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CONTENTS

Adaptive Homing Sequences for Partial Weakly-initialized Observable FSMs

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***Abstract* — Finite State Machine (FSM) based state identification problem is widely used for analysis of discrete event systems. A homing sequence (HS) allows to determine the current state of an FSM under investigation. An HS is known to always exist and has polynomial length with respect to the number of states for a non-initialized reduced complete deterministic FSM where for each input sequence there is exactly one output sequence and any state can be an initial state. The HS problem becomes more complex if partial, non-deterministic or weakly-initialized machines are considered; for such FSMs an HS not always exists and can be much longer when existing. In particular, it has been proven that for a complete weakly-initialized non-deterministic FSM, length of a shortest adaptive HS (AHS) can be exponential with respect to the number of FSM states but HS length was not evaluated. In this paper, we consider the HS problem for partial observable possibly non-deterministic FSMs. In particular, we suggest a criterion for the existence of an AHS for a partial observable FSM and estimate the length of a shortest AHS.**

Keywords — Weakly-initialized Finite State Machine (FSM), Partial FSM, adaptive homing sequence

I. INTRODUCTION

Finite State Machine (FSM) based test derivation methods [1-3] are actively applied in analysis of software and hardware components of digital systems. Such test suites have guaranteed fault coverage but often have exponential length with respect to the size / number of states of a system under test. Length of a test suite can be reduced using state identification sequences of the specification FSM [4] while preserving fault coverage. Such identification sequences as distinguishing (DS), homing (HS) and synchronizing (SS) sequences allow to determine an initial (DS) or a current state (HS and SS) of a system under test. In particular an HS takes the system of interest into the known state which can be determined based on observing responses to a homing sequence. If an FSM is non-initialized reduced complete and deterministic then length of a shortest preset HS is polynomial with respect to the number of states of the machine [5]. However, for partial or non-deterministic FSMs an HS may not exist or can have exponential length with respect to the number of states [6]. In this case, an adaptive HS (AHS) can be considered, i.e., an HS where the next input of the sequence depends on the previous outputs. For non-deterministic machines adaptive homing sequences exist more often and are usually shorter than the preset. Criteria of the AHS existence for different kinds of complete FSMs have been established and there exist methods for AHS derivation [6].

Due to the fact that the system specification can be incomplete or inconsistent, the behavior of a corresponding FSM can be only partially specified at some states, i.e., an FSM under investigation can be partial. Therefore, it is important to study the HS problem for partial FSMs. It has been proven that this problem is PSPACE-hard even for deterministic FSMs [7]. However, the precise lower bound on length of a shortest AHS for partial FSMs is not established yet. Some lower bounds on length of shortest synchronizing sequences for partial machines are established in [8] but these bounds are not precise.

In this paper, we suggest a criterion for the AHS existence for partial observable weakly-initialized FSMs and estimate length of a shortest AHS for partial observable weakly-initialized FSMs. Given a partial FSM, a proposed criterion allows to construct an HS using the known methods for complete FSMs. We also prove that length of a shortest AHS for a partial observable weakly-initialized FSM with n states can reach $C_n^{\lfloor \frac{n}{2} \rfloor}$ and show that this lower bound is not precise and should be increased.

The rest of the paper is structured as follows. Definitions and notations are presented in Section II. Section III presents the criterion of the AHS existence for a partial observable weakly-initialized possibly non-deterministic FSM. In Section IV, we determine a class of partial observable weakly-initialized FSMs such that length of a shortest AHS for an FSM with n states reaches $C_n^{\lfloor \frac{n}{2} \rfloor}$, and Section V concludes the paper.

II. PRELIMINARIES

Definitions and notations of this section are mainly taken from [9, 10, 11].

