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Requirements Model for Multi-Agent Autonomic Fetus Monitoring System

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Abstract: *Ubiquitous Healthcare system provides the environment where users can receive medical treatment remotely at any time, any place. The purpose of u-healthcare monitoring system is to provide convenient healthcare service to patients and ease to diagnose patient's health condition based on monitored physiological data for physicians. These devices perform many computing tasks like monitoring data, diagnosing vital signs remotely. The patient is equipped with one or more wearable devices which are attached to his/her body. The wearable devices have body sensors. The body sensors are connected with mobile apps through mobile gateways.*

In this paper, a fetus monitoring system is presented using wearable technology and U-healthcare. The wearable device is equipped with autonomic multi-agent software to monitor fetus's and mother's body parameters. Some of the parameters which can be observed are fetus heart rate, fetus body movements, mother's BP and sugar level as well as contractions. The system generates alerts when body parameters of a mother and fetus change abnormally. If the parameters are changed drastically, the system sends the alert message to gynecologist of lady and also to family caretaker. This approach helps to keep watch on fetus development remotely since monitored data will be stored at the backend of the system. It reduces hospital trips and saves time and efforts of hospital staff for monitoring mother frequently [2][3]. The aim of this research paper is to represent requirements of Fetus Monitoring System in proper requirements models for generation of design phase models as well as development phase. This system uses PASSI technology (Process for Agents Societies Specification and Implementation) which is a step-by-step requirement-to-code methodology for designing and developing multi-agent system. The development of software using PASSI methodology is iterative and incremental [4]. This paper creates system requirements models which identifies domain for the system, identifies agents and task of agents. The research work generates requirements engineering models for FMS which consists of i) domain identification models to represent domain knowledge in suitable format, (use case diagram) ii) agent identification model to identify and represent agents of the system (package diagram) iii) role identification models based on scenario (class diagram) and iv) task specification model to represent logical capabilities of agents (activity diagram). AUML notations are used to generate these models. The requirements models are enhanced with case base reasoning with feedback loop to make the system adaptive. Case base reasoning cycle represents domain in the representation of cases. The MAPE-k loop identifies the scenario change, finds similar case from domain and plans for its implementation [6]. If no similar case is identified, it will be considered as new scenario or case and it will be added to case base as well as domain identification model is updated. These models help for further development of software.

Keywords: *Autonomic fetus monitoring system; wearable technology; multi-agent system; PASSI technology; system requirements model;, case base reasoning; feedback loop.*

I. Introduction

Due to diversity, heterogeneity and advances in technology, fetus monitoring, has made remarkable progress. Over the past few decades, electronic fetal monitoring systems have emerged as a very promising tool for use by midwives, obstetricians, and labor and delivery nursing staff. Further, wearable devices have provided unbiased, accurate data for monitoring patient's activity and this has enabled the healthcare community to monitor patient's outcomes and analyze overall trends. Chuan-Jun Su and Ta-Wei Chu [1] have presented a mobile system for fetal monitoring, however, it does not monitor the fetus from the first trimester. This paper presents a wearable device equipped with autonomic multi-agent software to monitor fetus's and mother's body parameters when mother is busy in her work, right from the first trimester of conception. This devise will help the working mothers to monitor fetus, It will monitor all the activity till the device in ON. The device will monitor fetus movements and heart beats. It will also generate alarms after regular time interval for water and food intake. Traditionally, doctors and nurses could only periodically and physically monitor the baby's heartbeats using sonography or colour Doppler methods. This approach did not allow them to detect changes in fetal heartbeats at any time or offer continuous surveillance. Thus, physicians still lacked the important information for reducing perinatal or neonatal mortality rates. The proposed device will help physician to monitor fetal safety. When the water level goes down in mother's body, or the baby does not show any movement for long interval of time, the device will generate alert message for mother. So she will be alert and may drink water to maintain appropriate water level. If mother's water level or fluid level become very low or BP level becomes abnormal then monitoring system will detect and record the changes and send alert message to home caretaker and obstetrician. So they can reach patient immediately or suggest medicine on call. If the emergency index is very high then the monitoring system can also track the nearest ambulance to send patient to hospital.

