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Finite Automata Model For SEIHRD Epidemic Model Of COVID-19

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ABSTRACT:

Epidemics is a critical vicinity of situation for all living beings in the world. If we no longer cope with a pandemic situation in a right manner,it cannot be controlled and it results in a disaster as huge quantity of human population is concerned. Here we evolve a non-deterministic finite automata (NFA) for the Susceptible-Exposed-Infectives-Hospitalized-Recovered-Death (SEIHRD) model for computational purpose. Through this version we could show there will be certain languages which can be regular in epidemic model of automata since it is able to be compared with the languages which are normally regular, for which we are able to have NFA. We made an attempt to expose how the epidemic model could behave in order that we may better broaden our methods that could tackle this epidemic scenario. The objective of this work is to find a computation model in terms of nondeterministic finite automata (NFA) by which we may better infer the pandemic environment.

Keywords: Epidemic, Pandemic, COVID-19, SEIHRD epidemic model,Epidemic NFA.

1. INTRODUCTION:

Modeling and simulation are vital decision tools that are developed and used to control human and animal diseases.Since each disease shows its own and specific biological characteristics or symptoms, the models need to be tailored to every peculiar case so as to handle real situations. Epidemics is a key zone of concern of existence in the world. If we do not handle this situation in a proper way, it cannot be controlled and it leads to a disaster as huge amount of human populace is involved. A.Senthil[21] has introduced finite automata for SIR model.Here we evolve a fundamental model of computation in phrases of non-deterministic finite automata(NFA) for the Susceptible-Exposed-Infectives-Hospitalized-Recovered-Death[7] ,[8],[9],[10],[11][12](SEIHRD) model .

In his pioneering paper Zadeh.L.A. [21] introduced the notion of fuzzy set and developed by himself and others as found many applications in the domain of Mathematics and in other areas of Science and Technology. Further, several authors extended the fuzzy set theory by

introducing Intuitionistic fuzzy sets [IFS], interval-valued fuzzy sets [IVFS], vague sets [VS], multi-fuzzy sets [MFS] etc. Infact a fuzzy set Υ: Z→[0,1].The degree of membership function of a fuzzy set communicates the degree of association of element to fuzzy set. The

fuzzy set theory gives membership of an element Z only, it means the indication of Z association to Υ, but it does not take care of the indication against Z association to Υ. To offset this problem, Gau.W.L

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and Buehrar.D.J[6] introduced the notion of vague sets. In

accordance to their theory, a Vague Set P of a non-empty set Ŧ can be identified by functions (tP,fP) where tP and fP are functions from Ŧ → [0,1], such that tP(x)+ fP(x) ≤ **1**for all x ∈Ŧ , where tP is called the truth function (or)membership function, which gives

indication of how much an element x belong to Ŧ and fP is called the false function (or)

non-membership function, which gives indication of how much an element x does not belong to Ŧ.Thesemethodologies are being directed in various fields like decision making, fuzzy control etc. In such a sense the ideology of vague sets(VS) is a generalization of Fuzzy set(FS) theory. Ranjit Biswas [16] investigated the study of vague algebra by introducing the conception of vague groups and vague normal subgroups. In succession the authors T.Eswarlal, Ramakrishna.N, Y.Bhargavi,B.Nageswararao,S.Ragamayi introduced and studied Boolean vague sets(Bo -VS),Vague groups(VGs), vague gamma semi rings(VGSRs), translate operators on Vague groups and Vague gamma near rings(VGNRs),Bipolar Fuzzy sets,Bipolar vague Sets [3], [4],[15],[16]and investigated some of their applications[18], [19][20].