A. Finite State Machines

The main notion of this paper is a Finite state machine (FSM), that is a tuple $\mathcal{M} = (S, I, O, h_M, S_{in})$ where S is a finite non-empty set of states with the set S_{in} of initial states, I (O) is input (output) alphabet and $h_M \subseteq S \times I \times O \times S$ is a *transition relation*. We say that $\mathcal{M}$ is *non-initialized* if $S_{in} = S$; if $|S_{in}| = 1$ then the FSM is an *initialize*d machine, otherwise $\mathcal{M}$ is *weakly-initialized* FSM. We say that $\mathcal{M}$ is *non-deterministic* if for some pair $(s, i) \in S \times I$, there exist at least two pairs $(o, s') \in O \times S$ such that $(s, i, o, s') \in h_M$; otherwise, the FSM is *deterministic*. FSM $\mathcal{M}$ is *complete* if the transition relation is defined for each pair $(s, i) \in S \times I$; otherwise, the FSM is *partial*. If for every two transitions (s, i, o, s_1), $(s, i, o, s_2) \in h_M$ it holds that $s_1 = s_2$ then FSM $\mathcal{M}$ is *observable*. In the following, we consider partial observable possibly non-deterministic FSMs if the contrary is not directly stated.

In Fig.1, FSM $\mathcal{M}_5$ has three initial states, $S_{in} = \{3, 4, 5\}$. FSM $\mathcal{M}_5$ has the set of states $S = \{1, 2, 3, 4, 5\}$, the input set $I = \{x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}\}$, the output set $O = \{0, 1\}$. Given state 3 and input x_1, if x_1 is applied to the FSM $\mathcal{M}_5$ then machine performs transition $(3, x_1, 0, 4)$, i.e., produces output 0 and moves to state 4. Due to the fact that there are two transitions at state 3 with input x_{10}, namely, (3, x_{10}, 0, 1) and (3, x_{10}, 1, 1), FSM $\mathcal{M}_5$ is non-deterministic. The machine is partial, since, for example, at state 1 of the FSM, transitions are not defined for inputs x_7, x_8, x_9, x_{10}.

FSMs are used for transforming sequences of input actions into those of output actions. The behavior of an observable FSM $\mathcal{M} = (S, I, O, h_M, S_{in})$ over a sequence of actions of the set I is defined using the notion of a trace. Formally, given state s_1, an input word $\alpha = i_1i_2\ldots i_n$ and an output word $\gamma = o_1o_2\ldots o_n$, a trace α/γ at state s_1 is the sequence of input/output pairs $\alpha/\gamma = i_1/o_1 \ldots i_n/o_n$ if for each $j \in \{1, \ldots, n\}$ there exists a transition $(s_j, i_j, o_j, s_{j+1}) \in h_M$ of FSM $\mathcal{M}$.

The α/γ-successor of state s is a state where FSM moves after applying α and observing γ (written: $succ_{\alpha/\gamma}(s)$). If trace α/γ is not defined at state s then we say that $succ_{\alpha/\gamma}(s)$ is empty or does not exist.

Given a non-empty subset of states $Q \subseteq S$, the notion of the successor is inductively defined. For the input/output pair i/o, if a transition under input i is defined at every state of the subset Q, then the $succ_{i/o}(Q)$ is the set of i/o-successors over all states of Q that can be the empty set and in the latter case, we also say that i/o successor of Q does not exist. The i/o-successor of Q is empty or does not exist if a transition under input i is not defined at some state of Q. Consider trace $\alpha/\gamma(i/o)$. If $succ_{\alpha/\gamma}(Q)$ does not exist then $succ_{\alpha/\gamma(i/o)}(Q)$ does not exist too. If $succ_{\alpha/\gamma}(Q)$ exists then $succ_{\alpha/\gamma(i/o)}(Q) = succ_{i/o}(succ_{\alpha/\gamma}(Q))$. In other words, $succ_{\alpha/\gamma(i/o)}(Q)$ exists if and only if a transition under input i is defined at each state of the set $succ_{\alpha/\gamma}(Q)$ and the set of i/o-successors over all states of $succ_{\alpha/\gamma}(Q)$ is not empty. By definition, if i is undefined at some state of $succ_{\alpha/\gamma}(Q)$ then $succ_{\alpha/\gamma(i/o)}(Q)$ does not exist.