The monitoring data will be stored as patterns. The collected data patterns will be useful to determine the status of fetus during prenatal stage or birth process. Such fetal remote monitoring system will allow pregnant woman to track fetus development as well as it will reduce the number of hospital trips. If some abnormal patterns of data are detected, then the obstetrician can suggest medicines to pregnant woman on call. If the abnormality is severe, then the obstetrician may tell her to visit the hospital. The proposed system is useful in the scenario when the pregnant woman is engrossed in her work and forgets to drink water or take food or forgets to keep a watch on baby movements, especially in second and third trimester. The agent at front end is wearable technology which will monitor and generate patterns. These patterns will be stored in storage. At the backend there will be mobile app which will be connected to patient's remote mobile application[2].

This paper performs analysis of multi-agent autonomic fetus monitoring system and identifies agents and interactions among the agents for the system. The major contribution of this study will be to proposecase base reasoning for making the monitoring autonomic by consideringreal-timescenarios.Thus fetus andpregnant woman's safety is improved and medical staff is relieved from tedious data monitoring task and during repeated hospital visits.

Section 2 will define PASSI (Process for Agents Societies Specification and Implementation) methodology and case base reasoning. Section 3 describes requirements models for fetus monitoring system. Section 4 explains design implementations of requirements models. Section 5 concludes the research work.

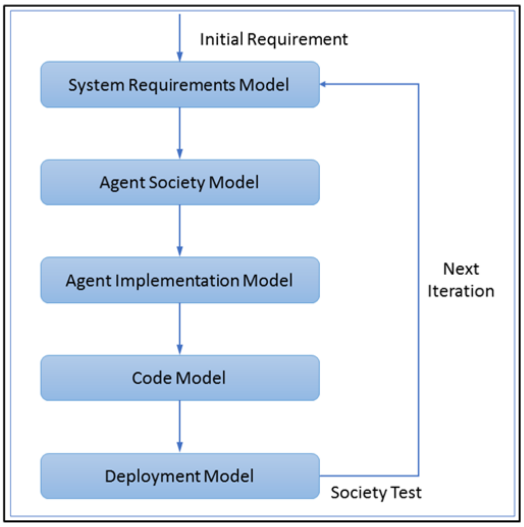

Figure 1: PASSI Process Flow

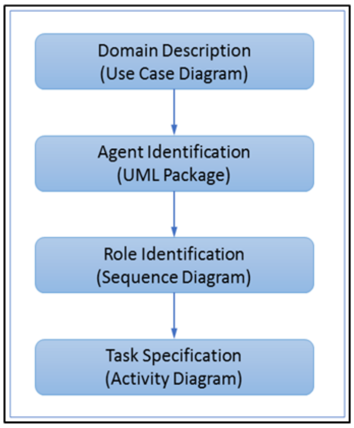

Figure 2: Requirements Engineering Models using PASSI

II. Literature Review:

2.1 PASSI:

Massimo Cossentino [3] Proposes Process for Agents Societies Specification and Implementation. It is a step-by-step requirement-to-code methodology for designing and developing multi-agent system. The development of software using PASSI methodology is iterative and incremental as shown in figure 1.

During systems requirements modeling, the agent is autonomous entity which can take decisions, implement actions and has social relationships with other agents in organization. The agent performs sequence of tasks as a role. When agent implements some behavior in collaboration with itself or with other agents, it will be considered as a task. Each agent's behavior is mentioned in ontology.

Here PASSI (Process for Agents Societies Specification and Implementation) methodology is applied for requirements engineering of mentioned system. According to PASSI process flow, during requirements engineering activities executed are shown in figure 2 [3].

