A Study on Automata and Finite State Machines

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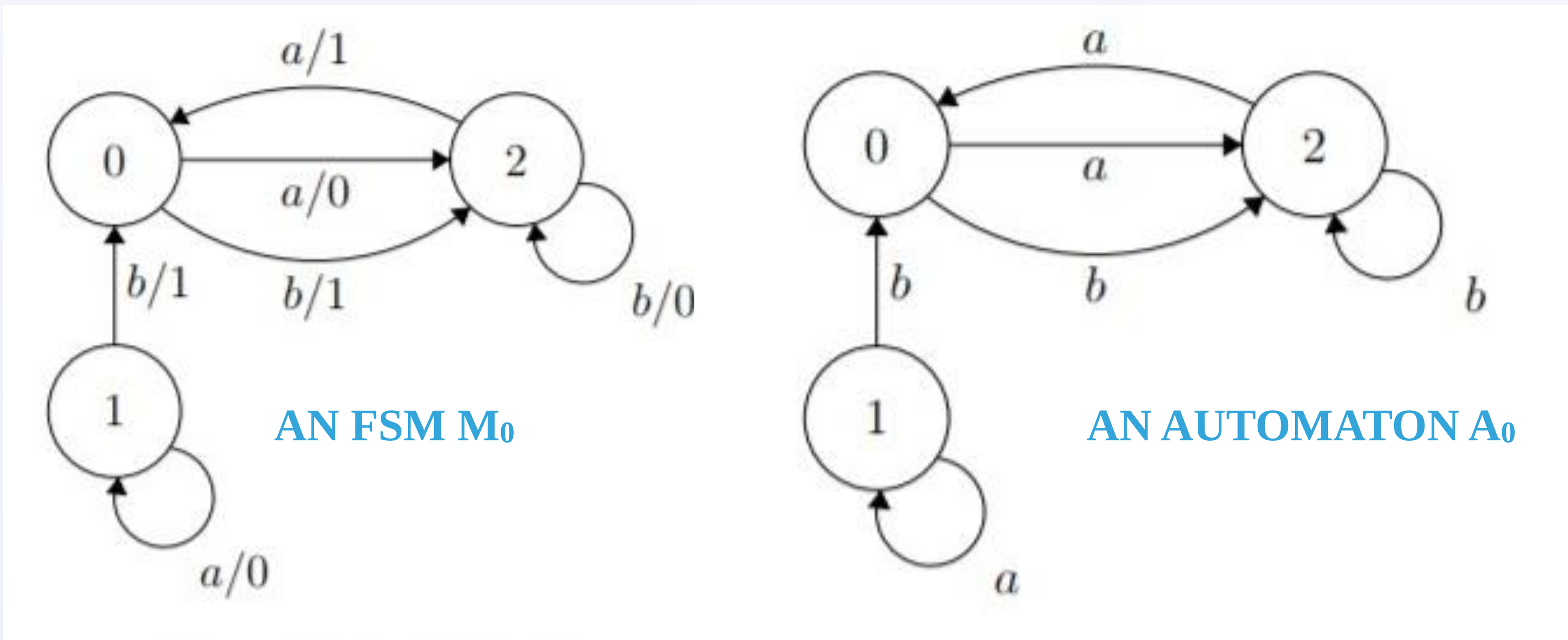
ABSTRACT



• Finding a shortest synchronizing sequence (SS) (Eppstein, 1990) and a shortest homing sequence (HS) (Sandberg, 2005) are both NP-HARD problems which are well-known in literature. There are heuristics to find a short synchronizing sequence but heuristics to find a short homing sequence are not widely studied.