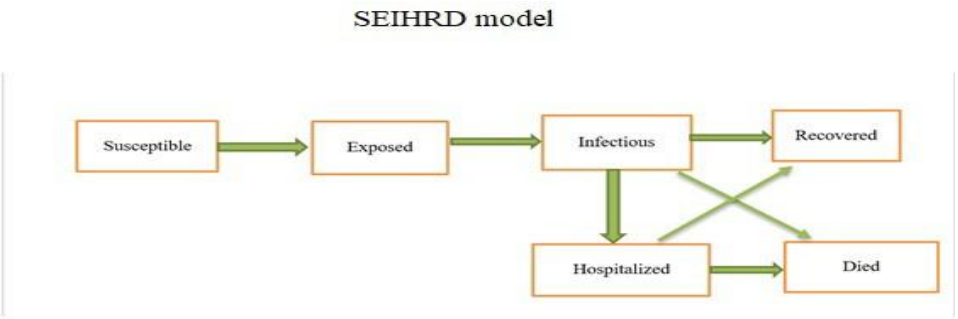

Figure 1. SEIHRD compartmental model

Infact Coronavirus disease 2019(COVID-19) is an infectious disease emerged in Wuhan- China in December 2019 and then rapidly spread around the country and subsequently it affected all the countries all over World.In this connection WHO declared COVID-19 to be a pandemic on 11 March 2020. This is a new virus with unknown medical treatment.The first case of COVID-19 pandemic in India was reported on 30 January 2020,originating from China. As of 26 Sep 2020, the Ministry of Health and Family Welfare have confirmed a total of 960969 active cases, 4849584 recoveries and 9337 deaths. The infection rate of COVID-19 in India is reported to be 1.7 .To lower its spread , India made control measures which include isolation, controls on movement of humans(LOCKDOWN), and severe investigation on infected and suspected cases. and several researchers are doing the work on COVID-19using AI and Machine learning[1],[2],[5].

We made an attempt to show how these control measures affect the regulation of the pandemic. The objective of this work is to find a computation model in terms of nondeterministic finite automata (NFA) by which we may better infer the pandemic environment.

2. PRELIMINARIES:

Definition2.1:ANFAisdefinedbyfivetupleM=(Q;Σ;δ;q0;F)where Q, the set of states of theautomaton;

Σ, the input alphabet;

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δ,thetransitionfunction(TF)oftheautomatondefinedbyδ:Qx(Σ∪{λ})→2^Qq0∈Qistheinitialstateofthea utomatonF ⊆Qisthesetoffinalstates.
The language of a NFA is formally L(M) = {w ∈ Σ*: δ*(q0,w)∩ $F \neq \phi$}
by Using this as a base line we evolve automata for the SEIHRD epidemic model.

Definition 2.2 [1]:Mathematical representation of SEIHRD model

- $\frac{dS}{dt}$= -βSI/N
- $\frac{dE}{dt}$=(βSI/N)-(σE)
- $\frac{dI}{dt}$= (σE)-(ϒE)-(μE)
- $\frac{dR}{dt}$=ϒE
- $\frac{dD}{dt}$=μE

Where Contact rate is denoted by β ,Mean recovery rate is denoted by ϒ,Incubation rateis denoted by σ,Mortality rate is denoted by μ.

3. Epidemiological characteristics of COVID-19

In this section we present the epidemiological characteristics of COVID-19. As per the known characteristics of the COVID-19 pandemic, we suppose that each person could be in one of the below compartments.

- **Susceptible (denoted by S):** The person is not affected by the diseasepathogen.
- **Exposed (denoted by E):** The person is in the incubation period after infected by the disease pathogen with clinical signs. The individual could infect other people but with a lower certainty than people in the infectious compartments. After the incubation period, the person passes to the Infectiouscompartment
- **Infectious (denoted by I):** After the incubation period, it is the first state of the infectious period, where nobody is expected to be detected yet. The person has finished the incubation period, may infect other people and starts developing clinical signs. After this period, people in this compartment can be, either taken in charge by sanitary authorities (and we classify them as hospitalized), or not detected by authorities and continue asinfectious.
- **Hospitalized or in quarantine at home (but detected and reported by the authorities) that will recover (denoted by H):**The person is in hospital (or in quarantine at home) and they still infect other people. At last in this state, a person passes to the next state that is Recovered compartmentR.
- **Recovered (denoted by R):** The person was previously detected as infectious, survived

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the disease, is not more communicable and has developed immunity to fight with thevirus.

- **Dead by COVID-19 (denoted by D):** The person has died due to thedisease.

So as to control the pandemic COVID-19 spread the start up has raised by the authorities.

Isolation: This means going without human contact, being isolated from others, and having nill contact with others except the medical professionals.However, infection of those specialists additionally

occurs. Isolated sufferers acquire medication that reduces the COVID-19 fatality rate.

Quarantine: Motion of people in the region of provenance of an inflamed person is restrained and controlled (e.g. brief sanitary checkpoints at airports) to avoid that feasible infected people unfold the disease.

Tracing: The aim of tracing is to pick out main infectious contacts as they may have infected person orspread COVID-19 to other people. Increase the number of tests so as to achieve raise in the percentage of detected infectedpeople.

