IEEE Sensors Council

Situation-Aware BDI Reasoning to Detect Early Symptoms of Covid 19 Using Smartwatch

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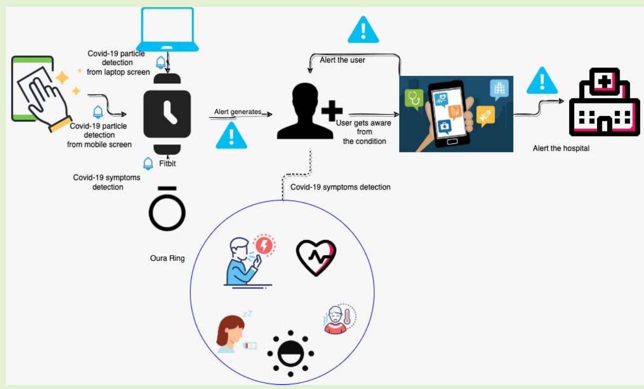
***Abstract*—Ambient intelligence plays a crucial role in healthcare situations. It provides a certain way to deal with emergencies to provide the essential resources such as nearest hospitals and emergency stations promptly to avoid deaths. Since the outbreak of Covid-19, several artificial intelligence techniques have been used. However, situation awareness is a key aspect to handling any pandemic situation. The situation-awareness approach gives patients a routine life where they are continuously monitored by caregivers through wearable sensors and alert the practitioners in case of any patient emergency. Therefore, in this paper, we propose a situation-aware mechanism to detect Covid-19 systems early and alert the user to be self-aware regarding the situation to take precautions if the situation seems unlikely to be normal. We provide Belief-Desire-Intention intelligent reasoning mechanism for the system to analyze the situation after acquiring the data from the wearable sensors and alert the user according to their environment. We use the case study for further demonstration of our proposed framework. We model the proposed system by temporal logic and map the system illustration into a simulation tool called NetLogo to determine the results of the proposed system.**



***Index Terms*—Situation-awareness, ambient intelligence, healthcare, Covid-19, NetLogo, belief-desire-intention (BDI).**

I. Introduction

COVID-19 has been a threat due to its dynamic occurrence in different variants [1], [2]. Everyone is at risk of getting infected by this virus [3], [4]. Although the significant improvement of vaccines has improved the Covid-19 situation, this threat is far from over. Covid-19 is very contagious, and we are living in an era of ambient intelligence [5]. Ambient intelligence has made a huge impact in smart healthcare systems to give people a life outside the hospitals [6]. Healthcare improves health by diagnosing the disease, preventing it, treating it, and other mental or physical illnesses and injuries. Health professionals in allied health fields deliver healthcare. Physicians and physician associates are a part of health professionals [7]. However, in the pervasive computing healthcare system based on ambient intelligence, a person is monitored outdoors, and care providers observe his daily activities. Situation awareness was introduced in the smart healthcare system using ambient intelligence after 2005. It can be through wearable sensors, sensors to monitor patients' condition while performing their life routine activities. Different technologies like WSN and WBAN are used for letting the care providers know about patients' health and to keep them aware of their patient's context [8]. The absence of condition has been identified as the most critical risk factor for human error. Situation awareness has been linked to aviation,

Manuscript received 27 January 2022; accepted 28 February 2022. Date of publication 3 March 2022; date of current version 12 January 2023. The associate editor coordinating the review of this article and approving it for publication was Dr. Hari P. Gupta. *(Corresponding author: Thippa Reddy Gadekallu.)*

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Digital Object Identifier 10.1109/JSEN.2022.3156819

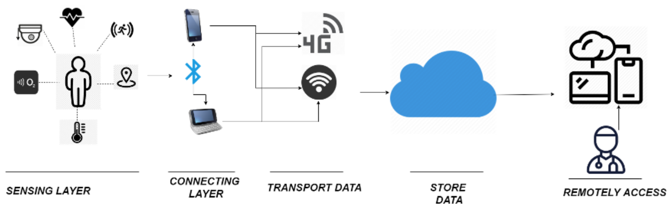

Fig. 1. An overview of situation-aware healthcare system.

aviation control, navigation, health care, emergency response, military command enforcement, and oil and marine energy plants management.

Fig. 1 shows the traditional situation-aware healthcare system. Usually, the healthcare system is based on layers. The first layer is the sensing layer, which collects the data from the patient related to their healthcare situation and then passes it to the connecting layer. The connecting layer uses the Internet to transport the data to the doctors to monitor the patients regularly. In an emergency, the sensor can collect the user's location and forward it to the nearest hospital to alert the rescue team to help the patient.