For example, consider FSM $\mathcal{M}_5$ in Fig.1. If $\alpha/\gamma = x_1/0\ x_2/0$ then α/γ-successor of the set {1, 2, 3} is the set {1, 2, 5}, i.e. $\{1, 2, 5\} = succ_{\alpha/\gamma}(\{1, 2, 3\})$. However, for $\alpha/\gamma = x_1/0\ x_1/0$, the α/γ-successor of the pair {1, 4} is empty, since input x_1 is not defined at state 4.

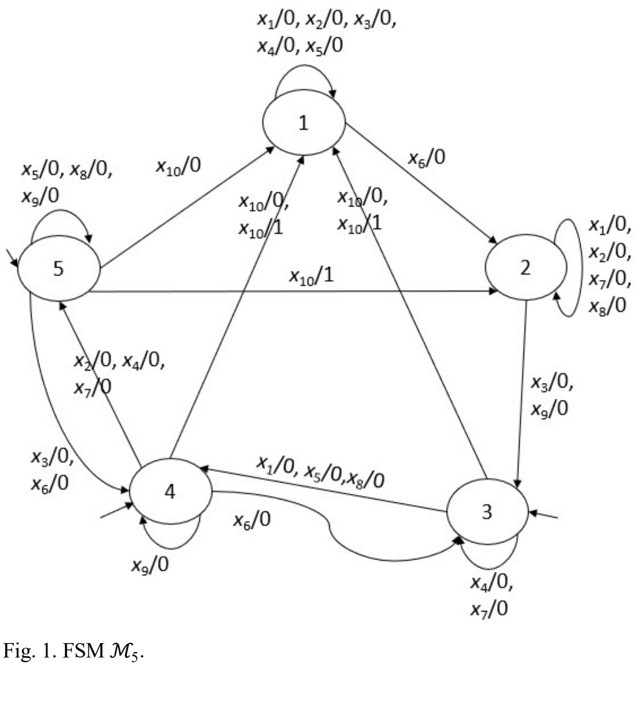

Fig. 1. FSM $\mathcal{M}_5$.

B. Adaptive Homing Sequence

Let α be an input sequence then we say that α is *adaptive* if the next input depends on the output responses to the previous inputs. For the representation of an adaptive sequence, a so-called test case is usually utilized. An observable FSM is *single-input* if at most one input is defined at every state. A state is a *deadlock state* if there are no defined inputs at this state. The FSM is *output-complete* if at each state, for every defined input, a transition is defined with every output. Given a possibly partial and non-deterministic FSM $\mathcal{M} = (S, I, O, h_M, S_{in})$, an initialized connected single-input output-complete observable FSM $\boldsymbol{P} = (P, I, O, h_P, p_0)$ with an acyclic transition graph is a *test case* for $\mathcal{M}$ if for each trace $\alpha/\gamma(i/o)$ of FSM $\boldsymbol{P}$ at the initial state, it holds that if the $succ_{\alpha/\gamma}(S_{in})$ of $\mathcal{M}$ is not empty, then the input i is a defined input at each state of the $succ_{\alpha/\gamma}(S_{in})$ in $\mathcal{M}$. In other words, given FSM $\mathcal{M}$ and its test case $\boldsymbol{P}$, for each trace α/γ which takes the test case $\boldsymbol{P}$ from the initial state to state with a defined input i and takes the $\mathcal{M}$ from S_{in} to a non-empty subset of states, input i is defined at each state of the set $succ_{\alpha/\gamma}(S_{in})$. Thus, represented by the above test case, an input of an adaptive input sequence is never applied at a state of $\mathcal{M}$ where this input is undefined. Note that when $\mathcal{M}$ is complete, the above condition always holds. We note that for partial FSMs the above condition is softer than the condition for the existence of a preset input sequence α with appropriate features, since in this case, α has to be a defined input sequence at every initial state. For an adaptive sequence, this is not required, as different inputs can be defined at the successors with different outputs. Correspondingly, we can expect that for partial FSMs, adaptive sequences with appropriate features exist more often than the preset.