Increase of sanitary resources: The quantity of beds in the hospital and sanitary personal to be had to detect and medicate affected human beings should be increased, generating a lower probability in the infectious period

for the compartment I.

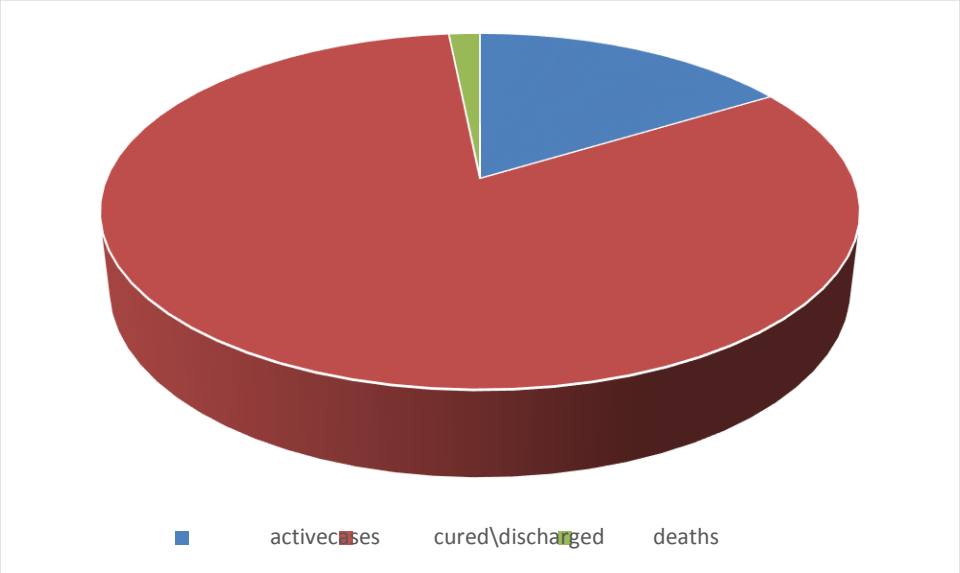

Figure 2. Infected, recovered,died cases of Covid-19 in India upto26th Sep 2020

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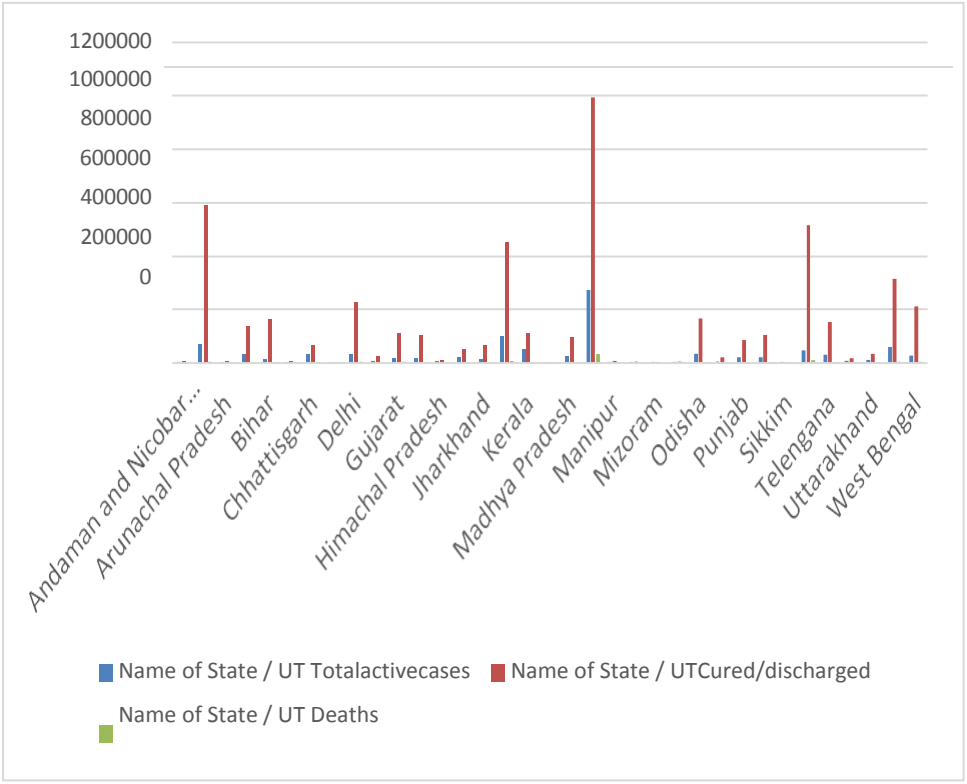