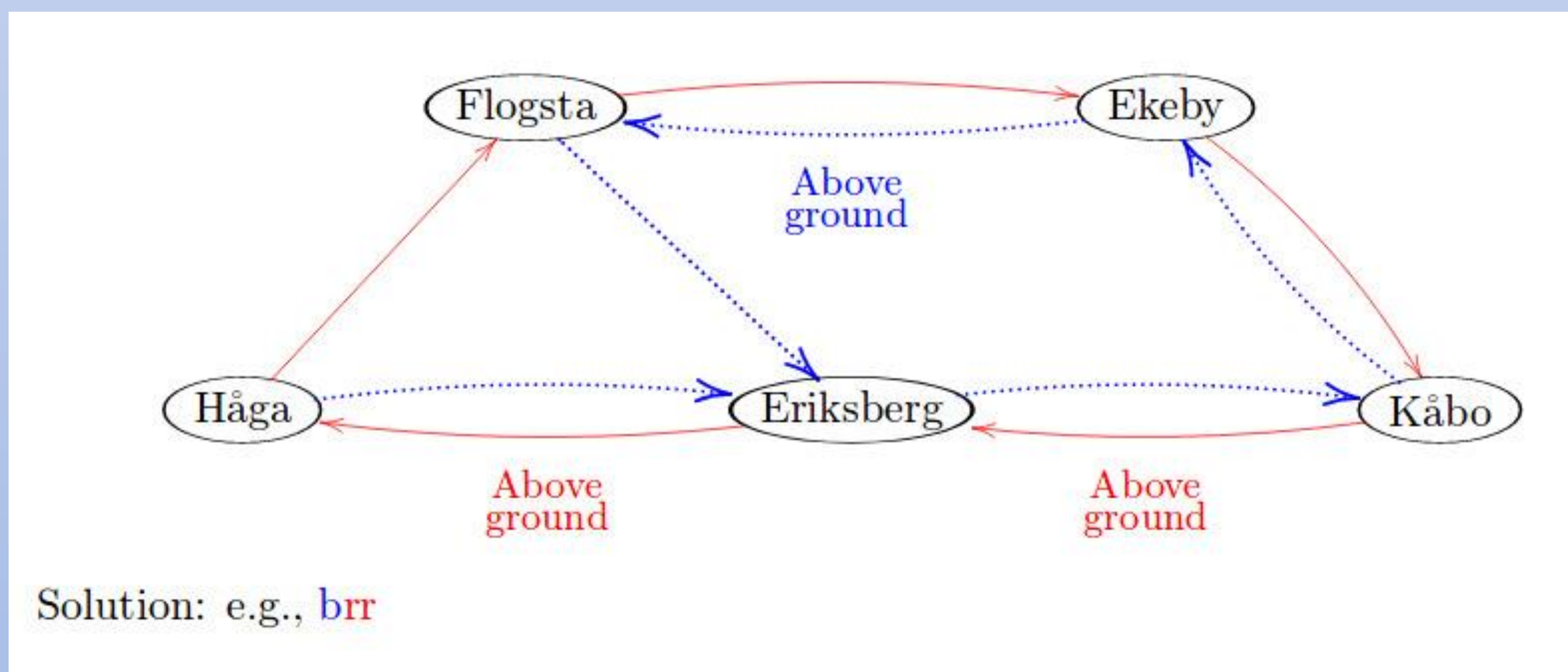
• We discover a relation between homing sequences and synchronizing sequences so that SS heuristics can be applied to find a homing sequence.

• We adapt synchronizing (SS) heuristics to homing sequences.

OBJECTIVES

1) Creating a pair automaton called homing automaton (HA) from the given FSM
2) Using synchronizing heuristics on HA to find homing sequences
3) Adapting synchronizing heuristics to homing sequences in order to reduce the homing automaton creation time