Patients' data can be stored in a database like a cloud SQL server to give remote access to the doctors' data. After collecting data, sensors need a medium to transfer the data into the remote server. Therefore, laptops, smartphones, smartwatches are used by sensors. Moreover, for the sensitivity of data, cloud storage has been used more often for security reasons. Due to digital transformation (industry 4.0) in the healthcare system, it can be helpful to prevent the pandemic from spreading in the early stages. [9]–[13] Every country is still trying their best to handle Covid-19 pandemic by applying multiple approaches related to machine learning, deep learning, and artificial intelligence [2], [3], [14]. However, the problem is that prediction algorithms of COVID-19 detection may work most of the time, though they fail to provide an accurate result when we expand it further. The problem occurred because the situation is entirely dynamic. We still do not have complete access to the factors that we are facing in this pandemic [15]–[17]. Moreover, other approaches like contact tracing, which have been applied in Australia, are claimed as "mission creep" because of the privacy concerns of people [18], [19].

This paper aims to provide the most feasible approach for early detection of Covid-19 symptoms to take precautions as soon as possible using ambient intelligence. Therefore, we propose a framework regarding the ambient intelligence approach with an intelligent decision making support system for the early detection of Covid-19 symptoms. Covid-19 is a healthcare pandemic. With the advancement of IoT and body area network (BAN), we can emerge using the situation-awareness technique with ambient intelligence. Through ambient intelligence, the healthcare systems monitor the patient's life outside the hospital and detect the problem in an emergency. Therefore, with the significant enhancement of the IoT paradigm, we can use the ambient intelligence technique in the healthcare system to detect the early symptoms of Covid-19 in patients. With situational awareness of the patient's condition, the patient can further take precautions in any emergency.

Therefore, we propose an IoT-based approach with ambient intelligence using a situation-awareness mechanism for the early detection of Covid-19 in the healthcare system. We assimilate the temporal aspects to examine and indicate the scalability of the proposed system to specify and reason with the events occurring in a timely aspect. We conducted a thorough case study using NetLogo to model and implement the intelligent reasoning mechanism called BDI for the agents to make informed decisions and alert the user about the situation to be self-aware.

The structure of the paper is as follows. Section II provides the core notions of our proposed system. Section III discusses the situation-aware healthcare formalism using the BDI reasoning mechanism. In Section IV, we model the comprehensive case study for early detection of Covid-19 symptoms. Section V presents the discussion and Section VI concludes the paper.

II. Preliminaries

A. Situation Awareness

The most common definition of situation awareness, commonly used, is presented by Endsley as "observing (seeing) events in nature, understanding their meaning and performing the course of action accordingly." Situation Awareness is a concept that originated in aviation training and is often used to reveal potential quality issues in medical care and increase patient safety.

B. Belief Desire Intention (BDI)

Literature has revealed numerous reasoning approaches in dynamic environments, such as the rule-based reasoning BDI approach. Among others, BDI reasoning is considered to be the most promising approach for dynamic and complex environments such as robots in critical and emergencies [20], disaster-rescue [21].

The BDI model has captured how humans perceive the knowledge from the situation and form their own belief set over it. Due to the general information and recently perceived beliefs, humans tend to achieve the desired state of goals efficiently [22], [23].

With the BDI reasoning mechanism, agents perceive the data from the situation and have a set of beliefs over it, take the analysis of the acquired information to assign specific actions to the task, and come up with a plan to achieve the desired goals [24].

III. Healthcare Formalism Using BDI With Situation Awareness Technique

We propose a temporal logic formalism based on situation-awareness to imitate an intelligent decision-making system with a BDI thinking mechanism for Covid-19, to enhance the user's self-awareness and alert the hospitals in emergency. The slogan and purpose of the system are "Enhance the self-awareness to the victims of their health situation using an intelligent mechanism." The system we propose uses the situation-aware technique with a BDI reasoning mechanism

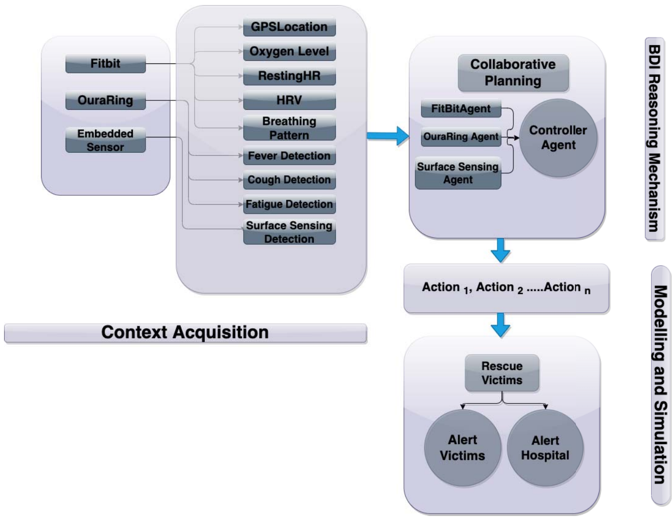

Fig. 2. The architecture of the Early detection Situation-aware system for Covid-19 victims.

to monitor the situation without human interference, alert the victims immediately, and send help in emergency cases.