Figure 3. Graphical representation of 33 states Covid-19 cases upto 26th Sep 2020

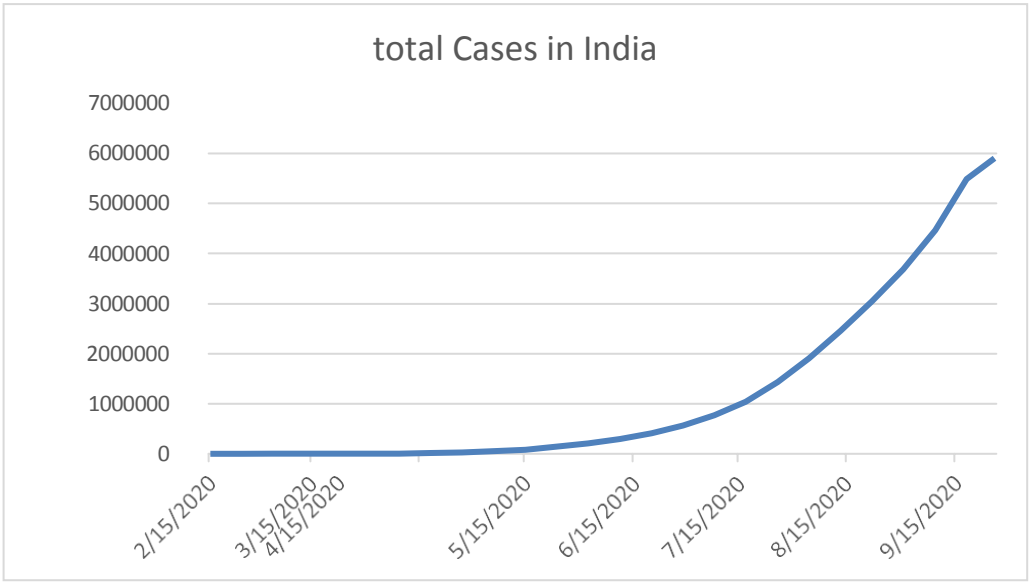

Figure 4. Datewise Covid-19 cases in India upto 26th Sep 2020

4. Epidemic Non-deterministic Finite Automata

4.1. States considered in Epidemic Automaton: In our epidemic model the primary states are susceptible state S, Exposed state E, Infected state I, Hospitalized state H, Recovered state R.

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Along with these states we have two more additional states in our model. Of those one is Dead state D for those who end their lives in this epidemic phase and the other is start state entitled epidemic state of start ES for a human who enters intoepidemic environment. Thus the possible states considered for the epidemic NFA would be:Q={ES,S,E,I,H,R,D}

4.2. The Input Alphabet Σ: As long as an epidemic automaton is considered, the inputsymbolsareconsidered to beamanorwomanindividual,sowe areunable tolimitourselvesto afinite setasin case of ordinary NFA.The epidemic environment also says that once a person is susceptible, eventually he/she is shifted to contamination state in the automaton when he gets inflamed. The inputalphabet**Σ**inthisconsideredepidemicautomataisaninfinitesetoftuples.Particularlyeachtuplecontai n two elements of the form {t_i, u}.Here ti refers to a man or woman individual having unique id i where i ranges from 1 to n. Here $t_i$is infinite and u∈{ES,S,E,I,H,R,D} is a finite set.Thus input alphabet for the considered epidemic automaton is taken as a combination of finite and infinite set. Therefore **Σ**= < t_i,u >,< t_i+ 1, u >,……..< t_n, u >,in which $t_i$to t_n are unique ids of individuals andu∈{ES,S,E,I,H,R,D}.

4.3. The Transition function *δ*: Formally, the transition function δ: Q x Σ → 2^Q.The rangeof δispowersetof2^Q,whereitsvalueisnotjustasingleelementofQ,butitssubset.Thissubsetishence defined as the set of all possible states that can be obtained by the transition. If for example the present state is S (susceptible),then symbol < t_i,S > is read then ***δ***(S,< t_1, S >) = {S,E,I,H,R,D}means theautomatonisinsusceptiblestateSandifanindividual t1isinsusceptiblestatethenhe\shemayhave either S; or E or I or H or R or D as the next state of the epidemic NFA.

