0.889272	103.202 2.02956	3.54168 1.95862
154	16178.99724	5580.387414	10.230902	6080.995557	1307.610773	218463.135251	5584.625148	0.933164	894.196529	51.4926	1173.35	1075.82
155	1706.471367	262.884754	186709.296336	1400.151465	150.185959	38653.414697	266.434936 8391.430609		301.180884	15.8498	356.111	307.222
156 157	31033.207799 13632.066678	8394.946111 3316.652083		7682.692732 7622.875742	1677.868762 2817.598291	266766.920241 286465.070358	3303.005596		18.487265 17.83602	0.25973	0.181208 0.544121	0.135074 0.513884
158	37299.559778	7427.001169	_	11932.253756	1323.329209	203194.289008	7477.675271		14.721081	0.078633	0.042891	0.037916
159 160	7171.197885 12624.955898	792.117961 13079.569403	_	3239.359109 7537.781844	334.305193 5965.265223	87721.851293	798.628823 13112.392476		12.219974 25.713391	4.11286	0.020812 1.38871	0.019845 1.35089
161	3014.453779	1052.694406	_	1732.460644	925.574537	54083.698377	1065.248821	86182.541929	137.968114	10.2965	65.2517	59.0592
162 163	321.953688 69301.891827	424.647958 20386 956949	5835.126812	313.305808 35244.514003	407.331353 3073.70916	2190.613647	430.417568 20608.009451	3684.230864	645.470005 1219.507269	246.814 185.466	5349.34	15.6676
163	50467.580967	12143.641613		22939.072069	2059.774596		12191.860051		491.701933	24.3906	344.826	295.121
165	900.119475	2527.189853	229450.949514	427.419542	1674.815145	14088.522186	1668.984261		669.73483	103.229	1855.68	19.1249
166 167	61877.566011 6025.840466	10592.16409 2106.595957	=	27231.728372 2014.666615	2829.030989 591.527781		10634.998355 2115.024527		30.266735 15.29079	0.886239	0.401529 0.019568	0.404298
168	5578.988753	5999.51595	_	4688.487494	3021.671143	_	6068.657945		85924.730808	1912.41	_	1125.29
169 170	1964.589162 57352.819918	929.561866 17147.205087	=	1658.178446 16842.37867	832.435233 6171.83486	83643.695975	930.362201 17241.939818		619.524577 14.342761	6.23493	132.517 0.021964	98.2303 0.021871
171	6674.55902	3105.268986	_	5320.107196	1858.619998		3105.004937		1451.014447	319.929	475.491	442.283
172	460.425091	182.345901	28547.293964	331.240123	97.309232	11313.275309	184.7498	-	9.986372	_	0.021043	0.0201
173	156.454967 1512.062476	49.430627 210.260925	1675.219344 14771.283857	119.312277 985.520936	51.990281 149.916162	455.264241 4233.676028	51.528292 213.936386	121153.694297 89349.27674	31.821535 161.733762	11.6271 0.80294	12.1727 181.652	11.1268 153.046
175	35695.422827	9426.525207	_	15786.679614	998.035702		9502.333416		13.577139		0.020835	0.024717
176	2978.356668 2218.149484	3026.665628 248 380404	 80388.905348	2655.215613 1315.231019	1259.114731 82.5459	7762.349315	3036.412232 252.131091	31209.740359	11.557116 25.54321	0.396494	0.019768	0.022608 0.768782
178	4439.364074	4435.710826	-	1917.142861	3165.739478	130033.554527	4465.835882		17.594339	0.865652	0.556469	0.527812
179 180	1200.18496	545.444146 2853 85473	_	967.980932 3151.209172	444.301636 1550.101077		547.492509 2858.229265		26190.843044	301.023	0.026005	1735.62
181	7118.959603 21460.739773	2853.85473 12960.146468		9897.462238	2490.715842		13013.348313		13.818348 477.228648	22.3538	53.5208	0.022246 47.2678
182	4918.740025	576.467824	_	2593.598973	336.821784	116470.332433	581.837212	_	673.28537	189.727	_	287.116