PROJECT DETAILS



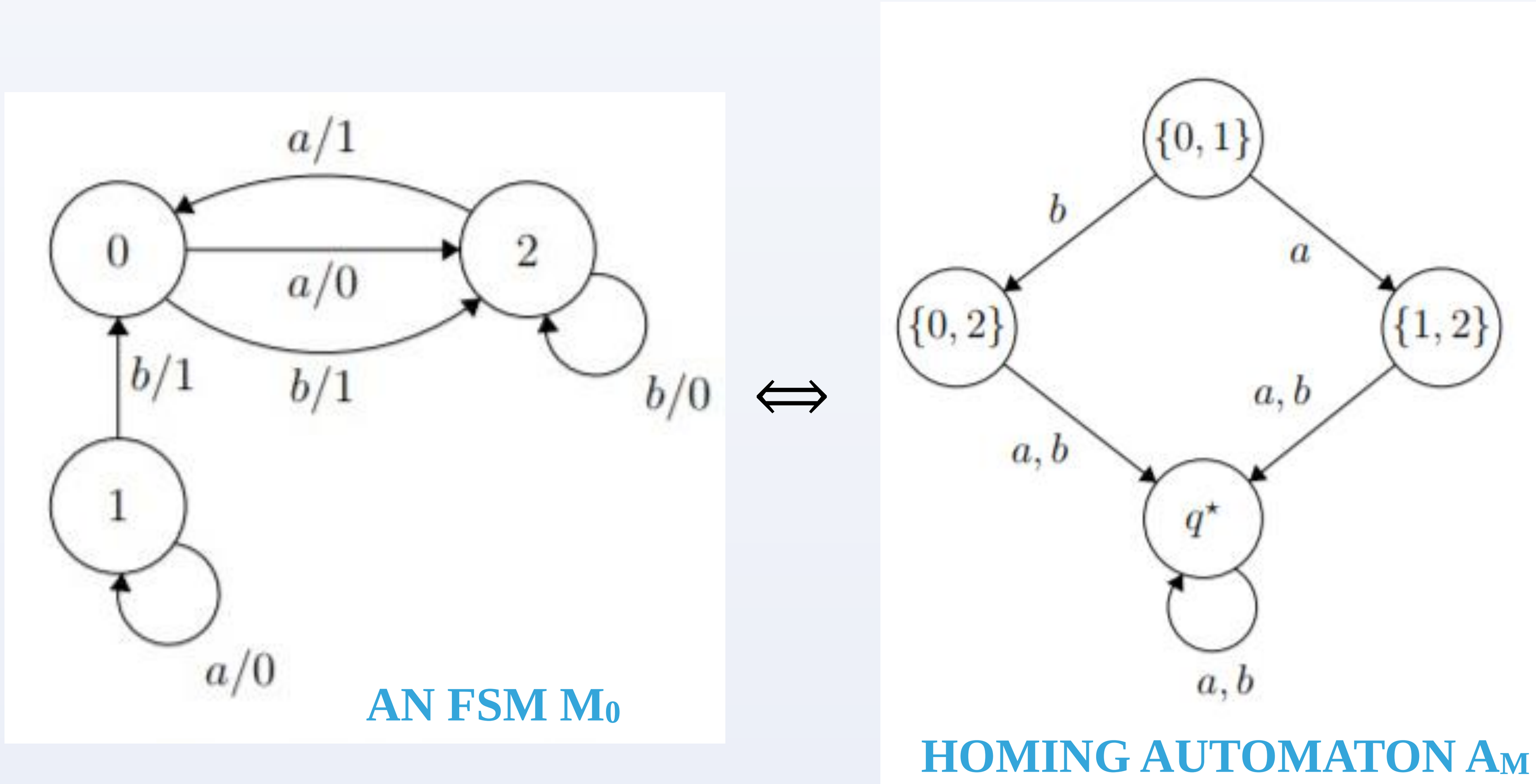
• A synchronizing sequence(SS) S is an input sequence that takes the machine to the unique final state regardless of the initial state.

• A homing sequence(HS) H is an input sequence such that for all states output sequence to H uniquely identifies the final state.

• Given an FSM M_0, it is possible to find a homing sequence for M_0 by applying synchronizing heuristics to its corresponding homing automaton H_A.

• Moreover, we can adapt widely known synchronizing heuristics to homing sequences which enables us to work on the given FSM M_0 omitting the homing automaton creation step.

PROJECT DETAILS II



Theorem. Let $M = (S, X, Y, \delta, \lambda)$ be an FSM and $A_M = (S_A, X, \delta_A)$ be the HA of M. An input sequence $\bar{x} \in X^*$ is an HS for M iff $\bar{x}$ is an SS for A_M.

Proof. If $\bar{x}$ is an HS of M, for any two states s_i and s_j in M, $\lambda(s_i, \bar{x}) \neq \lambda(s_j, \bar{x})$ or $\delta(s_i, \bar{x}) = \delta(s_j, \bar{x})$.
Since $\delta_A(\{s_i, s_j\}, \bar{x}) = q^*$ for any $\{s_i, s_j\} \in S_A$.
For q^*, $\delta_A(q^*, \bar{x}) = q^*$. Hence $\bar{x}$ is an SS for A_M. ◻

$$\delta_A(q,x) = \begin{cases} \{\delta(s,x), \delta(s',x)\} & , \ (q = \{s,s'\}) \wedge (\delta(s,x) \neq \delta(s',x)) \wedge (\lambda(s,x) = \lambda(s',x)) \\ q^* & , \ (q = \{s,s'\}) \wedge (\delta(s,x) = \delta(s',x)) \\ q^* & , \ (q = \{s,s'\}) \wedge (\lambda(s,x) \neq \lambda(s',x)) \\ q^* & , \ (q = q^*) \end{cases}$$