4.4. The Start State: The initial state of this epidemic NFA is taken as the ES state which is the starting state of the Epidemic NFA. The automata is in this state before reading any input symbol. The input would be in the input tape and the tape is divided into equal length cells. Every cell holds a symbol (one tuple) of the form <ti,u>.This would be added on the right side of the tape. The input is read from left to right one tuple at atime.

4.5. Final States: The final states for this automaton based on the SEIHRD epidemic model are the Recovered and the Dead states respectively.The reason for this is that a person comes out of the epidemic environment in the SEIHRD model either as a recovered or died in various stages of automaton.

5. Transition Table

5.1 Transition Table of Epidemic NFA

	<t_i,ES>	**<t_i,S>**	**<t_i,E>**	**<t_i,I>**	**<t_i,H>**	**<t_i,R>**	**<t_i,D>**
ES	**S**	***φ***	***φ***	***φ***	***φ***	***φ***	***φ***
S	***φ***	**{S,E,I,H, R,D}**	***φ***	***φ***	***φ***	***φ***	***φ***

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E	φ	φ	**{E,I,H, R,D}**	φ	φ	φ	φ
I	φ	φ	φ	**{I,H, R,D}**	φ	φ	φ
H	φ	φ	φ	φ	**{H, R,D }**	φ	φ
R	φ	φ	φ	φ	φ	**{R ,D }**	φ
D	φ	φ	φ	φ	φ	φ	φ

Here in this transition table of the epidemic NFA the column heads represent the input alphabet tuples and the row heads denotes the states of the automaton.