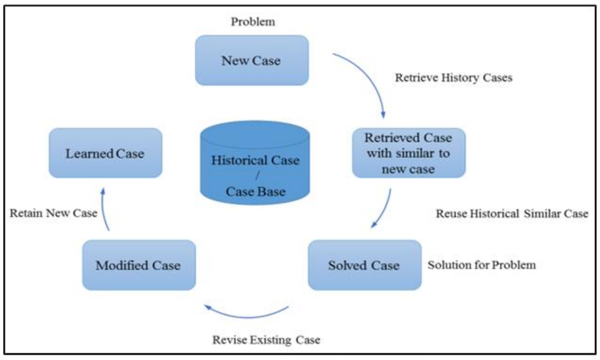

Fig 3: Case Base Reasoning Cycle

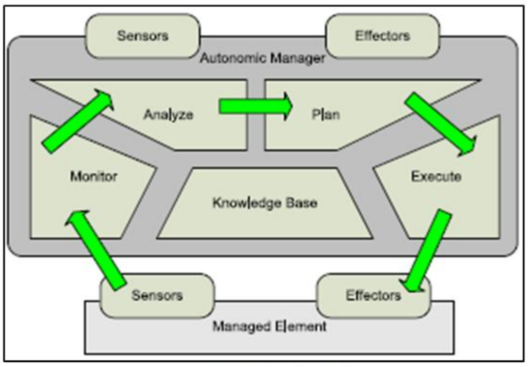

Fig 4: MAPE-k Cycle
Source: Model-Driven Engineering of Adaptation Engines for Self-AdaptiveSoftware: Executable

2.2 Case Base Reasoning with MAPE-k loop:

Case-BasedReasoning resembles human reasoning where symptoms represent problem, diagnosis and treatment represent asolution. CBR collects cases where each case consists of a problem, solution and its result. The CBR cycle is as shown in figure 3. The CBR cycle consists of 4 steps which are performed on case base. i) The Retrieve phase selects one or several similar cases from the case base. ii) In Reuse phase, historical similar cases are decided to be implemented. iii) In the revised phase, the matched solution is verified according to environment and corrected or improved if required. iv) Finally, the retain phase takes the feedback from the revise phase and updates the case base. Thus, CBR either converts new cases in learned cases which will be available for future decisions or finds similar historical case and reuses it[4].

Fig 4 describes MAPE-k (Monitor, Analyze, Plan and Execute-Knowledge) Cycle. Kephart and Chess [6] designed the architecture for self-adaptive system with autonomic element. The autonomic element consists of managed element and autonomic manager. The managed element is adaptable software and autonomic manager is adaptation engine to execute MAPE-k engine. MAPE-k engine consists of monitor to sense the managed process, its context and stores relevant events in knowledge base for further reference. The analyzer compares scenarios with patterns in knowledge base to diagnose symptoms, the new symptoms can be stored in knowledge base. The planner interprets the symptoms and designs a planto execute change in managed process. The executor executes plans to adapt actual system and obtain the desired output. The sensors and effectors collaborate data and control among autonomic elements. MAPE-k cycle is called feedback-loop used for engineering self-adaptive software system. The feedback loop ensures that the adaptation engine helps the adaptable software to respond change in requirements from the environment [5]. Feedback loop helps self-adaptive software system approach from analysis design till implementation.

Case base reasoning can be incorporated with MAPE-k cycle for adaptivity. As shown in fig 3, case base reasoning consists of case base which represents all cases learned by the system. The case base can represent domain knowledge or ontology for the system. Using case base, the analyzer of MAPE-k loop can analyze the scenarios and if new scenario occurs then it will be compared with existing scenarios. The scenario is converted into case and case base is updated if completely new scenario is identified i.e. retain process is followed. The planner plans the new scenario with the reference of new case. The implementation of MAPE-k cycle will be easy with case base reasoning.

2.3 Existing Systems for fetal monitoring:

Hammar and Hewlett Packard developed first commercial electronic fetal monitoring device in 1978. This device was used to monitor heart cycle, heart sound during labor [2]. Jansuz developed fetal heart rate signal processing. Czabanski, R.; Jezewski, M.; Wrobel, J.; Jezewski, J.; Horoba, K. developed artificial neural network to evaluate risk of low fetal birth weight using cardiography signals. New innovations are going on for electronic fetal monitoring using wireless communication technologies, portable monitoring devices like RFID. Fetal data can be transmitted to remote locations via wireless communication devices[2][7].

A research group of Sandy Pentlandidentified location, movement and communication data from smart phone to identify flu and gastrointestinal problems. William Kaiser from UCLA developed healthcare software for stroke patient monitoring and guidance for rehabilitation over 20 countries[8].

