Multiple CAs Based Framework to Provide Remote Palliative Care for Patients Undergoing Chemotherapy

H. Lathashree[1](✉), Niveditha J. Moka Katte[1], K. P. Pooja[1], K. Bhargavi[1], and B. Sathish Babu[2]

[1] Department of Computer Science and Engineering, Siddaganga Institute of Technology, Tumakuru 572 103, India
lathashreeharish01@gmail.com, niveditha10181@gmail.com, kppooja96@gmail.com, bhargavi.tumkur@gmail.com

[2] Department of Computer Science and Engineering, R.V. College of Engineering, Bengaluru 560059, India
bsbabu@rvce.edu.in

Abstract. Cancer is one of the deadly diseases in the world today. Cancer, also called as malignancy is the abnormal growth of cells in any part of the body that crowds out normal cells leading to tumours. Chemotherapy is one of the immensely used cancer treatment methods. It is accompanied by highly damaging side effects that need to be monitored with care in order to reduce the side effects. In this paper, a remote health palliative care framework that uses multiple cognitive agents is proposed for the patients undergoing chemotherapy. The objective of the paper is to provide palliative care to remotely located patients undergoing chemotherapy by identifying the side-effects of the treatment in early stages using cognitive agents as the agents possess self-instructing, self-learning ability while taking health critical decisions. The performance of the proposed framework is good in terms of delay, accuracy, and throughput.

Keywords: Chemotherapy · Cognitive agent · BOB model
Textual conversation · Facial analysis

1 Introduction

Cancer is a class of disease characterised by out-of-control cell growth which begins when genetic changes occur in the cell [1]. These cells form a mass called tumour which can be *cancerous* or *benign*. These affected cells, when multiplied to a greater extent, causes various symptoms indicating various forms of cancer-based on types of cell-targeted. Cancer can be treated in early stages using one of the or combinations of following methods: surgery, radiotherapy, bone marrow/Stem cell transplantation and chemotherapy [2].

Chemotherapy [3] is one of the widely used cancer treatments where powerful drugs are used to kill active cells, which grow quickly by dividing themselves. This treatment destroys both cancerous as well as healthy cells. Destruction of healthy cells causes many

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side effects which deteriorates the health condition of the patient. One of the solutions to this problem is to provide palliative or supportive care which includes continuous monitoring of the patient's health conditions after chemotherapy treatment [4].

Remotely monitoring the patient is a majorly sought requirement by doctors to make the given chemotherapy treatment effective while keeping the patient in comfort zone. Remote palliative care using Cognitive Agents (CAs) is one of the promising approaches [5] to provide long term care for patients suffering from life limiting disease like cancer and who are incapable to handle their daily chores. CAs have the relatable human intelligence to perceive the environment, make decisions, learn and stimulate reflexive actions [6]. These characteristics of the agent are exploited in the proposed framework to effectively monitor patients undergoing chemotherapy.

The organization of the paper is as follows: Sect. 2 documents the related works, Sect. 3 contains details on definitions of the medical terminologies used in further descriptions of the paper, Sect. 4 describes the proposed framework, Sect. 5 briefs on the results of the proposed framework and finally, Sect. 6 concludes the paper.

2 Related Works

A scalable, patient-centric, cloud-based social network styled platform i.e., Tiatros is proposed in [7] which provides collaborative services to cancer patients. The services are provided by care team members to the patients who upload medical data about their chemotherapy sessions through secure messaging, simple notification or email services. However, this platform does not notify the hospital team about the status of the patients during the emergency which minimizes the effectiveness of remote monitoring scheme.

In [8], a multi-layer remote mobile health monitoring system is proposed. It provides pervasive and continuous health-monitoring services to patients through mobile phone and web browser. The system consists of three parts, i.e., a portable terminal, smartphone and remote server. The portable terminal fetches input from the patients and the data flows to a remote server through the smartphone. The system provides stable monitoring of health in the indoor environment. But, the proposed system lacks in prior data analysis of the medical information obtained from the portable terminal which reduces the accuracy of health decisions taken.