The epidemic NFA transition diagram(TD) would be as following

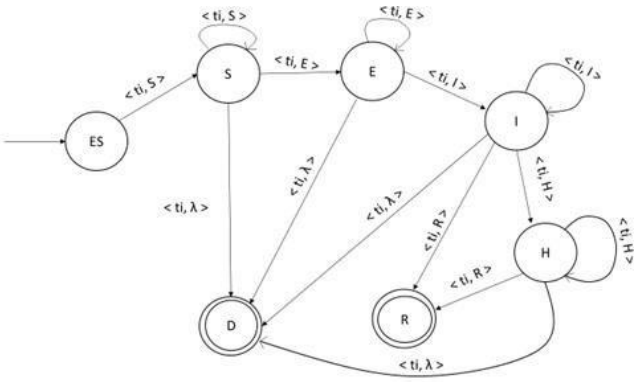

Figure 5. Transition diagram

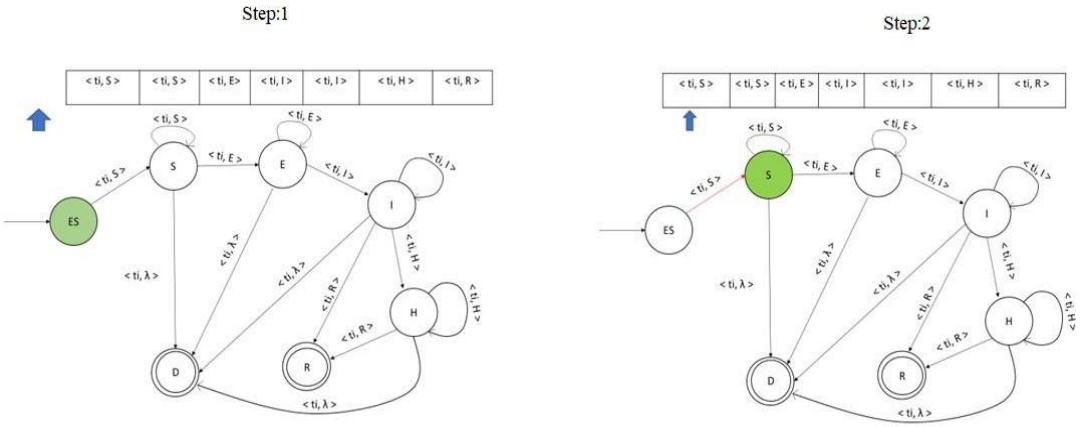

Figure 6. Step 1 and 2

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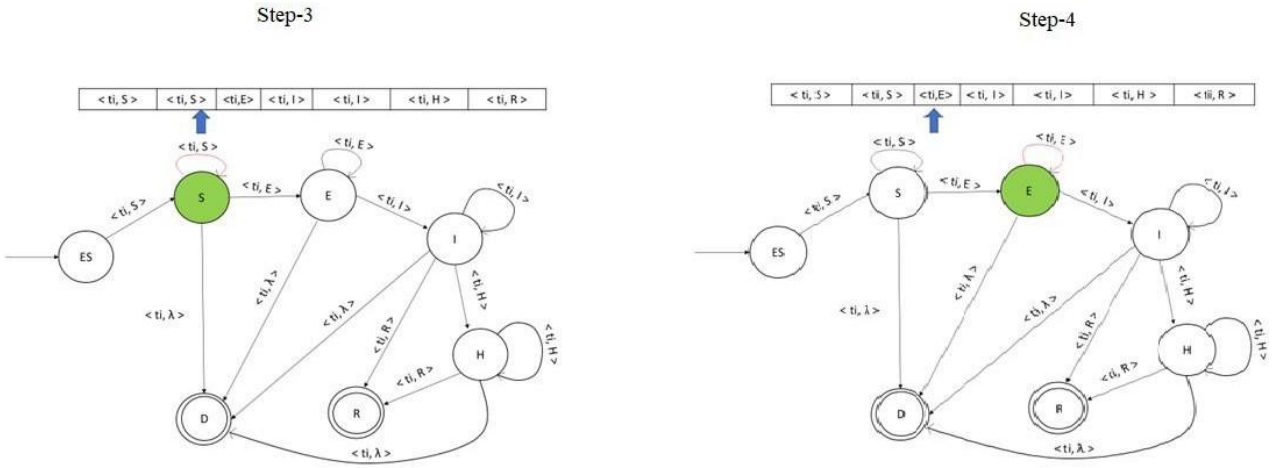