A test case $\boldsymbol{P}$ with the above features defines an adaptive sequence [9] for $\mathcal{M}$. We define the *length* of a test case (adaptive sequence) as the length of a longest trace of $\boldsymbol{P}$ from the initial state to a deadlock state.

A test case $\boldsymbol{P}$ for an FSM $\mathcal{M}$ is a *homing test case* (*HTC*) for $\mathcal{M}$, if for each trace α/γ of $\boldsymbol{P}$ from the initial state to a deadlock state, the α/γ-successor of S_{in} does not exist or is a singleton. An HTC represents an *adaptive homing sequence* (AHS). If all the singletons reached in FSM $\mathcal{M}$ at deadlock states of the homing test case $\boldsymbol{P}$ are contained in a proper subset S' of S, then an AHS is S'-AHS.

As an example, consider an HTC in Fig. 2 for FSM $\mathcal{M}_5$ shown in Fig. 1 where {3, 4, 5} is the set of initial states. At the first step, the x_{10} is applied to FSM $\mathcal{M}_5$ in states 3, 4 or 5. If $\mathcal{M}_5$ responds by the output 0, then due to the fact that (3, x_{10}, 0, 1), (4, x_{10}, 0, 1), (5, x_{10}, 0, 1) $\in h_M$, HTC moves to state 1 and we can conclude that S_{in} is set into state 1. At the same time, if $\mathcal{M}_5$ responds by 1 then HTC moves to state 1 or 2 depending on the initial state due to the fact that (3, x_{10}, 1, 1), (4, x_{10}, 1, 1), (5, x_{10}, 1, 2) $\in h_M$. Height of the HTC is seven. Due to the fact that all paths lead to a deadlock state {1}, the AHS shown in Fig. 2 is a {1}-AHS.

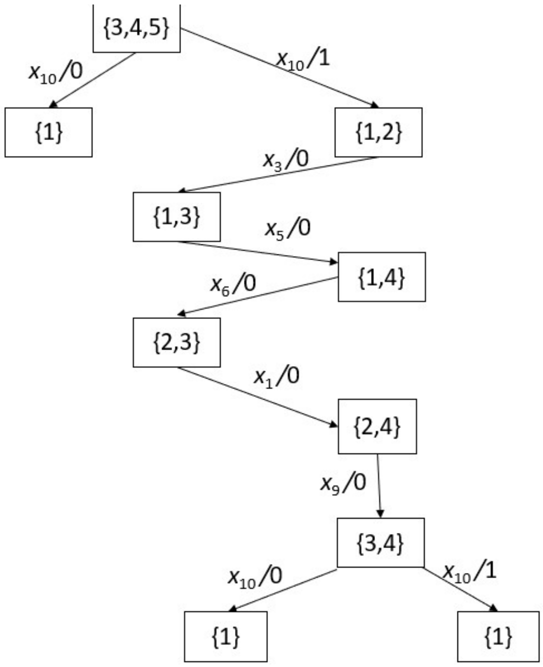

Fig. 2. A Homing Test Case (HTC) for $\mathcal{M}_5$ where S_{in} = {3, 4, 5}.