183 184	26654.568844 105082.351867	8278.120658 9318.458338	_	15026.973824 37719.803386	2336.326819 2182.231576		8327.205193 12035.521509		663.222007 319.625418	26.2672 3.10239	293.646 98.2574	280.087 85.5925
185	1841.308396	1107.083979		1351.742624	843.160771	21917.655036	1115.405179		55.302201	0.900347	10.5427	10.4077
186 187	5400.538605 77.348688	10210.82647 33.063103	319.82038	2320.610713 75.964589	7573.119709 31.691205	328.309881	10132.022664 35.770088	— 597.799583	29611.582465 8.382514	_	0.023103	1141.17 0.020895
188	52705,399489	12313.960524	J17.02030 —	21620.465995	11067.986696	_	12369.005884	J71.177J03	19.019091	0.118786	0.047728	0.043407
189	2166.855752 3423.156429	667.440482	_	1863.451564	631.06023	51599.980016	668.998207	_	136.07284	2.33931	61.6339	44.8029
190 191	3423.156429 37006.790973	1180.704461 43987.657949		1983.868365 16835.994323	580.904182 5262.302384	104803.961273	1216.911949 44211.67202		261.294819 13.15319	17.1509	124.224 0.02037	97.7855 0.02033
192	3120.547025	406.631921	-	2021.676032	181.53723	96330.613703	409.170327	_	56.432046	0.911682	5.34221	5.0989
193 194	7612.3916 9650.589142	3345.973773 1239.938393	_	4015.510995 3597.52765	2280.830814 271.520215	251820.036698	3365.77402 1247.186943		12.196418 40.559617	4.81336	0.023429 3.06805	0.021565 2.72841
195	4594.91338	2552.50645	=	3396.514908	681.968567	=	2555.767786	=	6782.573859	_	_	140.145
196 197	137241.710162 266388.935722	12255.087332 6683.160582		43988.323536 79972.106672	11062.177676 2508.379313		12455.915282 6582.474163		19.57524 11.538611	0.306246	0.325604 0.020827	0.264715 0.020185
198	799.534564	1001.008714	16531.158981	412.304098	255.222232	1187.619676	998.926169		12.746187	0.08157	0.110509	0.116022
199 200	4591.594191 134.885049	745.938874 197.101716	10687.9206	2847.790609 129.829116	433.639815 184.091086	207420.804878 6110.367231	748.746559 200.996485	_	791.821771 159.586774	122.295 32.8202	431.142 154.981	391.303
200	1.34.063049	177.101/10	10007.9200	147.029110	104.071000	0110.307231	200.790483		4//08د.ود1	32.8202	134.981	132.285

Table 26: Results on Single Counter, time in milliseconds.

name	Nike Hash True First	Nike Hash False First	Nike Hash Random	Nike Bdd True First	Nike Bdd False First	Nike Bdd Random	Nike Multithreaded	Cvnthia	Lvdia	Lisa Symbolic	Lisa Explicit	Lisa
counter_01	18.058177	18.350703	18.060843	18.169518	18.933748	18.692677	19.607023	16.453027	6.978378	0.2575	0.118257	0.112888
counter_02	24.204002	31.358584	23.964412	47.131896	50.575059	47.358771	32.82203	211.518911	8.89128	2.61965	0.280484	0.288077
counter_03	67.810516	114.23335	104.986782	134.0321	171.003919	150.686689	119.903069	693.556915	12.781949	90.6461	16.9257	0.889436
counter_04	428.059632	831.486601	698.842123	588.71692	944.899279	944.688069	787.3057	2522.781763	25.034847	1218.46	27.5305	3.34075
counter_05	3754.291805	7568.91302	6852.560534	4065.36963	7778.351135	5770.683935	6975.687144	_	67.723467	13715.5	58.4356	381.417
counter_06	34590.517551	70189.903347	51550.536626	35831.825415	70901.656923	48650.17893	65032.73378	_	248.148853	143515.0	484.092	3020.43
counter_07	_	_	_	_	_	_	_	_	1107.050207	_	4089.62	27384.9
counter_08	_	_	_	_	_	_	_	_	5562.659418	_	30637.1	
counter_09	_	_	_	_	_	_	_	_	27463.526719	_	_	_
counter_10	_	_	_	_	_	_	_	_	125102.602996	_	_	
counter_11	_		_	_		_	_		_	_	_	_

Table 27: Results on *Uright*, time in milliseconds.