The [9] proposes an autonomous health monitoring software framework consisting of multi-agents for remote patient monitoring. The framework consists of several Internet of Things (IoT) devices and software agents that are used to get the medical state of the patient using biometric sensors and internet-based microcontrollers. Although the framework proactively monitors the patient information using the cloud, the design is more generic and complex which reduces the performance and increases the cost of the multi-agent system.

A remote real-time telehealth monitoring system for blood cancer patients undergoing chemotherapy through a mobile phone application is proposed in [10]. The application requires data input to be given by the patient and this is sent to the real-time server where the data is analysed using static algorithms. Based on the results of the analysis, the nurse is notified about the status of the patient and the self-care module of the application gives appropriate advices. However, the transmission and communication of each and every input data from patients to server of the hospital increases the network traffic and the static algorithms used to analyse the medical data of the patient provides not so accurate status about the patients.

3 Definitions

In this section, the explanation for definitions and terminologies used in the paper are provided.

Vital Parameters: Vital parameters indicate important human body factors used to determine the condition of the patient.
Example: Blood Pressure (BP), blood glucose level, pulse rate, Body Mass Index (BMI), Red Blood Cells (RBC) count and White Blood Cells (WBC) count.

Textual Conversation: It is the process where caretaker of the patient is allowed to enter patient's symptoms in the textual form which will be synthesised and analysed to draw a conclusion that aids to determine the condition of the patient.
Example: Feeling uneasy, severe hair fall, drowsiness, imbalance in the sleep-wake cycle, and so on.

Facial Analysis: It is the process of capturing the facial image of the patient and performing analysis using neural visual model [11] by considering the important human facial factors.
Example: Hair density, size of the face and skin discoloration.

Patients Condition Storage (PCS): This database is located at Cognitive Agent-Patient (CA-P) for maintaining dataset about behaviours exhibited by patient's body. Each tuple in PCS contains attributes like blood pressure, pulse rate, blood glucose level, BMI, RBC count and WBC count.

Patients History Storage (PHS): This storage is located in hospital's private cloud that is directly linked to Cognitive Agent-Doctor (CA-D) and it stores beliefs and complete history of patients.
Example: Regular Condition (RC), Alarm Condition (AC) and Critical Condition (CC).

Behaviour-Observation-Belief (BOB) model [12]

Behaviour: Behaviour is derived from the vital parameters exhibited by the patient's body.

Example: A behaviour *'Normal BP'* is obtained when one of the vital parameters BP is in range of 120–139/80–89 mmHg.

Observation: An observation is the aggregation of various behaviours formulated over the patient's body.
Example: An observation *'Usual'* is deduced by using behaviours such as {Normal pulse rate, Normal weight, Normal RBC count and Normal WBC count}.

Belief: A belief is a collection of various observations formed over the patient's body. The working of BOB model is shown in Fig. 1.
Example: A belief *'Critical'* is derived when observations are {Attention, Alert}.