III. Checking the Existence and Derivation of an Adaptive Homing Sequence

When deriving a distinguishing sequence for a partial machine, the researchers sometimes add a DON'T CARE state and all undefined transitions are directed to this state [12]. In this section, we use the same trick for deriving an AHS for a partial observable possibly non-deterministic FSM. We add to the set of states S an additional state $N \notin S$ and for each undefined transition at state s under input i, we add transitions to state N under i with all outputs. Such an augmented FSM is denoted as $\mathcal{M}^N$. By definition, if $\mathcal{M}$ is observable then $\mathcal{M}^N$ is a complete observable FSM. Formally, given $\mathcal{M} = (S, I, O, h_M, S_{in})$, FSM $\mathcal{M}^N = (S \cup \{N\}, I, O, h_M \cup h_M^N, S_{in})$ where $h_{\mathcal{M}}^N$ contains each transition (s, i, o, N), $s \in S$, $i \in I$, $o \in O$, where input i is not defined at state s, or $s = N$.

Given a partial observable possibly non-deterministic FSM $\mathcal{M} = (S, I, O, h_M, S_{in})$, the condition for the existence of AHS for FSM $\mathcal{M}$ is stated in the following theorem.

Theorem 1. Given a partial observable possibly non-deterministic FSM $\mathcal{M}$, a test case TC is an HTC for $\mathcal{M}$ if and only if the TC is an S'-HTC for $\mathcal{M}^N$ for some $S' \subseteq S$.

$\Rightarrow$ If $\mathcal{M}^N$ has an S'-HTC $\boldsymbol{P}$ then none of the traces of $\boldsymbol{P}$ passes the state N since $\mathcal{M}$ at this state has only transitions to N with all input/output pairs i/o and $N \notin S'$. Consider a trace $\alpha/\gamma(i/o)$ of FSM P at the initial state, such that $succ_{\alpha/\gamma}(S_{in})$of $\mathcal{M}$ is not empty. Then the input i is a defined input at each state of the α/γ-successor of the set S_{in} of states of $\mathcal{M}$, since otherwise, state N will be reached in $\mathcal{M}^N$ by some trace of the test case $\boldsymbol{P}$.

$\Leftarrow$ Let now FSM $\mathcal{M}$ have an HTC $\boldsymbol{P}$. Consider again a trace $\alpha/\gamma(i/o)$ of FSM $\boldsymbol{P}$ at the initial state, such that $succ_{\alpha/\gamma}(S_{in})$ of $\mathcal{M}$ is not empty. By definition of a test case, the input i is a defined input at each state of $succ_{\alpha/\gamma}(S_{in})$.

Since $\boldsymbol{P}$ is HTC and $N \notin S$, if $succ_{\alpha/\gamma}(S_{in})$ of $\mathcal{M}$ is empty (or a singleton) then $succ_{\alpha/\gamma}(S_{in})$of $\mathcal{M}^N$ is empty (or a singleton) too. Therefore, for each trace of $\boldsymbol{P}$ from the initial to a deadlock state, $succ_{\alpha/\gamma}(S_{in})$ of $\mathcal{M}^N$ is empty or is a singleton of the set S.

According to the above theorem, all the methods for deriving an S'-AHS for complete FSMs can be used for deriving adaptive homing sequences for partial FSMs. If a partial FSM is non-initialized then it can be an iterative method that starts with a pair of initial states and then adds states one by one [6]. If the partial machine is weakly-initialized then a method based on a homing FSM [10] can be applied.

We briefly illustrate the latter method for an FSM $\mathcal{M}_5$ shown in Fig. 1. At the first step, we augment the machine with transitions to state N for each undefined transition and obtain the FSM $\mathcal{M}_5^N$ a fragment of which is shown in Fig. 3. For example, in FSM $\mathcal{M}_5^N$, at state 5 input x_1 is not defined; thus, transitions $(5, x_1, 0, N)$, $(5, x_1, 1, N)$ are added to FSM $\mathcal{M}_5^N$. Then, a so-called Homing FSM is derived [10] where after iterative deleting states with undefined inputs a S'-HTC can be obtained for $\mathcal{M}_5^N$ which is an AHS for $\mathcal{M}_5$ shown in Fig. 2.

