**A Machine Learning based path guidance system for safe**

**evacuation of a hospital building in case of fire**

**A PROJECT REPORT**

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Introduction

Innovations are happening at a tremendous rate. The job of engineers around the world is to

make the lives of everyone around them and beyond, easier, more accessible, faster and

safer.

This constant pursuit of making things better in one domain often compromise with another

domain.

The world is becoming safer day after day. Although it is becoming safer, it is also becoming

more complex. In such a complex world, people don’t necessarily make the most optimal

decisions or which have the most utility. Mathematicians from time immemorial have been

improving upon methods and more formally - algorithms, to find the best possible solution to

everyday problems. Finally, in the current times, more often than not, we possess both the

algorithms and the computational power to find solutions to problems unperceivable by most.

But the major problem remains in bridging this wide gap between Man and Machine. Even if

we know the solution to a problem using the most recent algorithms and the most powerful

computers, that solution needs to be shipped to the customer for him to use it.

This may seem not very difficult do. Communications have never before been better than

right now. But here arises a major problem - accidents.

By the definition given in the Oxford Dictionary, an accident is an unfortunate incident that

happens unexpectedly and unintentionally, typically resulting in damage or injury.

In such cases, two major problems arise out of which only one can be resolved. First, due to

the nature of the accident, in most cases, systems to find the optimal solutions are not

present beforehand. This can be resolved by analysing the possible shortcomings and

potential hazards of the environment, products and technologies that are being used.

Second, shipping the solution from the system to the victims of the accidents takes time and

in such situations, more often than not, victims are terrified and hence not able to think

rationally.

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Problem Statement

“A Study on Hospital Fires and Patient Reaction”

Objectives

The objectives of the report will be to:

● To Suggest additional possible exits.

○ Based on the dead ends and bottlenecks faced by the people during data

collection.

● To suggest the best places for entry of "Fire Department Team" for optimum

evacuation to minimise casualty.

○ Based on most encountered windows and balcony during data collection.

● To train the Nurses to direct and collect those people who get lost or stuck in dead

ends and then move them along the most probable, humanly intuitive and safe path.

○ This path will be tailored according to the position of the fire and previous

patient data collected using an RL inspired algorithmic model.

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Literature Review

(De-Ching et al., 2011) explains that the evacuation procedure should proceed in three

stages:

1. Patients who are able to self evacuate in the first stage.

2. Next, patients who need assistance from staff to evacuate in the second stage.

3. And finally, patients who have no mobility and are ambulatory.

But there are some limitations in this research, it presumes some facts such as

pre-evacuation time is around 1300 seconds, which is not experimentally proven, no real

experiment was done on people to prove their facts. The research is focussed more on the

fire extinguishing rather than safe evacuation by the people themselves until the fire-brigade

appears for their help.

G. R. F. Murphy and C. Foot did a study on ICU fire evacuation preparedness in London,

they took a survey of 50 adults of an ICU, and handled them a 90 questions questionnaire

asking about patient characteristics, design, equipment, training, and their evacuation plan.

Thirty-five of 50 (70%) responded within 2 months of the study.Significant weaknesses were

reported in unit design, equipment, and planning. Unit design was compromised by

inadequate fire doors (20%), ventilation cut-outs (17%), and escape routes (up to 60%).

But the method is limits itself to just a survey questionnaire rather than putting patients in a

virtual fire condition. The research more emphasises on the fault of the hospital safety

conditions, it fails to generate any methodology to escape without any casualty.

Qiao et al. did a remarkable work in binding human interaction with safety evacuation, they

propose a methodology with the help of human interaction which may be used to train

people for safe evacuation. But they failed to propose that how will it be possible. They

proposed that human interaction can make safe evacuation much better.

Rita F. Fahy et al. have done a significant work in binding safety evacuation with the help of

human interactions. They studied Human Behavior in the World Trade Center Evacuation.

This paper includes analyses of the behavior of the tower occupants only, that is, those who

were on Floors 11 and above at the time of the incident. There were 225 such respondents

from Tower 1 and 157 from Tower 2. The bomb was placed closer to Tower 1 than Tower 2

and responses to many of the questions differed significantly between occupants of the two

towers.