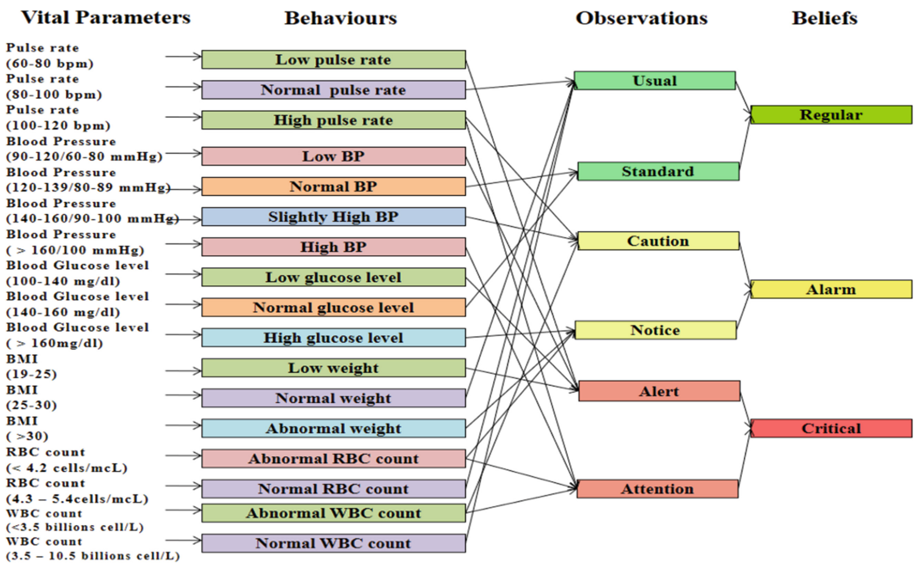

Fig. 1. The BOB model

4 Proposed Framework

The architecture of proposed multiple CAs based framework to provide remote palliative care for patients undergoing chemotherapy is shown in Fig. 2 [10]. The framework consists of three cognitive agents i.e., CA-Patient (CA-P), CA-Intermediate (CA-I) and CA-Doctor (CA-D). In this section, the functions of CAs are described with their corresponding algorithms.

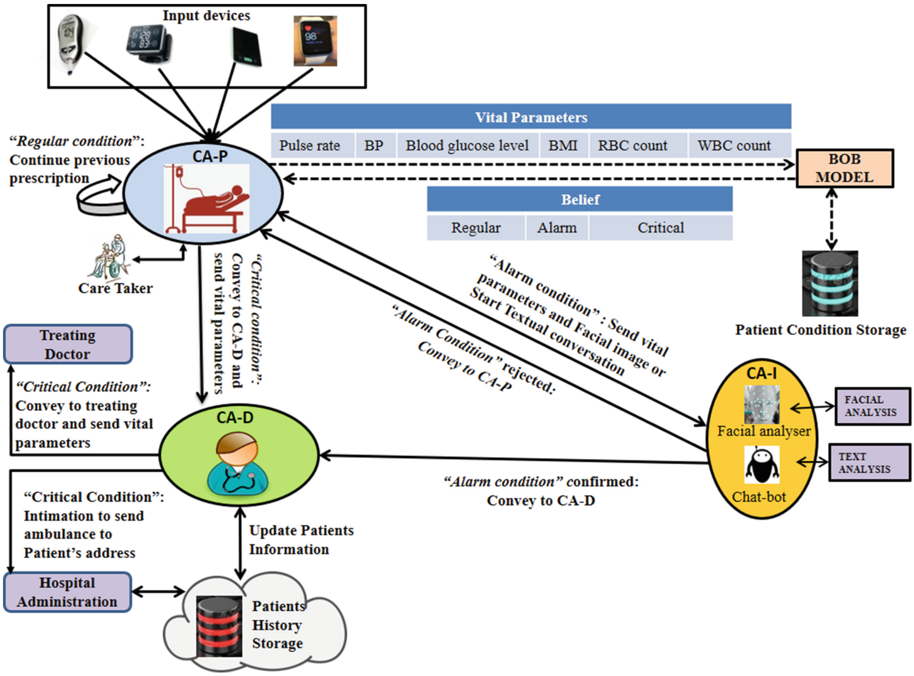

Fig. 2. Multiple CAs based framework to provide remote palliative care for patients undergoing chemotherapy

CA-P: The CA-P is deployed remotely in patient's environment whose role is to monitor the health condition of the patient periodically. Different devices like blood pressure monitor, blood glucose monitor, weighing device, RBC analyser and WBC analyser are used to obtain various vital parameters readings. These vital parameters are fed as input to CA-P by the caretaker.