name	Nike Hash True First	Nike Hash False First	Nike Hash Random	Nike Bdd True First	Nike Bdd False First	Nike Bdd Random	Nike Multithreaded	Cynthia	Lydia	Lisa Symbolic	Lisa Explicit	Lisa
uright01	14.999567	15.462853	14.883559	14.865238	14.998477	13.940153	17.356649	1.995103	5.247303	0.138404	0.200602	0.055955
uright02	15.094761	15.38919	15.500275	14.319042	14.88239	14.062963	17.449376	0.702015	5.354601	0.064368	0.063398	0.068017
uright03	16.635718	15.695066	15.027712	14.483598	15.092849	14.438113	17.078239	0.620635	5.450475	0.057319	0.058338	0.059256
uright04	16.45286	16.809773	15.015942	14.84263	14.561528	15.816918	17.335316	0.715294	5.706349	0.046205	0.041596	0.040328
uright05	16.294455	16.307927	15.276146	15.317786	14.232395	14.600184	17.449579	0.30296	6.080545	0.042322	0.041693	0.042551
uright06	16.366488	15.497276	15.429629	15.02954	14.025922	14.222141	17.509895	0.695206	6.644925	0.065597	0.047732	0.048302
uright07	16.42893	16.002619	15.165841	15.164762	13.981411	14.432798	17.490425	0.692417	7.502385	0.052625	0.052897	0.063675
uright08	16.378655	16.174357	15.041196	15.793256	14.303577	14.115701	17.550876	0.579435	9.404088	0.093533	0.087099	0.089628
uright09	16.076093	16.063872	15.394778	15.188866	14.070482	14.398683	17.197007	0.557215	12.554514	0.139596	0.153389	0.136166
uright10	16.442906	15.984441	15.796126	14.347479	14.307109	14.676375	17.338181	0.564401	18.952341	0.194126	0.195148	0.196753
uright11	16.356052	15.645867	15.502792	14.265181	14.434716	14.739665	17.456657	0.490677	53.599676	0.303638	0.309067	0.334009
uright12	16.20536	16.260699	15.948424	14.291558	14.712576	15.052945	17.538113	0.990094	135.791584	0.486728	0.479552	0.479855
uright13	16.347945	15.890228	15.679354	14.140014	15.432763	15.739051	17.516188	0.43267	374.838683	0.861209	0.909934	0.87649
uright14	16.184014	15.617293	16.58412	14.618667	14.841335	15.104607	17.572259	0.72968	982.782789	1.59976	1.59355	9.61871
uright15	16.557987	15.913101	15.912645	14.744371	14.667065	14.96852	17.549767	0.490422	2566.476664	27.3199	15.2491	19.1711
uright16	16.39883	16.23711	16.080889	15.02702	15.378931	14.773313	17.599218	0.557976	6131.468587	22.4675	22.4194	22.6145
uright17	16.846842	15.619689	16.134446	15.255978	15.36376	15.070621	17.666699	0.791338	18033.003794	37.0282	37.1113	37.1563
uright18	17.409017	15.844109	15.955344	14.858477	14.707132	15.251954	17.750981	0.551119	_	81.6887	83.0052	99.4015
uright19	16.963635	16.71334	16.158252	14.982198	14.950929	15.667326	17.848841	0.601733	_	_	_	_
uright20	17.155057	16.049239	16.167525	15.394496	14.773912	16.415535	18.05109	1.001365	_	_	_	_