CONCLUSIONS

					SS based heuristics						HS based heuristics						
			Shortest		HA Time	P1 Time	Greedy SS		SynchroP SS			Fast Homing		Greedy Homing		SynchroP Homing	
States	Inputs	Outputs	Length	Time			Length	P2 time	Length	P2 time	P1 Time	Length	P2 time	Length	P2 time	Length	P2 time
32	2	2	6,1	2410,83	46,39	11480,64	7,59	10,36	6,69	1925547,43	81,66	7,69	181,93	7,71	149,62	7,22	3019,61
32	2	4	4,02	320,36	27,18	7372,63	4,79	5,68	4,32	1134028,55	52,08	4,8	120,58	4,8	104,72	4,65	2127,39
32	2	8	3,04	96,07	16,99	5493,58	3,54	3,42	3,21	465578,61	33,31	3,58	86,7	3,57	55,12	3,41	1594,03
32	4	2	5,2	10253,94	54,23	10298,575	7,15	7,21	6,21	2341436,82	56,83	7,2	117,17	7,14	85,84	6,76	1850,09
32	4	4	3,7	580,23	53,43	10158,075	4,69	5,84	4,07	1306012,45	49,48	4,7	126,91	4,7	88,79	4,59	2272,51
32	4	8	3	154,82	33,38	7649,155	3,56	3,73	3,05	516154,69	16,27	3,59	89,11	3,59	56,87	3,49	1784,65
32	8	2	5	41776,44	127,54	16875,96	7,07	7,78	5,62	2922721,11	66,46	7,1	132,64	7,09	99,72	6,7	2167,34
32	8	4	3,19	1590,49	80,34	11880,44	4,67	4,71	3,92	1328281,55	28,43	4,7	98,81	4,7	67,25	4,54	1823,6
32	8	8	2,97	394,53	69,37	11249,46	3,56	3,84	3,1	561097,23	18,41	3,58	95,27	3,58	63,24	3,52	2004,3
64	2	2	7,65	24051,55	185,61	240952,53	9,46	24,16	8,45	559041289,51	278,64	9,53	313,19	9,66	302,35	9,14	25852,08
64	2	4	4,93	2281,29	161,1	203926,01	5,81	22	5,13	359077761,35	278,61	5,68	282,08	5,84	253,67	5,64	27990,49
64	2	8	3,73	695,04	123,11	202362,82	4,28	21,52	3,98	145568201,2	231,76	4,27	231,24	4,27	194,09	4,24	26139,92
64	4	2	6,95	278938,97	447,14	365706,26	9,18	24,12	7,75	795062568,44	424,43	9,24	385,75	9,24	351,03	8,59	30794,32
64	4	4	4,25	10815,85	298,89	280419,83	5,69	16,92	5	428513432,51	292,72	5,69	270,94	5,73	243,5	5,57	26754,09
64	4	8	3,12	1052,35	237,58	367358,17	4,24	12,77	3,81	154977902,12	222,99	4,29	217,17	4,29	193,86	4,27	25266,44
64	8	2	6,24	6746717,82	806,23	525592,545	9,04	23,63	7,33	1000322128,91	474,91	9,15	356,29	9,14	320,09	8,72	27811,68
64	8	4	4	19652,27	628,88	400603,525	5,65	16,96	4,9	456867018,86	328,66	5,69	298,41	5,69	260,82	5,54	27936,65
64	8	8	3	1222,58	459,7	411719,73	4,24	13,03	3,78	154973825,85	164,02	4,29	217,94	4,29	182,97	4,24	24772,96

• We have implemented 2 heuristics which work on the created homing automaton and finds SSs on the homing automaton, which are equvailent to HSs on the initial FSM.

• We have implemented 3 homing heuristics by adapting synchronizing heuristics for homing sequences. They work on the initial FSM.

• SS Heuristics (which work on the HA) generally find shorter homing sequences but, as a trade off, these heuristics consume much more time because of the homing automaton.

• Among HS heuristics we implemented, SynchroP HS is the best in terms of the sequence length since it performs a deeper analysis on the FSM.

REFERENCES

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• S. Sandberg.: Homing and synchronizing sequences. In: Broy, M., et al. (eds.) Model-Based Testing of Reactive Systems. LNCS, vol. 3472, pp. 5–33. Springer, Heidelberg (2005).