BOB model in-turn uses these parameters and generates three beliefs i.e., RC, AC and CC. Based on the belief generated for a patient, the periodicity_value of collecting vital parameters is decided. The working of CA-P is given in Algorithm 1.

Algorithm 1: CA-P

```
//periodicity_value: value decided by CA-P
Begin
Initialize PCS to NULL
for periodicity_value do
    Accept vital parameters {V_1, V_2..., V_n} from measuring devices.
    for each vital parameter V_i do
        Identify a behaviour be_i
    end for
    Generate behaviour set BE= BE U be_i
    for each matching be_i in BE do
        Generate an observation ob_j
    End for
    Generate observation set O = O U ob_j
    for each matching ob_j in O do
      Formulate a belief b_k
    End for
    if b_k is regular-condition then
       Convey to CA-P to continue the previous prescription
    else if b_k is alarm-condition then
        if behaviours recorded are high BP, high pulse rate, low blood glucose level
        then
            Choose facial analysis method and capture the facial image of the patient
            Send belief b_k and captured facial image to CA-I
        else
            Choose the chat-bot method
            Send belief b_k to CA-I and start the conversation with caretaker via chat-
        bot
            for each question asked by CA-I do
                Fetch care taker's response and send it to CA-I
            End for
        End if
    else if b_k is critical-condition then
        Send belief b_k to CA-D
    End if
    Periodically update PCS
End for
End
```

CA-I: CA-I is initiated when CA-P detects AC which conveys that the condition of the patient is in ambiguous range i.e., it is neither RC nor CC. Since there exists dilemma in deducing the condition, a double check is made by CA-I. It performs facial analysis or initiates textual conversations with the caretaker of the patient based on the method chosen by CA-P. The working of CA-I is given in Algorithm 2.

Algorithm 2: CA-I

```
Begin
while alarm condition is received do
    if method chosen for the double check is
    facial analysis then
        Perform facial analysis by fetching facial parameters
        Compare fetched data with recent data to confirm the alarm-condition of the
        patient
    else if method chosen for the double check is chat-bot then
        do
          Question caretaker about symptoms of the patient
          Perform text analysis on care taker's response
        until patient's health condition is determined
    End if
End while
if alarm-condition is confirmed then
    Convey the deduced condition to CA-D along with vital parameters
else if alarm-condition is rejected then
    Convey the condition to CA-P
End if
End
```

CA-D: The CA-D acts as a collaborating agent between all the CA-Ps situated at patient's remote environment and Hospital. CA-D informs the corresponding patient's treating doctor about the CC of the patient. Meanwhile, it also intimates the hospital administration to send an ambulance to patient's location. The working of CA-D is given in Algorithm 3.

Algorithm 3: CA-D

```
Begin
for each condition received do
    if condition received is critical or alarm condition is confirmed then
        Consult PHS to fetch case history, patient's details
        if CC is due to abnormal WBC count, abnormal RBC count, high BP, high
        pulse rate then
            Inform treating doctor about patient's condition along with vital parameters
            to re-look into prescription
        else if CC is due to low weight, low glucose level, low pulse rate, low BP
        then
            Intimate hospital administration to send an ambulance to patient's location
            Intimate treating doctor to provide emergency services
        End if
        Update PHS with patient's current health condition
    End if
End for
End
```

5 Results and Discussion

This section discusses the comparison between proposed framework and the existing work [10].

The number of varied vital parameters in patient's health condition versus throughput is represented in Fig. 3. Here, throughput is defined as the number of vital parameters handled per second. For every condition, the BOB model intelligently maps various vital parameters into a single belief. This combined knowledge of belief over a patient increases the throughput by 45%. Whereas in the existing work to arrive at a decision over patient's health condition various stages of parameter processing is done which decreases the rate of processing of vital parameters.