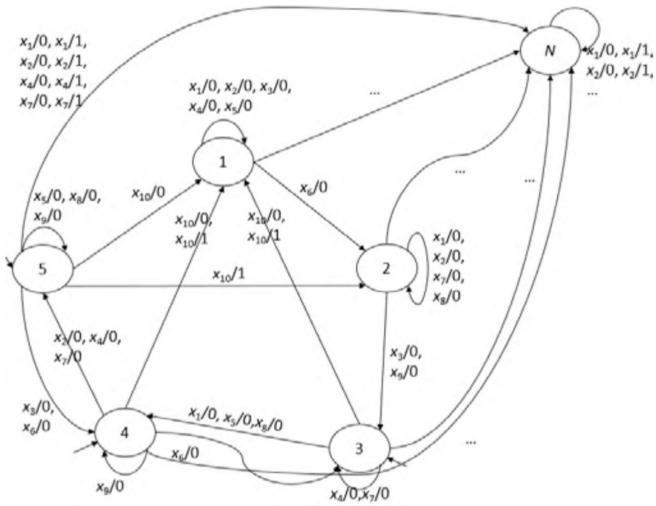

Fig. 3. A fragment of FSM $\mathcal{M}_5^N$.

IV. Evaluating Length of a Shortest Adaptive Homing Sequence For Partial Observable FSM

In this section, we estimate length of a shortest adaptive homing sequence for weakly-initialized observable FSMs. Formally, suppose that $\mathcal{M}(n)$ is a set of all weakly-initialized observable FSMs with n states; and $\mathcal{M}_{AHS}(n)$ is a maximal subset of FSMs of $\mathcal{M}(n)$ which have an adaptive homing sequence. We denote by $\psi(M)$ length of a shortest AHS for FSM $M \in \mathcal{M}_{AHS}(n)$; and $\psi(n) = \max_{M \in \mathcal{M}_{AHS}(n)} (\psi(M))$ is maximal length of a shortest AHS for weakly-initialized observable FSMs with n states which have an AHS (the Shannon function). In [8], the lower bound of $\psi(n)$ is evaluated for a preset synchronizing sequence (SS) that is defined at each state of a partial automaton and takes the automaton from any initial state to one and the same state. However, the authors are not aware on any results on the lower bound of $\psi(n)$ for adaptive homing sequences for weakly-initialized partial FSMs. In order to evaluate the lower bound of $\psi(n)$ for adaptive homing sequences, we introduce a special class of partial weakly-initialized deterministic FSMs (called C_n^m −stepped FSMs) with n states and C_n^m inputs, $1 < m < n$, such that each FSM has an AHS and length of a shortest AHS is not less than C_n^m. As a corollary, we can conclude that for $n > 3$, $\psi(n) \geq C_n^{\lfloor \frac{n}{2} \rfloor}$.

Given a set $S = \{1, 2, \dots, n\}$, $n > 1$, consider the chain of all subsets of m items of S, $m < n$, written $Comb(n, m)$, and assume that the subsets of the chain are represented in the lexicographic order $\{1, 2, \dots, m\}$, $\{1, 2, \dots, m+1\}$, …, $\{n-m+1, \dots, n\}$, i.e., the linear order is specified over the set of all subsets of m items of S: $\{1, 2, \dots, m\} \prec \{1, 2, \dots, m+1\} \prec \dots \prec \{n-m+1, \dots, n\}$ where $\{n-m+1, \dots, n\}$ is a final or terminal subset of the chain $Comb(n, m)$. Given a non-final subset $\{j_1, j_2, \dots, j_m\}$ such that $\{j_1, j_2, \dots, j_m\} \prec \{j'_1, j'_2, \dots, j'_m\}$ and there is no subset $\{j''_1, j''_2, \dots, j''_m\}$ such that $\{j_1, j_2, \dots, j_m\} \prec \{j''_1, j''_2, \dots, j''_m\} \prec \{j'_1, j'_2, \dots, j'_m\}$, we say that $\{j'_1, j'_2, \dots, j'_m\} = next(\{j_1, j_2, \dots, j_m\})$. For example, $Comb(4, 2) = \{1, 2\} \prec \{1, 3\} \prec \{1, 4\} \prec \{2, 3\} \prec \{2, 4\} \prec \{3, 4\}$ where $\{2,4\} = next(\{2, 3\})$ and $\{3, 4\}$ is the terminal (or final) subset of the chain. If n is even then $\lfloor \frac{n}{2} \rfloor = n/2$ while if n is odd, $\lfloor \frac{n}{2} \rfloor = (n + 1)/2$.