Sheeba Angel A.⁎ , Jayaparvathy R. did worked on Performance modeling of an intelligent

emergency evacuation system in buildings on accidental fire occurrence. They introduced an

intelligent method to study the evacuation dynamics of high rise buildings under fire

emergencies. The system performance is evaluated in terms of pre evacuation delay,

normalized system throughput and evacuation time by varying the number of evacuees. By

these results they were able to explain where emergency exits should be placed, but they

failed to develop a system which will guide people inside the building to escape without any

causality until fire brigade comes.

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Kelly Rendon Rozo et. al. worked on Building evacuation plans using agent based

simulations considering pedestrians behaviour. Results of the work were able to identify the

weakness in the buildings with multiple exiting routes using some score techniques. But

when it comes to the pedestrians behaviour, they didn’t use the real time data of random

people using any virtual reality technique which can make significant differences in the

original result and the theoretical result.

(Jiang et al., 2014) tries to analyze the main factors that affect the fire safety evacuation

performance of hospital buildings by observing large amounts of pedestrians’ walk velocity in

a hospital, by cameras and videos.

A correlation analysis between the special behavioral characteristics of populations in

hospitals and pedestrian walk velocity and other features show that the speed of walking of

hospital patients is approximately 10%~20% less than that of the healthy population.

The same paper shows that approximately 33% of the patients have no clue about what to

do after the fire-alarm is sounded.

Sujata Pathak from K.J. Somaiya College of Engineering in 2019 published a work on

Automated Fire Evacuation System with Congestion Control. They used modified Dijkstra

algorithm for the path planning system. But the algorithm itself is limited only to the 2D paths,

The algorithm may fail for a multistoried building. Moreover they did not work upon the

human behaviour in case of fire. The modified Dijkstra algorithm itself is quite complicated to

be applied for 2D maps, the algorithm only ensures the optimality of the path, it may or may

not be feasible for a human being to pass through that path. Adding to the above, It just

shows one optimal path, as the fire is dynamic so it may be possible that fire encloses that

optimal path, and in that case the algorithm fails to guide the optimal path.

Huang De-Chinga et. al. did a Study for the evacuation of Hospital on Fire during

Construction, his focus was on evacuation time of patients and staff that often draws major

attention because of the hospital’s diverse population, mix of patient conditions, and having

multiple units on one floor. They worked on the different factors such as temperature which

affects the fire spread in the hospital.

Adam Stančík et. al. used building information modelling. They used visual programming to

model an evacuation plan, but it fails to bind it with human behaviour, moreover the plan fails

to suggest some new emergency exits in the building in order to avoid any chaos.

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Method

In the previous researches done by some great scientists in this field we saw that some

important points were missing in them, their studies lacked human reaction in case of fire.

We have done that study and have discovered a way to build a path guidance system based

on human reaction with the help of Virtual Reality environment and Reinforcement Learning.

With a Reinforcement Learning based approach we have successfully been able to predict

the safest path in case of fire to evacuate the hospital building.

While performing experiments, we noted the time taken to bail out of the building by the

volunteers. The paths taken by the volunteers to escape were noted, the paths were

recorded as integer nodes, each node was coded as a unique integer as shown here:

Based on the time noted, and corresponding path recorded, we defined some scores

**● 3 Time Score**

**● Azimuthal Score**

These scores are directly proportional to the instantaneous optimality of path, the better the

score, more will be the **instantaneous optimality** of the path.

3 Time Score

Time score will be used to calculate how well a particular agent does as compared to the

worst case time (or the maximum time). It will be a value between 0 and 1.

Azimuthal Score

Azimuthal score will be used to calculate how well a particular agent does in finding a path

on the same floor. A rational human will prefer to exit from the same floor rather than from a

different one.

To do this, we will define the three angles (α, β and γ) from the start position to the exit point.

It will be between 0 and 1.

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Underlying Assumptions

● Path cannot be retraced.

● Loops are unacceptable.

Calculation and Post Calculation of Scores

The calculated scores will be added to the dataset. Following this, the revised dataset will

then be used by another algorithm to suggest all the possible paths on which people tend to

go, and rank them based on how optimum they are for escaping.

Here we found the number of possible paths, in the testing time (real scenario), based on the

Human Behaviour Model. We then used the scores to determine the best possible path out

of the possible paths.