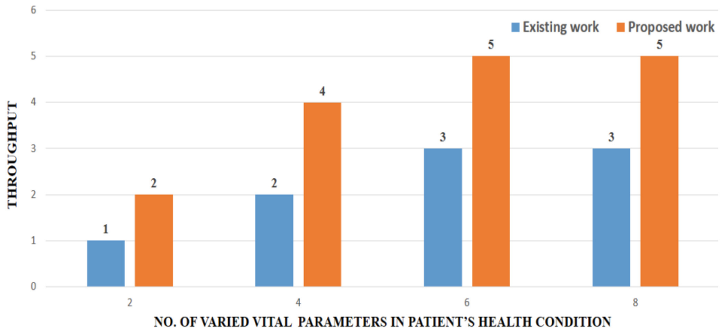

Fig. 3. Number of varied vital parameters in patient's health condition versus throughput

Figure 4 shows the graph of time versus delay. In the proposed framework, CAs are trained to handle all possible health conditions so that whenever similar condition appears the belief is chosen that avoids recurrent processes of belief generation thereby delay is reduced by 35%. Whereas in the existing work for every condition the patient's parameters are fetched and sent to the server at the hospital which consumes time.

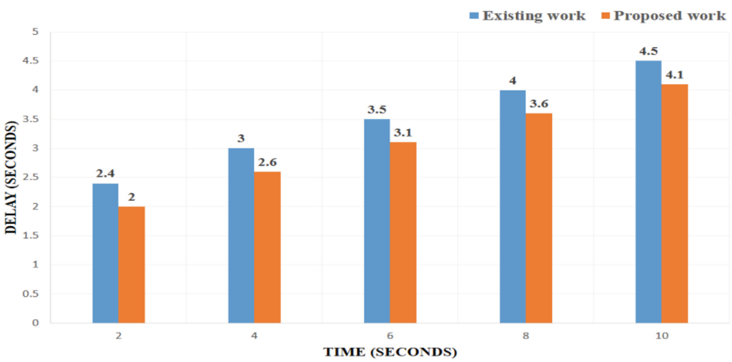

Fig. 4. Time (seconds) versus delay (seconds)

The graph of beliefs formulated versus decision accuracy is shown in Fig. 5. It is observed from the graph that the accuracy of the proposed CAs based framework is higher than the existing work because when the patient's vital parameters fall in the ambiguous range, the CA-I's suggestion is taken into consideration before arriving at the final decision. Whereas in the existing work ambiguous situation is not handled.

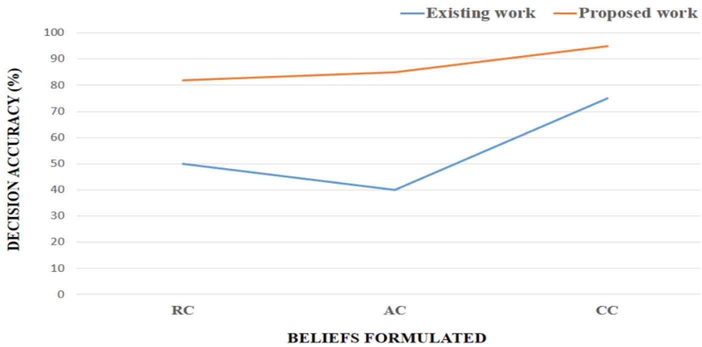

Fig. 5. Beliefs formulated vs. decision accuracy (%)

In Fig. 6, the graph of time versus the number of messages exchanged is shown. It can be observed that the number of messages exchanged is minimised compared to the existing work, as the CAs present in the proposed framework takes independent decisions and works autonomously. Whereas in the existing work the decision is taken by the hospital management with many interactions involved between the management and application that in-turn increases the number of messages exchanged.