Consider integers $n > 3$, $1 < m < n$, and construct an FSM $\mathcal{M}_{Comb(n, m)} = (S, I, O, \rho_M, S_{in})$ such that

- the set of states $S = \{1, 2, \dots, n\}$;
- the set of inputs $I = \left\{ i_1, \dots, i_{C_n^{\lfloor \frac{n}{2} \rfloor}} \right\}$;
- the set of outputs $O = \{0, 1\}$;
- the set of initial states $S_{in} = \{1, 2, \dots, m\}$;
- The transition relation ρ_M is defined in a following way; each input $i_{(j_1, j_2, \dots, j_m)} \in I$ is defined only in states $j_1, j_2, \dots, j_m$
  - If $\{j_1, j_2, \dots, j_m\}$ is not a terminal subset of $Comb(n, m)$ and $\{j'_1, j'_2, \dots, j'_m\} = next(\{j_1, j_2, \dots, j_m\})$, then transitions from the subset $\{j_1, j_2, \dots, j_m\}$ are specified in such a way that under this input, FSM $\mathcal{M}_{Comb(n, m)}$ is taken from the subset $\{j_1, j_2, \dots, j_m\}$ of states to the subset next($\{j_1, j_2, \dots, j_m\}$) with the output 0;
  - For a terminal subset $\{n - m + 1, \dots, n\}$ of the chain $Comb(n, m)$, ρ_M has transitions $(j, i_{C_n^m}, 1, 1)$, where $j = n - m + 1, \dots, n$.

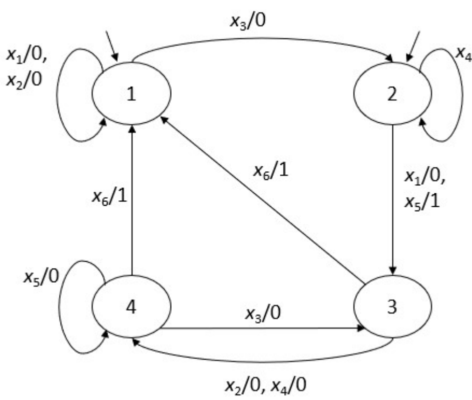

Fig. 4. C_4^2- stepped FSM.

An example of an C_n^m −stepped FSM described above for $n = 4$ and $m = 2$ is shown in Fig. 4. By definition, the FSM is a partial deterministic FSM and has an $HS = x_1, \dots, x_{C_n^m}$. By direct inspection, one can assure that for an FSM in Fig. 4 every homing sequence is a continuation of an $HS = x_1x_2x_3x_4x_5x_6$ and thus, the same holds for an adaptive HS for which a corresponding HTC is shown in Fig. 5. C_n^m −stepped FSMs give a hint to the following statement about the lower bound of a shortest AHS.

Theorem 2. For every $n > 3$ and $1 < m < n$, there exists a weakly-initialized partial observable FSM with n states such that length of a shortest AHS is equal to C_n^m.