We arrange the possible paths in the most likely order (based on human behaviour)

**Note** : *We show multiple paths in decreasing order of priority because in a realistic situation,*

*multiple people using the same path might lead to the situation of bottleneck and hence will*

*reduce the score (which is an indicator of the optimum path).*

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Data Description

So far we have collected data nearly from 25 different people with the help of **virtual reality**

simulations done in **UNITY3D** with the help of **oculus-rift and controllers** for the real-time

experience of the situation.

The data consists of some major columns such as “ Initial\_position”, “final\_exit”,

“path”,”azimuthal\_angle”, “t\_r(in\_sec)”, “fire\_position”, “fire\_in\_path”. During the experiment, the

rooms, compartments of the hospital building were being divided into some integer labeled

nodes.

“Initial\_position” shows the initial node position of the test subject from where it has to escape,

“final\_exit” is the exit node from which the test subjects successfully escapes, “path” is the comma

separated series of nodes through which the test subject passes during the test. “azimuthal\_angle”

angle is the acute angle made by the vector “initial\_position” → “final\_exit” with x, y, z axes

respectively. “t\_r(in\_sec)” is the time taken by the test subject to escape from the building through a

chosen path. “fire\_position” is the instantaneous node position of fire in the building, “fire\_in\_path” is

the one hot encoded column for the condition if fire is encountered in path or not.

Apart from these major columns, there are some minor columns as well for the further

analysis of the situation was handled by different kinds of people. These further analysis

were done on the basis of video gaming experience of people, on the basis of age, gender

etc.

Model

Since the data was dynamic and partially unsupervised so traditional machine learning

models for supervised or unsupervised data were discarded and a new model inspired by

Reinforcement learning was being introduced for the training purpose in which it takes

suitable action to maximize reward in a particular situation.

Reinforcement learning differs from the supervised learning. In **supervised learning** , the *training*

*data* has the **answer key** with it so the model is trained with the correct answer itself whereas in

**reinforcement learning** , there is no answer but the reinforcement *agent* decides what to do to

perform the given task.

Application of Reinforcement learning encounters the problem of dynamic fire, and is

intelligent enough to introduce new emergency exit gates to avoid any chaos.

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Solution approach

From the data collected, t\_r, azimuthal angles and their corresponding fire position, initial

position, final exit were being processed. For each combination of path, initial position, fire

position, final exit, a time score was being calculated:

**Time\_score = (1-1 / (1 +exp(-x/10)))**

**[ 0< Time\_score <1 ]**

Similarly azimuthal score was calculated as:

**a\_score = {2cos(a) + 2cos(b) + cos(c)}/5** {where a , b , c are acute angles from x , y , z

axes}

**[ 0 <a\_score <1 ]**

Then a final score was calculated using formula:

**Final\_score = (Time\_score \* a\_score)^½**

If there was fire encountered during the escape in experiment then immediately the final

score of that path, position combination was awarded 0.

Based on the Final score, best paths were sorted out with the help of algorithm. The best

path is considered as the path with maximum final calculated score, and the score is unique

for every path, position combination.

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The Pseudocode of the method goes like this:

Read the dataset

Read the column fire\_in\_path:

If yes:

Skip and assign total\_score as 0:

else:

Read α, β, γ, and time\_taken

Feed α, β and γ to a function to automatically convert them to

corresponding acute angles

If 0<= α, β, γ <=90:

It is ok;

Else if α, β &γ >90 and <180:

Do 180 - (α, β, γ):

Pass:

Continue till α, β, γ <=90:

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Calculate :

a\_score (i) = Σ i=0 to i < n {2cos( α i ) + 2cos( β i ) + cos( γ i )}/5 ; n = number of rows in the dataset

Now read the time\_taken:

For i less than n :

x i = time\_taken i

time\_score (i) = 1-1 / (1 + exp(-x (i) /10))

Define total\_score:

total\_score (i) = {time\_score (i ) \*a\_score (i) } ½

Add total\_score column to the main data set as a separate column

---------------Training part till here------------------------------------------------------

Now for the testing part:

Take initial\_position, fire\_position as input:

For a given initial\_position, fire\_position:

find the best route based on the scores calculated from the dataset:

Sort the shortlisted instantaneously optimal paths based on the scores:

if no route available for current initial\_position and fire\_position

Display “ can-not find any path ”

If current initial\_position in an intermediate position of a path:

Display “ N.A. (score not calculated for intermediate paths but the path shown is safe

from fire) ”

Display safe paths:

--------------------------------------------------------------------------------------------------

**This is how best routes will be displayed by the algorithm.**

Results:

We wrote the above pseudocode in python, processed the data into csv format, and applied

the algorithm, following results were obtained when tested on sample test set:

Rank

of path

Initial

Positio

n

Fire

positi

on

predicted safe paths score of path

1 202 131 202 , 203 , 201 , 801 , 101 , 991 0.341760

2 202 131 202 , 203 , 212 , 216 , 802 , 132 , 133 , 102 , 101 , 991 0.327951

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1 202 203 N.A. (No way out possible because fire is there in the adjacent node) 0.0

1 220 203 220 , 219 , 218 , 216 , 802 , 132 , 131 ,

992 0.26429

2 220 203 220 , 219 , 218 , 216 , 802 , 132 , 133 ,

102 , 101 , 991 0.065461

1 117 802 117 , 115 , 114 , 111 , 103 , 102 , 101 ,

991 0.35588

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1 **111\*** 216 117 , 115 , 114 , **111\*** , 103 , 102 , 101 ,

991

N.A. (score not calculated for

intermediate paths but the path

shown is safe from fire)

1 **111\*** 216 113 , **111\*** , 114 , 118 , 120 , 123 , 124 ,

993

N.A. (score not calculated for

intermediate paths but the path

shown is safe from fire)

\* intermediate position of a path

1 207 102 207 , 204 , 203 , 212 , 216 , 802 , 132 , 131 , 992 0.13049553139977288

Training Methodology:

As our methodology was based on Reinforcement learning related technique which definitely

required some training data to test. Our model included human interaction in a virtual

environment which definitely itself was a challenge. As working with oculus rift needs some

gaming experience. According to the survey of the people who were with us for the

experiment, nearly 27% of them had no gaming experience, a questionnaire was prepared

for the survey, and the results can be seen here:

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The volunteers were being provided some training in a fake environment to acclimate them

in the hospital VR environment.

**Fig: udayaditya singh giving training to use oculus controllers**

As per the survey, it was not difficult for most of the volunteers to get acquainted in the VR

environment:

However some sort of headache/nausea/ Motion-sickness was experienced by some of

them as revealed by the survey:

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According to the survey, 54.5% volunteers think that the system is very easy to understand:

Here are some snapshots of the training process:

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**Some glimpses of the VR hospital environment as seen by the oculus rift:**

Fig: VR view of first floor of building. Fig: satellite view of the hospital building.

Fig: VR view of the main entrance of the hospital building.

Limitations:

Although a lot of cases have been considered, but there are still some challenges for the

proposed model.

Lift was not considered while experiments assuming the fact that lifts are disabled during fire

situation.

It requires the whole Virtual-Reality simulation model of a Real Building in order to collect

experimental data which can be very costly as it requires a lot of graphics in it.

Node-labeling of each room and compartment of a hospital building and then testing can be

a rigorously long and time consuming process for large hospital buildings.

The proposed model requires fire and smoke sensors, blue guide lights and a server in

which we can feed the learnt model in order to process further, which again is a costly

process.

The experiments were done with static fire, although the algorithm can process the dynamic

fire as well.

All the experiments were done without programming any chaos happening inside the

building, which is different from the real scenario.

Although large efforts have been done to make the conditions realistic but still we lag in

some areas such as the propagation of fire and smoke, they depends upon the direction of

wind, and the type of material, which can not be defined inside UNITY3D as far as we have

come to know.

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Future Scopes:

Apart from the above limitations, the proposed model can be used efficiently for the safety

purpose.

This model has the capability to guide someone from one position to final exit via the safest

and the easiest path without being affected by the fire.

Apart from the path guidance, the algorithm can also help to introduce new emergency exits

from the building in order to avoid any chaos during fire emergency.

This model is not limited to a hospital building only, it can be applied in any type of building,

especially the large buildings where fire risks are more probable.

Special care has been taken while programming the model and it has been made enough

efficient to process large data fast at minimum system requirements.

The algorithm will also work as a normal path guidance system even if there is no fire in a

building, just like an automated path guide.

This reward based Reinforcement Learning model can also be used for traffic signals in a

city which can efficiently minimize the jamm condition on roads of a big city.

This reward based approach has application in Artificial Intelligence as well, such as

automated barriers, automated traffic cameras etc.

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