- Location Tracking Services: With the help of GPS, location estimation mechanism, location tracking services can be developed for elderly, visually impaired and intellectually disabled patients[7].
- Sleep Analysis: The patient sleeping patterns can be monitored using gyroscope and magnetometer. These devices are embedded into smart phones. The sleeping behavior is monitored by strapping the mobile phone on arm or on waist or keeping mobile below the pillow [7].

- Vital Sign Monitoring: There are iPhone add-on modules and mobile apps to record heart rate, ECG, blood pressure and blood sugar using Personal Area Network. This data is stored as patterns and can be useful for physician when needed [1][2].

III. System Requirements Models For MAA-FMS

When the pregnant woman is busy in her work, she may neglect her water and food intake. In critical pregnancy cases, heart rate, BP or uterine contractions or baby movements should be watched continuously. The illiterate pregnant woman may not know the quantity of water, food she has to take to grow fetus properly. If water intake is not in adequate quantity, the fetus may dehydrate. Inadequate food intake can cause malnutrition of fetus. It is practically impossible for obstetrician to keep watch on daily intake of water and food of mother as well as baby movements for 24* 7. Hence, it is essential to develop a system which works with wearable device and generates alerts device will generate alert for caretaker and obstetrician of the patient.

To satisfy these requirements, this research proposes Multi-Agent Autonomic – Fetus Monitoring System (MAA-FMS)in which wearable device will collect monitoring data and spontaneously inform pregnant woman for intake and caretakers about vital signs. The MAA-FMS consists of two parts: first component is front end MAA-FMS which will be the wearable device which pregnant woman will wear. Second component is back-end MAA-FMS which will be with caretaker agent and gynecologist agent. The functional view of the system is as shown in figure 5.

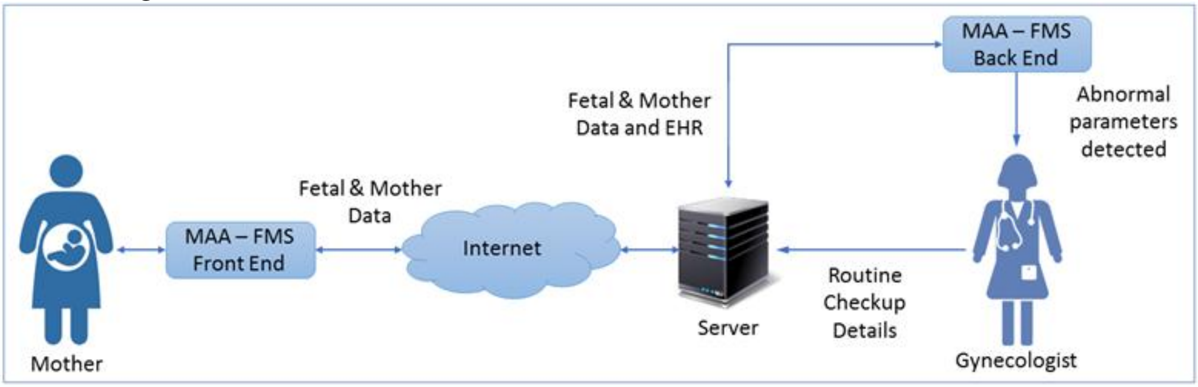

Figure 5: Functional View of MAA-FMS

The fig describes that MAA-FMS monitors the fetus and mother body paralmeters. When the parameters are chnaged drastically, the backend of the system will check for any emergency. This is supported by case base and MAPR-k loop. If the scenario is same as previously recorded scenario then the predecided actions are taken and alert is sent to gynecologist. If the new scenario, then immediately alert is sent to gynecologist. For this system based on functional requirements identified, following requirements engineering models are generated.

3.1 Domain Requirements Description Phase:

This phase describes functional description of the system in hierarchical series of use case diagrams. Two perspectives can be considered to describe domain requirements for MAA-FMS. One perspective is according to mother where she will make the wearable device “ON” before sitting on work desk. The device will start monitoring food and water intake for gravida and fetus. If the diagnostic agent senses some abnormal parameters, it will inform wearable device and generate alerts for mother and caretakers. All monitored data will be stored at knowledge –based data server so that whenever obstetrician needs data, it can be downloaded. The domain description model for mother’s perspective is as shown in figure 6.