Sketch of proof. Given $n > 3$ and $m < n$, consider C_n^m −stepped FSM $\mathcal{M}$. In this FSM only the last input can home the terminal subset of the chain. Therefore, every preset homing sequence is the continuation of the sequence which leads to the terminal subset of states. According to the structure of C_n^m −stepped FSM, only single sequence $HS = i_1, \dots, i_{C_n^{\lfloor \frac{n}{2} \rfloor}-1}$ leads from the initial subset of states to the terminal subset of the chain and length of this sequence is C_n^m. As at each subset only one input is specified, the same estimate holds for an adaptive homing sequence and this fact proves the theorem statement.

Corollary 1. Given an FSM $\mathcal{M}_{Comb(n, m)}$, $\mathcal{M}_{Comb(n, m)}$ has an AHS and length of a shortest AHS is equal to C_n^m.

Corollary 2. For $n > 3$, $\psi(n) \geq C_n^{\lfloor \frac{n}{2} \rfloor}$.

Indeed, the machine $\mathcal{M}_{Comb(n, \lfloor \frac{n}{2} \rfloor)}$ can be derived, and according to Corollary 1, $\mathcal{M}_{Comb(n, \lfloor \frac{n}{2} \rfloor)}$ has an AHS and length of a shortest AHS is equal to $C_n^{\lfloor \frac{n}{2} \rfloor}$.

As an example, in Fig. 3, a homing test case for an FMS $\mathcal{M}_4$ with $n = 4$ states is shown, the height of the test case is equal to $C_n^{\lfloor \frac{n}{2} \rfloor} = 6$.

In fact, length estimation for the chain $Comb$ is known [13]:

$C_n^{\frac{n}{2}} \sim 4^{\frac{n}{2}} / \left(\pi \left(\frac{n}{2}\right)\right)^{1/2} = (1/((\pi/2)^{1/2}))2^n$ and this is in $\left(\frac{\pi}{2}\right)^{1/2} \approx 1.25 * n^{1/2}$ times less than 2^n–1.

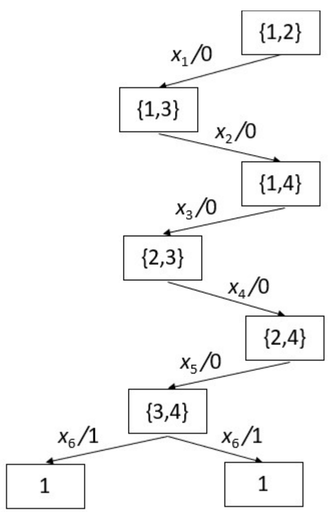

Fig. 5. HTC for C_4^2- stepped FSM.

The above statements give a lower bound of a shortest adaptive homing sequence for weakly-initialized observable partial FSMs. However, the lower bound is not precise. In particular, consider FSM $\mathcal{M}_5$ with $n = 5$ states with the set {1, 2, 3} of initial states shown in Fig. 2. Due to the fact that there exists only one input which is defined in three states, each homing test case for $\mathcal{M}_5^{nd}$ contains a trace γ shown in Fig. 3. Trace γ leads from {1, 2, 3} to {3, 4, 5} and the length of γ is $C_5^3 = 10$. Now to home the subset {3, 4, 5}, it is needed to apply an AHS with length seven. Then length of a shortest AHS becomes $10 + 7 > C_5^3$. The latter illustrates that $C_n^{\lfloor \frac{n}{2} \rfloor}$ is not the precise lower bound for $\psi(n)$.

V. Conclusion

In this paper, we have established a criterion for the AHS existence for partial weakly-initialized observable possibly non-deterministic FSMs. The criterion is based on the special augmentation of the original partial FSM, and using methods for deriving an AHS for complete FSMs. Then we have introduced a class of FSMs with n states, $n > 3$, for which length of a shortest adaptive homing sequence is not less than $C_n^{\lfloor \frac{n}{2} \rfloor}$. Moreover, we have shown that $C_n^{\lfloor \frac{n}{2} \rfloor}$ is not a precise lower bound for partial observable weakly-initialized FSMs, i.e., this estimate has to be improved.

VI. Acknowledgment

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