Regarding handling dynamic and complex situations like Covid-19, we develop intelligent agents with situation-aware capability, including the BDI decision support system. The primary duty of intelligent agents is to acquire and monitor the environmental situation and perform their thinking mechanism (BDI) to imitate the decision support system based on the situation-awareness technique. In the proposed formalism, BDI agents can understand the situation to recognize the problem from the victim's vitals, suggest an appropriate set of plans, and an initial set of actions. The system has its own set of intelligent agents based on BDI in which every agent executes its plan based on its belief and set of actions to perform to reach the desirable state. The system is formed by three different layers, as shown in Fig. 2. In the primary layer, we suppose that BDI agents acquire detailed information about the environment from the wearable sensors, e.g., Body Sensor Network. Therefore in the proposed model, each BDI agent has acquired the context information to its corresponding sensor, where the agent's beliefs are formed by predefined facts or recently gathered contextual information through the sensors/agents. Every agent has its own set of plans based on facts, goals, and intentions for every action. Moreover, every agent performs the assigned task in the system to reach the desired goals. With the BDI reasoning mechanism, the agent performs goal-directed tasks due to the belief set, where an agent can revise its belief dynamically and update them whenever the contextual information changes. Agent's intentions are the set of actions that an agent needs to run to detect the early symptoms of Covid-19. For instance, *IsAlertHigh (1)*, after acquiring this information, agent^i checks the contextual data to its own set of predefined facts known as beliefs, and agent^i's intentions start executing the step of actions. In this scenario, agent^i intends to tell agent^j about the condition of the victim, which seems critical to make sure the location of the victim is sent to the hospital. After acquiring the information from agent^i, Agent^j detects the location of the victim and collaborates with other agents to call an emergency service. In this case, both agents i and j have their intentions to handle the situation. However, the conclusive desire of all the agents is to help the victim as soon as possible. As the system is designed for early detection of Covid-19 symptoms, any human assistance plays a crucial role in coping with critical emergencies. Moreover, the system is intelligent and independent and can act dynamically by minimizing human assistance. However, the system has been categorized into two modes to handle the early detection and take action if the victim's condition is severe. The proposed system is based on two modes. 1) Automation mode and 2) Semi-automation mode. In the current section, we briefly describe these modes. In subsection III-B, these modes are described in detail according to the system preferences.

Automation Mode: After being aware of the situation, the agent verifies its belief set and acts accordingly. Agents set an optimal goal by collaborating with their defined actions according to the situation and enhancing user awareness.

Semi-Automation Mode: In this mode, the agent collaborates with the medical team to save the victim accordingly.

A. BDI Agent Transition System

There is n number of agents in the proposed system, where $n > 1$. In the system, variables i and j represent agents where iϵ agent has a program based on internal knowledge. Every belief of an agent contains context, which is obtained from its internal memory or knowledge base. State formulas or contexts are of the form of$\phi 1,\phi 2,\phi 3\ldots\phi n \rightarrow \phi$ orψ (both represent the state formulas) where the antecedents$\phi 1,\phi 2,\phi 3\ldots\phi n$ and consequentϕ are context information. The background of the knowledge base has complex contexts due to the n number of context combinations. Each agent ^{i}'s predefined facts (Beliefs) matches with the acquired context to drive the results. Moreover, in the model, agents can share situational information and new facts to help the victim in need. Hence, inferring the desirable goal state collaboratively between agents is an effective method to build a model based on situation awareness. Therefore, the communication primitives we assume between agents are based on ask and tell commands. Besides that, the communication mechanism has its own set of semantics where two agents communicate related to the context. For instance, *ask(i,j,ϕ)* and *tell(i,j,ϕ)* in which where agent ^{i} ask or tell agent ^{j} about the specific context ϕ. Fig. 3 illustrates the exchange of information between two agents. The communication protocol of agents would be like if an *ask(i, jϕ)* is in the knowledge base of an agent^i, then agent^j has exceeded its knowledge base with the communication, and agent^j listens to the messages from other agents. Similarly, when *Tell(j, i, ϕ)* is in the knowledge base of an agent^j, agent^i has exceeded its knowledge base with the communication and agent^i listens to the messages from other agents.