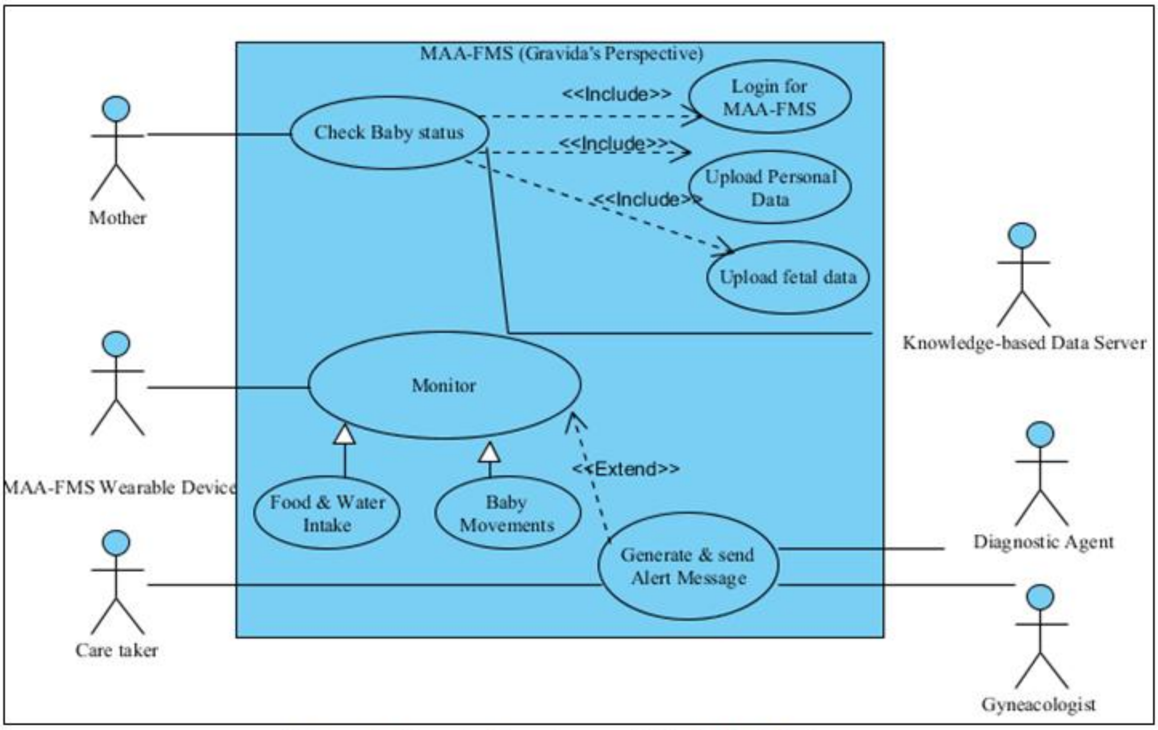

Figure 6: Domain Requirements Model for Mother

Second perspective is where obstetrician can retrieve the recorded data for specific mother when an alert is received for her from MAA-FMS. Gynecologist can immediately monitor the recorded data patterns and suggest medicine to gravida on phone. If emergency situation is observed, he can advice mother to visit hospital for emergency treatment. The domain description model for gynecologist's perspective is as shown in figure 7.