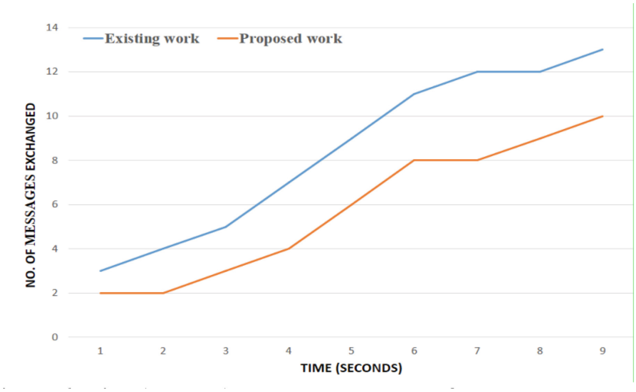

Fig. 6. Time (seconds) versus the number of messages exchanged

6 Conclusion

The proposed framework describes the remote health palliative care framework using multiple CAs for patients undergoing chemotherapy. The framework aims to provide effective treatment while keeping patients in comfort zone and tries to bridge the gap of communication and observation between doctor and patient. The performance of the framework is found to be encouraging in terms of accuracy, delay, throughput, and bandwidth utilization.

References

1. National Cancer Institute at the National Institute of Health. https://www.cancer.gov/about-cancer/. Accessed 10 Nov 2017
2. Price, P., Sikora, K.: Treatment of Cancer, 6th edn. A Hodder Arnold Publications, London (2008). ISBN-13 978-1482214949
3. Chu, E., DeVita, V.T.: Physicians' Cancer Chemotherapy Drug Manual, 17th edn. Jones & Bartlett Learning Publications, Burlington (2016). ISBN-13 978-1284124477
4. Kajal Singh, F., Divya Sharma, S., Shipra Aggarwal, T.: A real time patient health monitoring system based on artificial neural fuzzy inference system (ANFIS). In: Int. J. Comput. Appl. (2016). https://doi.org/10.5120/ijca2016910959
5. Baig, M.M., Gholamhosseini, H.: Smart health monitoring systems: an overview of design and modeling. J. Med. Syst. **37**(2), 9898 (2013). https://doi.org/10.1007/s10916-012-9898-z
6. Fernandes, C.O., De Lucena, C.J.P.: A software framework for remote monitoring by using multi-agent systems support. J. Med. Internet Res. Med. Inf. (2017). https://doi.org/10.2196/medinform.6693
7. Kim, K.K., Bell, J., Reed, S., Whitney, R.: A novel personal health network for patient-centered chemotherapy care coordination. In: International Conference on Collaboration Technologies and Systems (CTS), p. 81. IEEE (2016). ISBN 9780128021156
8. Zhang, Y., Liu, H., Su, X., Jiang, P., Wei, D.: Remote mobile health monitoring system based on smart phone and browser/server structure. J. Healthc. Eng. **6**(4), 717–738 (2015). https://doi.org/10.1260/2040-2295.6.4.717
9. Ghosh, A.M., Halder, D., Hossain, S.K.A.: Remote health monitoring system through IoT. In: 5th International Conference on Informatics, Electronics and Vision. IEEE (2016). https://doi.org/10.1109/ICIEV.2016.7760135
10. Sibilah Breen, F., et al.: Remote real-time monitoring for chemotherapy side-effects in patients with blood cancers. In: Collegian. Elsevier (2017). https://doi.org/10.1016/j.colegn.2016.10.009
11. Phimoltares, S., Lursinsapand, C., Chamnongth, K.: Face detection and facial feature localization without considering the appearance of image context. In: Image and vision computing. Elsevier (2007). https://doi.org/10.1016/j.imavis.2006.05.017
12. Bhargavi, K., Sathish Babu, B.: CAs-based QoS scheme for remote health monitoring over WMSN. In: Thilagam, P.S., Pais, A.R., Chandrasekaran, K., Balakrishnan, N. (eds.) ADCONS 2011. LNCS, vol. 7135, pp. 381–388. Springer, Heidelberg (2012). https://doi.org/10.1007/978-3-642-29280-4_45