B. Temporal Logic

We use temporal logic to model our proposed system for Covid-19 early detection in humans. Temporal logic is instrumental in expressing the activities and events of the

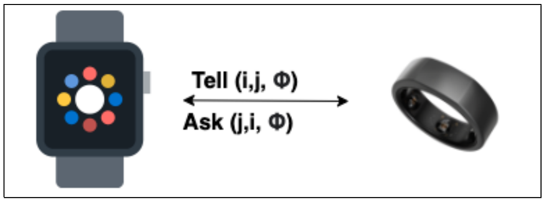

Fig. 3. Communication protocol among agents.

system at an explicit level [25]–[27]. We use computational tree temporal logic (CTL*) for our proposed system. The states correspond to the agent knowledge base and communication mechanism. In a multi-agent system, the agent fires a set of intentions to accomplish the desired state. Each agent may drive the new context after matching it with the belief set, likewise, collaborating with other agents' activities to ensure whether their process is idle or working in the system at that time.

When the agent acts on its intention, the system moves to the next state. By incorporating the situation-awareness model provided by Endsley into the BDI agent. BDI Agent's activity is driven by its belief set, intentions, and desires, by combining the BDI mechanism with situation-awareness, it has an impact on situation awareness technique; given below:

1) Perception of the Situation: Agents get aware of the situation by acquiring the context information and monitoring.

a) Reasoning in automation mode: Some information ϕ detected by agent^i which belongs to its knowledge base KB ^{i} or information did not detect by agent^i and information did not belong to knowledge base KB^i. For example, if fever is detected, thus the belief of fever detected belongs to the knowledge base, else not fever detected to it as shown in Eq. 1.

$$KB^i = Knowledge\ base$$
$$Self-trigger: \beta^i\phi \quad where\ \phi \in KB^i$$
$$\beta^i \sim\phi \quad where\ \phi \notin KB^i \tag{1}$$
$$Auto-trigger: \beta^i Tell(i, j, \phi) \tag{2}$$

Agent^i believes in telling agent^j some required context information. Therefore the agent^j can perform its tasks as shown in Eq. 2.

b) Semi-automation mode: In the case of medical assistance (MA) Agent^i belief relates to the context is accurate, and that context belongs to acquire the MA as shown in Eq. 3. For example, after the optimal selection plan, in case of emergency agent^i has the belief to send an alert to medical assistance to help the victims.

$$\beta^i \mu l\ \phi, \quad where\ \phi \in \mathbf{MA} \tag{3}$$

c) Success case: When agent^i gets the informationϕ about one state formula or agent^i gets the informationψ about other state formula or both. In either way, it is a successful case. For example, when agent^i gets the information about the fever or about oxygen level being true or both conditions being true as shown in Eq. 4. It is a successful case.

$$\phi^i \bigvee \psi^i \tag{4}$$

d) Partial success: An agent^i believes the data is not detected only if the certain information to agent^i is not detected. For example, fever is not detected is still a partial success case as shown in Eq.5.

$$\beta^i(\sim\phi^i) \quad where\ \phi \notin\ KB^{\ i} \tag{5}$$

e) Communication case: Agent^j can ask agent^i about the specific context or agent^i believes to tell the specific context to agent^j. For example, agent^j believes that it has to ask agent^i about fever detection, or agent^i believes that it has to tell agent^j about fever detection as shown in Eq. 6.

$$\beta^j ask(j, i, \phi)) \bigvee \beta^i\ Tell\ (i, j, \phi) \tag{6}$$

2) Interpretation of the Current Situation: After certain intervals of time, each agent observes the situation in the environment, and selects the execution plan to achieve its goal after revising the belief set. In simple words, after acquiring the contextual information, agent interprets what the information means to plan the next step accordingly.

a) Intentions in automation mode: As shown in Eq. 7, after agent^i belief is true, agent^i has intentionsγ to performθ certain actionsα. For example, if the fever detected belief is true, then agent^i has intentions to inform other agents therefore, agent^i performs certain actions according to its intentions.

$$\gamma^{\ i}(\theta(\alpha^i)) \tag{7}$$

b) Intentions in semi-automation mode: An agent^i has the intention to perform **MA** requirements. After selecting the optimal plan, agent^i would contact the *MA* to help the victim from further damage according to Eq. 8.

$$\gamma^{\ i}(\theta(MA)) \tag{8}$$

3) Prediction of Upcoming Future: When agents select the desired plan, agents trigger the course of actions to accomplish the optimal plan.

a) Desire mode: ϕ andψ both state formulas have to be true to accomplish the goal state. For example, agent^i does the set of steps and prioritizes the tasks to accomplish the desire δ, like the saturation level is less than the normal level, and the fever is detected, it creates an alert to self-aware the victim related to their early detection symptoms of Covid-19 with prioritization as shown in Eq. 9.

$$\phi^i \wedge \psi^i \Rightarrow \delta \tag{9}$$

The agent performs several intentionsδ $(\alpha_1, \alpha_2 \ldots \alpha_n)$ to achieve its desire δ where γ_i is the set of actions, performθ by agent^j in state of s. The set of action agent performs are as follows:

- $\gamma^{\ i}$ (θ (α^i)): After matching the context to the beliefs, agent^i has an intention (related to the belief), therefore, the actionsα of agent^i have performedθ to achieve the desires.
- β^i Ask(i,j,ϕ)): Agent^i believes to ask agent^j about the specific context, similarly,β^j Tell(j, i,ϕ)), where agent^j believes to tell agent^i about the specific context.

C. Proposed Algorithm

For the development of situation-aware early detection Covid-19 system, initially, we developed two algorithms that are established on detecting early symptoms on its BDI reasoning mechanism to send the alerts to the victims and the medical team in case of severe symptoms.

Algorithm 1 Early Symptom Detection of Covid-19

Input: Agent^i receives the Early symptoms contextual information= ES_i,$Flag$: a numerical value set either 0 or 1 to continue or halt the system respectively, max_val$_i$: the highest value of ES$_i$, min_val$_i$: the lowest value of ES$_i$.
Output: Alert when the abnormal ES$_i$ is generated
initialization;
$\forall$ Agent^i ϵ agents^n
$\forall$ Corresponding_authorities ϵ $\gamma^{\,i}$
Let ES_i detected by Agent^i
$\forall$ ES_i ϵ β^i
if $ES_i < max\_val_i$ && $ES_i > min\_val_i$ **then**
    $\exists$ β^j ask(j,i,ϕ)$\bigvee$ $\beta^{\,i}$ Tell(i,j,ϕ)
    Alert the CA
    Notify the victim $\rightarrow$ $\gamma^{\,i}$ $(\theta(\alpha^i))$
else
    invoke algorithm 2
end
if $Flag$==1 **then**
    terminate system
else
    maintain the process
end

Algorithm 1 is designed to detect the early symptoms of Covid-19 in the victim and alert the victim to take precautions. Algorithm 2 has been designed to alert the medical team in severe symptoms and emergencies.

In Algorithm 1, Agent$_i$ ϵ agent$_n$. Early detection symptoms are (ES$_1$, ES$_2$, …, ES$_n$) w.r.t its situational information. Corresponding authorities are victims and the medical team. Max and min values are the thresholds for the agent to identify if the situation is worse. When Agent$_i$ receives the contextual information related to early symptoms, it compares it with its own set of beliefs where early symptom contextual informationϵ Agent belief set. If the early symptom value is detected within the threshold set by the physicians or doctors. Agent collaborates and sends the value to controller agent CA. CA performsθ its intentionsγ by notifying the victim, which is the corresponding authority. If the ES_i value is beyond the threshold max value, then algorithm 2 invokes it. If the *flag* value is 1, it means the system has performed its tasks, and the system halts; else system continues to work.

In algorithm 2, Controller agent CA assigns the priority w.r.t the danger level of the symptoms. If more than three symptoms are detected, the situation can get worse. Therefore, the danger level will be high. If there are two symptoms are detected which are equal to or more than danger level 2 but less than danger level 3, then after collection and collaboration, agents alert the CA. CA performs θ its intentions γ and assigns the priority according to the danger level. If the danger level is 2, priority sets to OP, and an alert generates to the victim, else the priority sets to HP, which activates the Medical Alerts MA, CA sends the alert to the medical team with prioritization and alerts the victim about their symptoms. After performing the actions, the *flag* turns to 1, and the system halts, else the system continues.