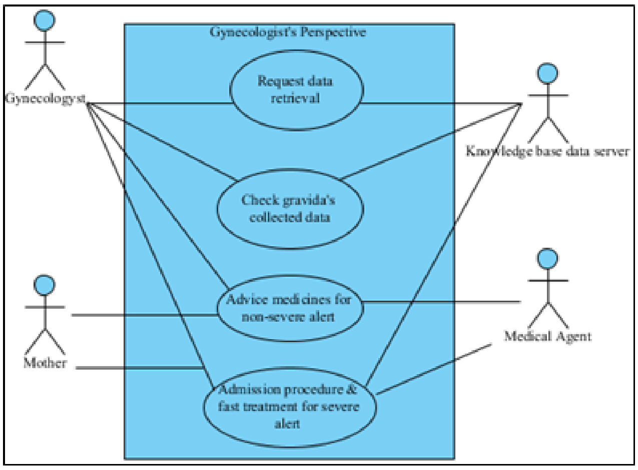

Figure 7: Domain Requirements Model for Gynacologist

3.2 Agents Identification Phase:

Agents identification is done from domain description models. One or many use cases are grouped and converted into stereotyped packages. Each package defines functionality of each agent. As shown in figure 7, the agents identified are GravidaUI, WearableDeviceUI, DiagnosticAgentUI and MedicalAgent. GravidaUI and WearableDeviceUI agents works for gravida, WearableDeviceUI is also responsible to store monitored data at knowledge base data server. The agents DiagnosticAgentUI and MedicalAgent work for obstetrician and caretaker. As shown in agents identification model fig.8, all autonomous agents form the organization where agents perform their roles in coordination. If agents' goals are not achieved then according to PASSI methodology the agents and their tasks are reorganized to achieve goals effectively.

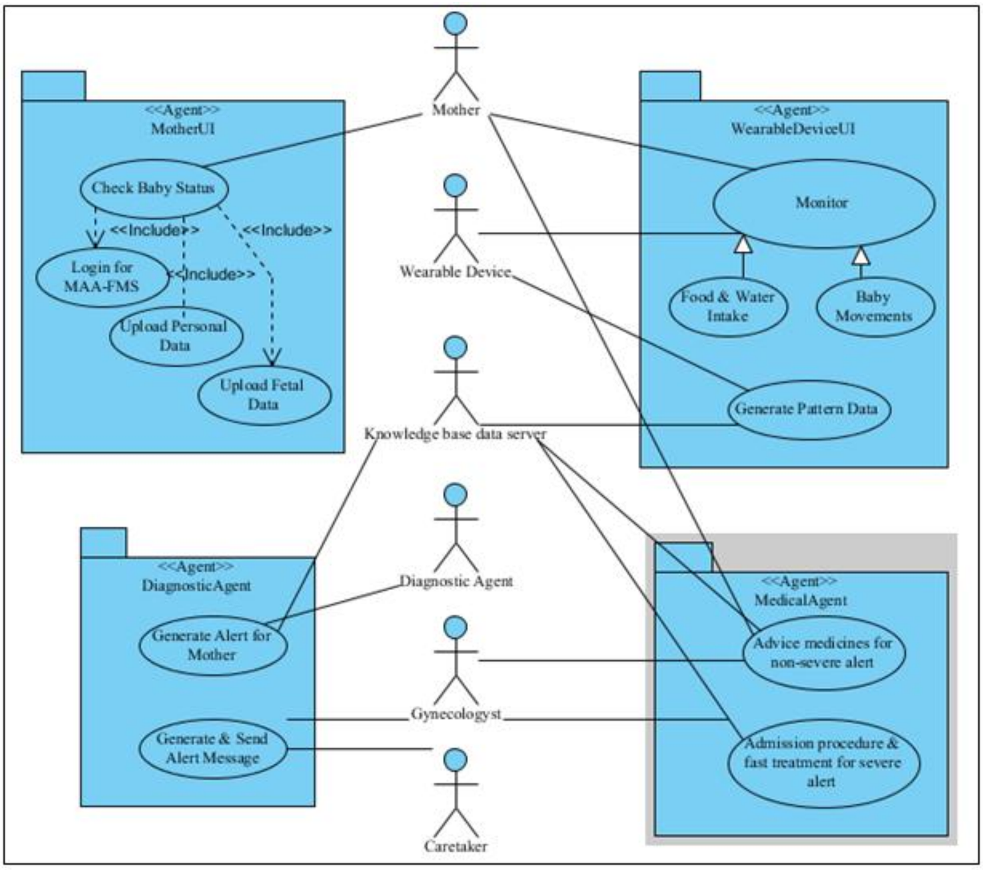

Figure 8: Agents Identification Model for MAA-FMS

3.3 Role Identification Phase:

Roles identification is based on evaluating all possible interactions among agent which is also called inter-agent communication. Multiple scenarios are identified based on requirements and goals of agents. