

Efficient Backward Non Deterministic Matching (EBNDM) Algorithm

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Abstract -Bit parallel string matching algorithms are the latest and the efficient class of algorithm for string matching. It uses the intrinsic parallelism inside a computer word is known as bit parallelism. BNDM is the most popular bit parallel string matching algorithm. This algorithm can directly use for various real world problem like as Detection of Intrusion in the network, Data extraction and mine, avoiding Plagiarism, use of Bioinformatics in various medical field. BNDM algorithm having their standard implementation where lots of bit wise operations are checking as not in bit parallel mode like as MSB of bit vector is one or not or the value of the bit vector is zero or non-zero. All these operations are the comparison based operation which are quite time consuming. If these operations are optimized or simplified in bit parallelism based operations than they have their best bit parallelism based implementation.

In this paper we are found out such operations and simplified in pure bit parallel based implementation. Here we simplified the popular algorithm BNDM and named as Efficient Backward Non Deterministic Matching (EBNDM) Algorithm. The working of Efficient Backward Non Deterministic Matching (EBNDM) Algorithm is same as classical one but due to use of bit wise operation in place of comparison operator our algorithm gives better result. Experimental results show that our EBNDM algorithm is better than the standard implementation.

Keywords-String Matching, Bit Parallelism, BNDM, TNBM, BNDMq, Efficient BNDM.

[1] INTRODUCTION

String Matching Algorithms [1] are used in various real world applications whether it is used directly or indirectly. So improve in the performance of these string matching algorithms the efficiency of these real world application like as Intrusion Detection System [2, 3], Data Mining [4, 5], Digital Forensics [6, 7], Plagiarism Detection [8, 9], Bio Informative [10] Video Retrieval[11] is also improved. Before nineties there are various character based algorithms that set their benchmarks in string matching and used like as Boyer Moore [12], BMH [13], Rabin Karp [14], Wu Manber[15] and Aho-Corasik[16]. By using the character based algorithms the efficiency of these algorithm can be improved up to certain level so improve in efficiency of sting matching algorithm Bit parallel string matching algorithm [17] are used which uses the intrinsic parallelism of the computer. There are various bit parallel string matching algorithms are used like as BNDM [18], TNBM [19], BNDMq[20], Shift OR [21], Shift OR with q gram [22]. Here, we present an Efficient BNDM. In our Efficient BNDM algorithm we try to improve the loop of algorithm

as well as use as much as bitwise operations like checking the bit vector is zero or not and the value of MSB is one or zero. These operations in classical algorithm are carried out with the help of comparison operators here, we use bitwise operator instead of comparison operators. Our experiments have shown that Efficient BNDM algorithm is much faster than compared to original one for the large text data.

[2] IMPROVEMENT PARAMETER

2.1. Character Mismatch

Character mismatch means pattern is not found at that position. It is important to identify to shift the window. In character based algorithms it can be checked directly but in case of bit parallel algorithms, it is checked by the value of bit vector. It means if value of bit vector D become zero. This is checked by simply comparison operator which is time consuming. So, instead of comparison operator we can use bit wise operator which can improve the performance.

2.2. Pattern Found

Similar to pattern mismatch pattern match is important which is clearly identifiable in character based algorithm while in bit parallel it is identified by the checking the MSB of the bit vector. In the case of BNDM algorithm and other bit parallel algorithm pattern are found when MSB is one. This checking of MSB is carried out by the comparison operator but in efficient BNDM algorithm we use the bit wise operator to get better results.

2.3. Iteration Minimization

In most of the bit wise algorithm like BNDM, TNBM, BNDMq we create loops to find the patterns in the text. These loops take lot of time to execute because it runs many times according to the condition until it is false. By doing some statement changes or conditions there is a possibility of getting efficient results. Because in the BNDM algorithm the value of D is left shift and compared with the limit to MSB check after the value of D become zero means no possibility to find the pattern. In the efficient BNDM algorithm these extra work is cut out from the algorithm.

[3] EFFICIENT BNDM ALGORITHM

BNDM [18] is an efficient bit parallel algorithm but there is possibility of improvement to get better results. In the Efficient BNDM algorithm for searching a pattern of length m, the inner loop of this new algorithm runs for pattern length m to 0 in search of the complete pattern in reverse

order, instead of running on D as in classical BNDM [18]. This loop will terminate when either a mismatch occurs or a prefix is identified by value of D becomes zero but, in case of classical one after getting the value zero it will also check the MSB value as well as left shift the value by one. In case if this loop completes its all iterations i.e. runs m number of times, then it reports an occurrence of pattern. With these changes some more changes are also carried out like in place of mismatch condition instead of using comparison operator we use simple bit wise NOT operator and in the case of pattern found use an bit wise AND operator which are faster than classical one. Comparison among both algorithms is shown in Table 1.

Table 1: Change Parameter of BNDM Algorithm

Change Parameter	Classical BNDM	Efficient BNDM
Mismatch (D all Zero)	$D \neq 0$	$!D$
Pattern Found (MSB Checking)	$D \geq \text{Limit}$	$D \& 10^{m-1}$
Iteration Minimization	After D is Zero It Check MSB Condition as well as Shift left D	After D is Zero it will come out of loop

Efficient BNDM algorithm after applying the basic parameter changes are shown below. Where p is the pattern of length m and T is the text of length n

EFFICIENT BNDM ALGORITHM
<p><i>EFFICIENT BNDM</i> ($p:p_1p_2..p_m, T:t_1t_2..t_n$)</p> <ol style="list-style-type: none"> 1. $pos \leftarrow 0$ Pre-processing 2. For $c \in \Sigma$ do $B[c] \leftarrow 0^m$ 3. for $i = 1$ to m 4. do $B[p_{m-i+1}] \leftarrow B[p_{m-i+1}] \mid 0^{m-i} 1 0^{i-1}$ Searching 5. while $pos \leq n-m$ do 6. $D = 1^m$ 7. $last \leftarrow m, j \leftarrow m$ 8. while $j > 0$ do 9. $D \leftarrow D \& B[T_{pos+j}]$ 10. if ($!D$) goto Outer loop 11. end if 12. $j--;$ 13. if ($D \& 10^{m-1}$) 14. $last \leftarrow j$ 15. end if 16. $D \leftarrow D \ll 1$ 17. end while 18. report occurrence at $pos+1$ 19. Outer loop: 20. $pos \leftarrow pos + last$ 21. end while

[4] TIME AND SPACE COMPLEXITY

Time complexity of the algorithm can be calculated by these different scenarios. Let ‘T’ be the text of length n and ‘P’ is the pattern of length m so we have to find P in T. Let us assume that $m \leq w$ holds, then the preprocessing time complexity is $O(m+|\Sigma|)$, where $|\Sigma|$ is number of distinct characters existing in pattern. The worst case when all the text as well as pattern are made of single character (when $T=an$ $p=am$) time complexity of Efficient BNDM is same as that of original one i.e. $O(mn)$. In an average case scenario, the inner loop of this Efficient BNDM algorithm has a frequency lesser than the frequency count of classical BNDM. Thus, on an average case this Efficient BNDM performs far better than classical BNDM. The best case (when $T=an$ $P=am-1b$) time complexity of this Efficient BNDM is $O(n/m)$ which is same as BNDM. However, our algorithm benefit by reducing the number of comparison’s up to 30% in best case. Efficient BNDM need occurrence vectors B for each character which is same as classical BNDM. So we can say that the space complexity is unchanged in efficient BNDM algorithm.

[5] EXPERIMENTAL RESULTS

This section gives the brief introduction to the experimental results and analysis. In this a long text and patterns of different length are taken and running time of algorithms improved algorithms have been calculated and on the basis of these results a table of comparison is formed as well as graphs which clearly represents that the Efficient BNDM algorithm has got considerable speedup as compared to classical BNDM and other variant of bit parallel as well as character based algorithm.

4.1 Experimental Environment

All the algorithms are tested on the system having following configuration:

Processor: 2.1 GHz Intel I3 CPU, 2.10 Ghz; RAM: 3 GB; L1 Cache: 128 KB; L2 Cache: 512 kB ; L3 Cache: 3 MB ;System Type: 32 Bit Operating System OS: windows 7

Implementations are done using Visual studio 2010 platform and developed in Visual C++.

4.2 Experiment Data

All the implementations are tested on text file of size 210 MB having large number of occurrences of pattern and five different Patterns of length 4, 8, 12, 16 and 32 bit. In the text file are taken from bible [23] and patterns are randomly taken from bible itself.

4.4 Efficient BNDM Algorithm

Efficient BNDM algorithm is compared with classical BNDM algorithm for different pattern sizes as shown in Table 2. And comparison of execution time of Improved BNDM algorithm with classical BNDM is shown in Figure 1.

Table 2: Comparison between BNDM & Efficient BNDM

Pattern Size	BNDM	Efficient BNDM
	Execution Time (mSec)	
4 bit	607	487
8 bit	515	402
12 bit	438	339
16 bit	294	203
32 bit	173	118

These table and figure are clearly shows that the our algorithm is better than the classical one and take lesser time as compare to existing one.

Comparison of BNDM & Efficient BNDM

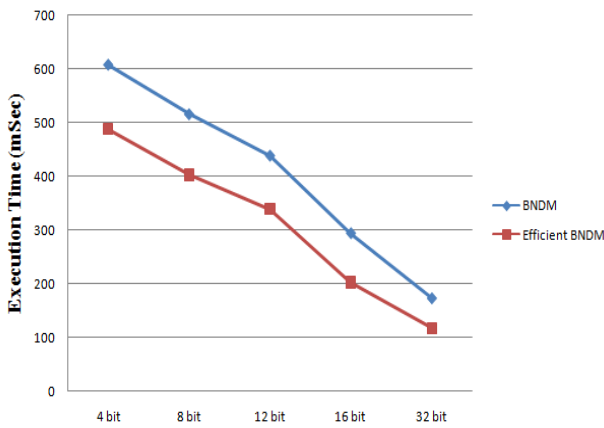


Figure 1: Comparative Analysis of BNDM and Efficient BNDM

Table 3 shows the comparison among the efficient BNDM algorithm to the other bit parallel algorithm on the 210 MB data and we get the improved results which is shown in the figure 2 with the help of graph chart.

Table 3: Comparison between various bit parallel and EBNDM algorithm

Pattern Size	Efficient BNDM	BNDM	TNDM	BNDMq
	Execution Time (mSec)			
4	487	607	583	537
8	402	515	476	441
12	339	437	407	383
16	203	294	274	247
32	118	173	158	151

Comparison Among Various Bit Parallel Algorithm to EBNDM

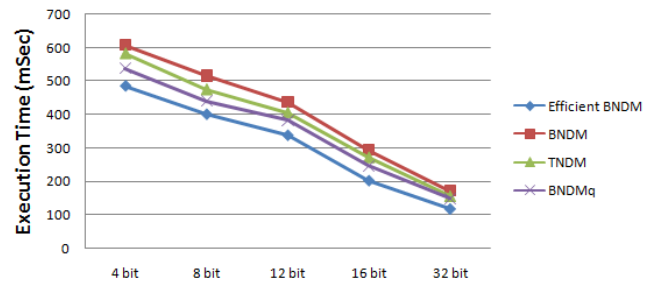


Figure 2: Comparison among various bit parallel algorithm to EBNDM

Table 4 shows the comparison among various character based algorithm and Efficient BNDM algorithm and data obtained is clearly shows that the our algorithm is far better than the character based algorithm which is also shown in figure 3 with the help of line graph.

Table 4: Comparison between character based and EBNDM algorithm

Pattern Size	Efficient BNDM	Boyer Moore	BMH
	Execution Time (mSec)		
4	487	719	698
8	402	647	587
12	339	516	486
16	203	421	383
32	118	313	297

Comparison Among Various Character Based Algorithm to EBNDM

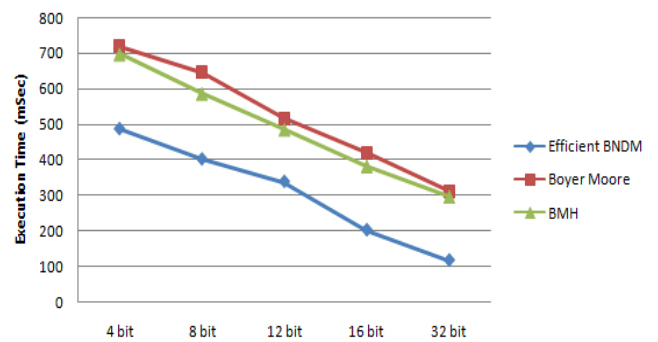


Figure 3: Comparison among various character based algorithm to EBNDM

[6] CONCLUSION

we have proposed and developed Efficient Backward Non Deterministic Matching (EBNDM) Algorithm to improve the efficiency of the Backward Non Deterministic Matching (BNDM) Algorithm. In this thesis we are found out such operations which can be improved like as comparison operator takes time so these operators improved in pure bit parallel based implementation. Here we improved the popular algorithm BNDM. The working of improved version of this algorithm is same as classical one but due to use of bit wise operation in place of comparison operator our algorithm gives better result. Experimental results and analysis shows that our simplified implementation is the better than the standard implementation.

[7] FUTURE WORK

We have performed detailed study on several bit parallel string matching algorithms. Bit parallel string matching algorithms are the faster algorithms among all string matching algorithms. Mostly bit parallel algorithms are single pattern matching algorithms so it can be implemented in multiple pattern matching algorithms. We can also effectively remove the limitation of word size present in the most of the bit parallel algorithms. These algorithms use bit wise operation so it can be easily implemented in the hardware. For further improvement on GPGPUs memory optimization can be done.

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