Algorithm 2 Emergency Situation

Input: Controller Agent = CA, $\forall$ ES$_i$ ϵ $\beta^{\,i}$, $\forall$ Agent^i ϵ agents^n, DangerLevel: Medium severity level($DL1$), High severity level($DL2$), Priority = Ordinary Priority (OP) OR High Priority (HP), Medical Alert: MA
Output: Notify Controller Agent to alert corresponding authorities i-e medical team in severe symptoms
initialization;
if $ES_i = DL1$ && $ES_i < DL2$ **then**
    $\exists\beta^{\,j}$ ask(j,i,ϕ)$\bigvee$ β^i Tell(i,j,ϕ)
    Alert the $CA \rightarrow \gamma^{\,i}$ $(\theta\ (\alpha^{\,i}\ ))$
    PRIORITY== OP
    Alert the Victim
else
    PRIORITY= HP
    MA == $Active$
    Alert the CA $\rightarrow$ γ^i $(\theta\ (\ MA\ ))$
    Alert the Victim
end
if $action\_performed$ ϵ $\gamma^{\,i}$ **then**
    Flag = 1
else
    Flag = 0
end

IV. Case Study Early Symptom Detection for Covid-19

The proposed system is formed on situation awareness in BDI multi-agents to alert victims for early symptoms of Covid-19. The only purpose of designing this system is to help the people manage the health situation on time. We build and map the detection scenario case study to demonstrate its working. Corresponding agents for the required sensors are as follows:

- Fitbit Agent and OuraRing Agent: Fitbit agent and OuraRing agent receive the early symptoms of Covid-19 from Fitbit sensor and OuraRing sensor.
- Surface Agent: Surface agent receives the alert from surface/embedded sensor about Covid-19 particle.
- Controller Agent: After receiving the alerts from corresponding agents, the Controller agent comes up with the plan individually or collaboratively to alert the victims and/or the hospital about the victim's health.

Moreover, we assume the data is acquired from victims' vitals through their corresponding sensors that can be wearable sensors. Moreover, researchers have worked on the algorithms that would help for the early detection of the Covid-19 symptoms like Fitbit Sensor and OuraRing Sensor [28], [29]. Despite that, GE research has received a grant to provide the embedded sensor on the layer of our smart devices, which would help to detect the Covid-19 particles on the surface of smartphones, keyboards, tablets [29].

A. NetLogo

Netlogo is a simulation tool-based multi-agent platform that has been involved with n number of agents. The crucial purpose of Netlogo is to reinforce a multi-agent platform to simulate a modeling environment for autonomous reasoning agents. [30]. Using Netlogo as a simulation tool, we can develop the rapid prototyping and initially test the multi-agent environment for our proposed system. Netlogo supports the reactive agent system. However, the communication mechanism of the BDI agent is still lacking in Netlogo. However, we use the vast libraries to engage the FIPA-ACL technique for communication mechanism [31]. We use the build-in library to provide the agents with a BDI reasoning mechanism. There could be another option to provide the BDI development platform with NetLogo, for example, JAM [31], but the installation is a lot more complex, which would increase the learning curve because of the complex fully-fledged environment. Therefore, we opt for a simpler alternative.

1) Intentions in NetLogo: The intention is based on two parts in Netlogo, the first one is the name of an intention, and the second part is the condition called intention done. Other architectures follow the semantics of the intentions: where agent follow the set of actions until the condition part results to be true

Implementation of Netlogo is straightforward. Each agent in Netlogo carries its stacks based on its intentions. In order to execute the intention, it is called to solicit the proactive behavior of the agent. Every agent is invoked multiple times to ensure the execution is happening in parallel in Netlogo. A Variable named “turtle-own” has been used to store the intentions in Netlogo.

Add-intention “Detected HRV” “true”

Add intention uses to push intention in the stack of the agent. It concerns the agent about HRV detection in the victim is true and executes the intention once because it has intention done condition. Netlogo reserves the word true for it.

2) Belief Management: With the BDI reasoning mechanism architecture, we can supervise the beliefs. Usually, a belief has two parts, its type and content. After declaring its type, it indicates the class the belief belongs to. For example, “Decreased HRV is Detected from fitbitSensor Positive (Early symptoms).” Moreover, reporters and procedures are responsible for creating and removing the set of beliefs in the current agent to manage beliefs. For example, the following line:

set agent belief create-belief “Decreased in HRV is Detected from fitbitSensor Positive (Early symptoms)” “Call Controller Agent”.

It includes the belief type “*Decreased in HRV is Detected from fitbitSensor Positive (Early symptoms)*” with content “*Call Controller Agent*” in the agent internal knowledge of its belief set. Therefore, the belief set of an agent is stored in their variable named beliefs.

B. FIPA-ACL Library

The communication and interaction mechanism of agents plays an essential part while managing the multi-agent system. Therefore, enhancing NetLogo with explicit message communication primitives was necessary. In the system, we use the FIPA-ACL format protocol of agent communication. For interaction protocol in Netlogo, groups of agents exchange messages to reach a viable decision. Therefore, using communication primitives are necessary in Netlogo.FIPA-ACL message format we use in our proposed system. The following format is used for FIPA-ACL: `[<performative> sender:<name> receiver:<name> content: <description>]`
`["CoughandFatigueDetection" "sender:3" "content:" ["Cough and Fatigue have been detected by OuraRingAgent"] "receiver:0"]`
For instance, the above message is the communication between agents 0 and 3, and its content is “Cough and Fatigue have been detected by OuraRingAgent,” and the performative is “CoughandFatigueDetection.”

Standard fields are used in the FIPA-ACL message format are performative, receiver, sender, and content. However, the library gives us the right to customize any field we need according to our desire. Both libraries, BDI and FIPA-ACL, are entirely executed in the NetLogo language.

C. Implementation and Results of Early Detection System for Covid-19

To illustrate the proposed formalism usage, we develop the case study of early symptoms detection of Covid-19. This system aims to self-aware the victim according to their surroundings. The proposed system uses NetLogo to simulate the behavior of BDI agents and take decisions intelligently while monitoring the victim’s situation and validate the results to perceive the system whether it could achieve the desirable states effectively or not.

To illustrate the working system thoroughly, we briefly describe an early detection case study scenario on how the system is modeled and simulated in a Netlogo environment. At the initialization level, agents have predefined belief sets and intentions in the system. When the system progresses with the vigorous changes, the agent revises its beliefs according to the victim’s situations, selects the best plan for them, and executes it. In our proposed system, we created four BDI agents. The NetLogo simulation tool models their beliefs, intention plan, and interaction protocol. For instance, the Surface sensor detects Covid-19 particles in the victim’s belongings and sends them to its corresponding agent surface. The surface agent receives it and alerts Fitbit and OuraRing agents to check the victim for early detection symptoms. Fitbit and OuraRing agents get invoked by the Surface agent. If Fitbit agent and/or OuraRing agent receives any positive input from their sensors. These agents immediately invoke the controller agent to alert the victim of their condition. In Fig. 7, Fitbit agent internal activity is showed.

The proposed system initialization is shown in Fig. 4. Fig. 5 shows the intentions of the agents while interacting with each other. As the system starts execution, if the early symptoms detected by the Fitbit agent and controller agent get invoked by it, it alerts the victim to be self-aware of their health condition.

Similarly, if the OuraRing agent detects early symptoms in the victim, then it sends the information to the controller

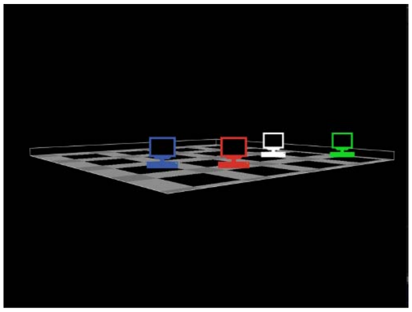

Fig. 4. Simulation environment Interface.

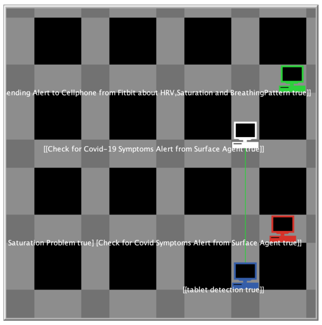

Fig. 5. Intention of agents during the interaction.

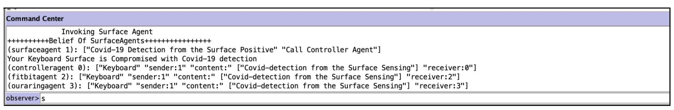

Fig. 6. Surface agent execution.

agent. If the victim's surroundings have more than 2 Covid-19 detections, the alert is sent to the victim about their condition and a bit of advice to check with the medical doctor. Similarly, when the Surface agent detects the Covid-19 particles on the functioning items of the victim, it generates an alert to invoke other agents to check whether the victim has been showing the symptoms of Covid or not and sends a message to the controller agent to alert the victim about their surroundings. Fig 6 shows surface agent execution. If the victim's surroundings have more than 3 Covid-19 detections, the system generates an alert to send the victim's health condition to the nearest hospital to help the victim as soon as possible. Fig. 8, shows the complete execution of our proposed system. Using NetLogo, we have demonstrated the work of our proposed system. In NetLogo, we use the possible intelligent decision-making mechanism according to the dynamic environment. The execution of the proposed formalism has shown that the user will be self-aware whenever there are any Covid-19 symptoms. The purpose of the proposed system regarding Covid-19 is to promptly alert the user, reducing the progression part of Covid-19. By modeling the proposed system and implementing it using NetLogo, it has been shown that the user is notified on a timely basis whenever there is the detection of Covid-19 particles in the surrounding of the victims.

V. Discussion

The aim of this research paper is based on two crucial questions. *Question 1: Computer Science sub-fields can be helpful to tackle the Covid-19?* Answer to this question is yes. *Question 2 is about what and how the computer scientist can play their role in this problem.* To manage this pandemic situation, it is a must to evaluate and predict how the situation could get worse, diagnose the problem within a minimum amount of time and cost, adopt the precautions as soon as possible. Computer scientists have proposed multiple models to predict future cases based on the previous data to manage the risk [9]–[13]. Artificial intelligence has made an impact regarding the Covid-19. Deep learning, machine learning, and NLP are a few fields that have battled the pandemic to improve the statistical part by predicting future cases. However, there have been some limitations and challenges while discovering the symptoms of Covid-19 and improving it from spreading. Due to its dynamic parameters, it is a crucial challenge to understand them to make a particular prediction. This is the limitation to using these approaches as safety-critical applications [32]. However, it is not just a statistical problem but a progression of the factors contributing to the pandemic. We can only significantly improve Covid-19 when we can find a way to overcome the progression part.

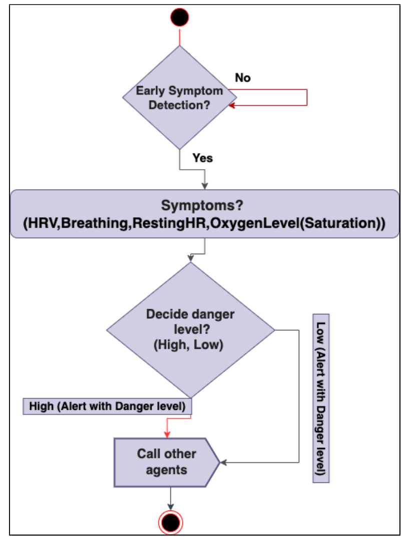

Fig. 7. Fitbit Agent cognitive activity.

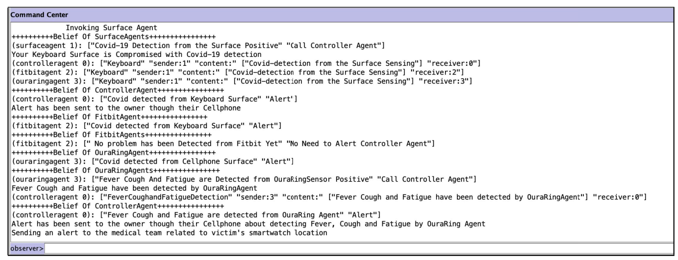

Fig. 8. Complete Simulation.

There have been some approaches to handle the progression part of Covid-19 [33]. However, according to the best of our knowledge autonomous intelligent decision-making system is still lacking to handle the pandemic situation dynamically. Therefore, to handle the escalation of Covid-19, we need a Situation-aware approach with an intelligent decision-making mechanism for a smart healthcare system where the system can detect the early symptoms of Covid-19 and enhance the user's self-awareness. The proposed system is based on the BDI technique with situation-awareness formalism to detect the early symptoms of Covid-19 and enhance people's self-awareness. Therefore, the victim can take precautions as soon as possible.

VI. Conclusion

Pandemic is a situation that occurs any time and anywhere. Response to this disaster situation promptly plays a vital role in reducing its after-effects and can save countless lives. Due to the dynamic occurrence of the Covid-19, it has been a considerable threat to handle the progression of this pandemic. Artificial intelligence has made a significant impact on the statistical part of Covid-19. To overcome the progression of this pandemic, an intelligent decision-making approach is required in a smart healthcare system using ambient intelligence. Therefore, this paper proposed BDI multi-agent system with situation awareness formalism to imitate the intelligent decision support system to detect symptoms of Covid-19 at an early stage. We assimilate temporal logic to illustrate the overall system behavior and determine the system's scalability. We use a Netlogo simulation environment to validate the proposed system and have seen promising results for early detection in Covid-19 symptoms. In the future, to inter-operate the proposed framework, it needs some extended plugins, which NetLogo also provides. Thus, we have researched to prove that we can implement this framework when we use the sensors to extract the data from the environment, and the agents will perform their reasoning on it to handle the pandemic situation by using Jason and ARGO with NetLogo [34].

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