Figure 7. Step 3 and 4

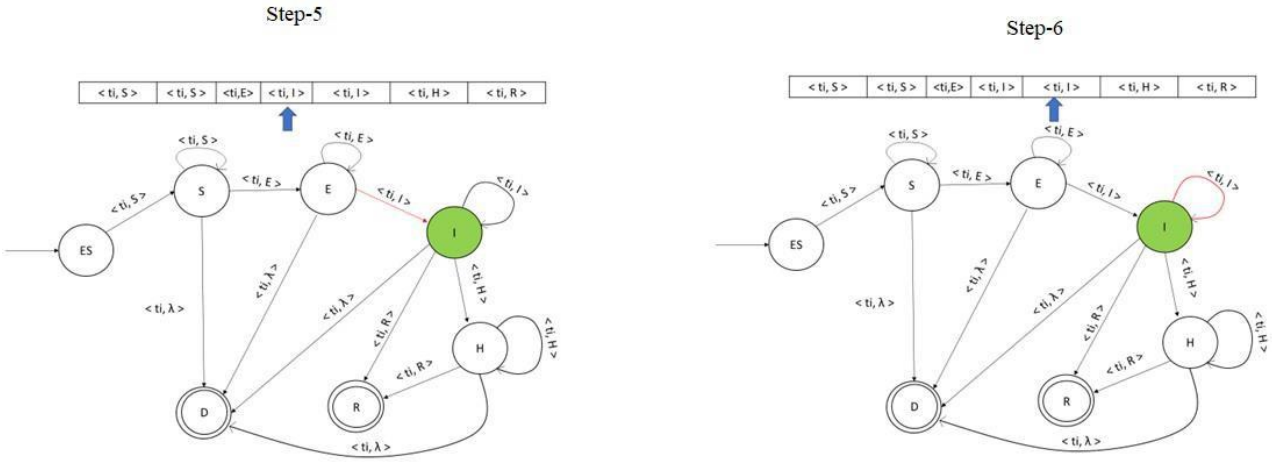

Figure 8. Step 5 and 6

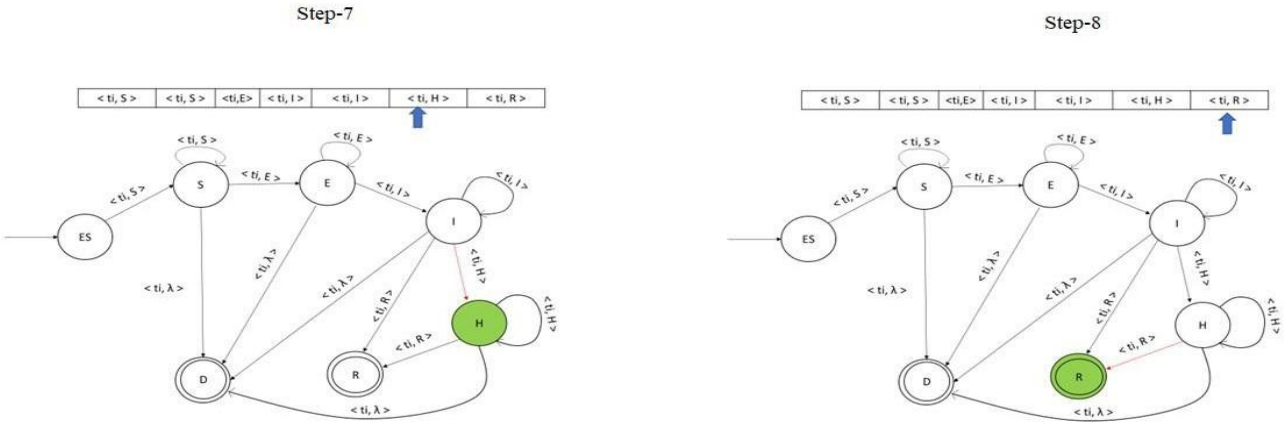

Figure 9. Step 7 and 8

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Having a glance in figure 9 at time step 8 the whole or total input was taken and read, and the automaton is on one the final state. According to the string acceptance definition of the epidemic NFA

,the string w is accepted. The transition from the susceptible state and infected state shows that an individual may die during the period when he is in susceptible ,exposed and infected period .So without taking input symbol, the automaton may take a move from S state to D state or E state to D or I state to D state. As after the death state of an individual there is no other process, we have D state is also treated as one of the final stateof the epidemicNFA.

6. Experimental Setup

- The examination of this model with the real time data has been done using Python.As the infection spread generally happens in the group of population over a geographical area, the population is taken constant. Colour codes have been defined for the main five states as susceptible cells in blue, exposed in yellow, infected in blue dots, recovered in green anddied cases in red. Contact rate is taken as 5,Mean recovery rate taken as ϒ=1/14,Incubation rate taken as 1/5,Mortality rate is taken as0.032

The graph given below shows the results of the epidemic automation.

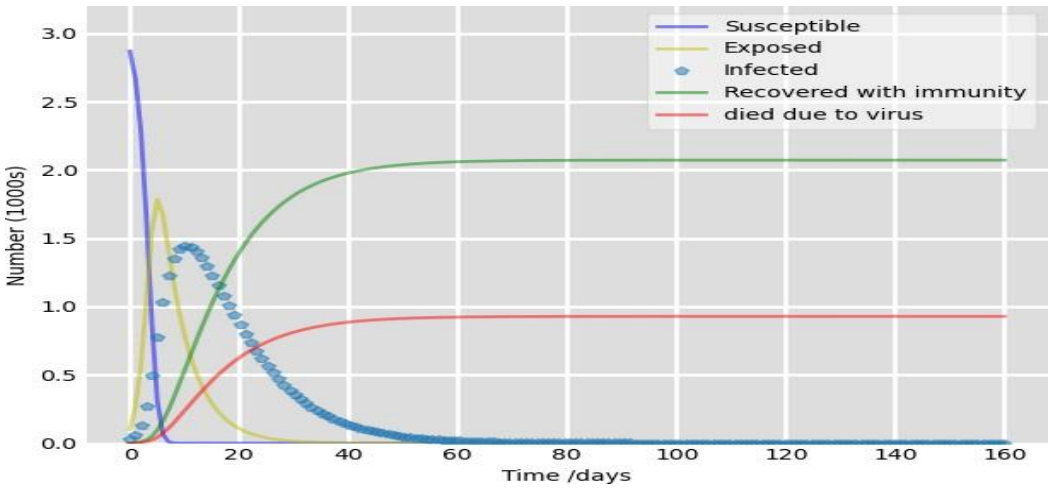

Figure 10. Automation graph of SEIHRD model for COVID19

7. Conclusion

We have proposed SEIHRD epidemic model that fits into the NFA which is one of the basic finite automata model.We have all the properties satisfied for the epidemic model as that of NFA. Moreover, We could also enhance this model by adding another state Vaccine, as we havevaccine for COVID-19 now and we are going to develop the model in fuzzy environment as there will be uncertainity in infection rate in the second wave of COVID-19 in India now.

Conflict of Interest:

The authors confirm that there is no conflict of interest to declare for this publication.

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References

[1] [1]SomasekharJ,Pavan Kumar P,AvinashSharma,RameshG",Machine Learning and Image Analysis applications in the fight against COVID-19 pandemic:DataSets,researchdirections,challenges and opportunities"(2020),Materials Today Proceedings, DOI:10.1016/j.matpr.2020.09.352

[2] Vatan, Avinash,Sharma,Sandip Goyal, "Artificial Intelligence on the Move: A Revolutionary Technology "'International Journal of Recent Technology and Engineering (IJRTE)' Volume-8 Issue-4, November 2019.

[3] Bhargavi, Y., Eswarlal,T.(2016)" Application of vague set in medical diagnosis".International Journal of Chemical Sciences, 14(2), 842-846,2016.

[4] Bhargavi Y., Eswarlal T. (2018)," Vague semiprime ideals of a gamma -semiring". Afrika Matematika 29(03-Apr), PP. 425-434.

[5] Yadav D., Maheshwari H., Chandra U., Sharma A. (2020) COVID-19 Analysis by Using Machine and Deep Learning. In: Chakraborty C., Banerjee A., Garg L., Rodrigues J.J.P.C. (eds) Internet of Medical Things for Smart Healthcare. Studies in Big Data, vol 80. Springer, Singapore. https://doi.org/10.1007/978-981-15-8097-0_2

[6] Gau W.L and Buehrer D.J(1993)," Vague Sets",IEEE Transaction on systems,Man and cybernatics,23(2),610-614.

[7] Hoya White.S, Martin del Rey.A, Rodriguez Sanchez G,(2009) ,Using Cellular Automata to Simulate Epidemic Diseases. Applied Mathematical Sciences,3(20), 959-968.

[8] Ivorra.B, Ferr_andez M.R, Vela-P_erez, and Ramosa A..M,(2020) Mathematical modeling of the spread of the coronavirus disease 2019 (COVID-19) taking into account the undetected infections. The case of China Commun Nonlinear Sci Numer Simul. 2020 Sep; 88: 105303.

[9] Ivorra B, B Martínez-López, J M Sánchez-Vizcaíno, and A M Ramos. Mathematical formulation and validation of the Be-FAST model for classical swine fever virus spread between and within farms. Annals of Operations,Research, 219(1):25–47, 2014.

[10] Ivorra B and A M Ramos. Application of the Be-CoDis mathematical model to forecast the international spread of the 2019 Wuhan coronavirus outbreak. ResearchGate Preprint, 9 February 2020:1–13, 2020

[11] Ivan Korolev.,Identi_cation and Estimation of the SEIRD Epidemic Model for COVID-19 [12]Kalpana Guleria,AvinashSharma,Umesh Kumar L,DevendraPrasad"Breast Cancer Prediction and Classification using Supervised Learning Techniques"

[12] published in Journal of Computational and Theoretical Nanoscience Vol. 17,06,2020 [13]mohfw.gov.in

[13] Nageswara Rao B,RamaKrishnaN,Eswarlal T (2016) " APPLICATION OF TRANSLATES OF VAGUE SETS IN CARIER DECISSION MAKING",International Journal of Chemical Sciences 14(1) 372 –380.

[14] Nageswara Rao B,RamaKrishnaN,EswarlalT (2016)"APPLICATION OF TRANSLATES OF VAGUE SETS ON ELECTORAL-DEMOCRACY MODEL",International Journal of Chemical Sciences 14(2) 762 – 780.

[15] Ranjit Biswas(2006) "Vague Groups", Int.journal of computational cognition.,4(2).

ISSN: 2233-7857 IJFGCN
Copyright ⓒ 2021 SERSC

[16] Senthil.A, Shukla V.P, Sangappa R. Biradar. (2013) Finite Automata for SIR Epidemic Model, International Journal of Engineering Research and Technology (IJERT) 2 Issue 9.

[17] Venkata kalyaniU ,Eswarlal T(2020) “Homomorphism on Bipolar Vague Normal Groups"Advances in Mathematics:Scientific Journal 9(6), 3315 – 3324.

[18] Venkata kalyaniU ,Eswarlal T(2020) “Bipolar vague Cosets"Advances in Mathemat- ics:Scientific Journal 9(9), 6777 – 6787.

[19] Venkata Kalyani U,Eswarlal T(2020),”Application of Bipolar Vague Sets on MCDM problems”,Materials Today Proceedings,https://doing.org/10.1016/j.matpr.2020.10.088

[20] Zadeh L.A,(1965) “Fuzzy sets" Information and Control, Vol.8, 338-353.

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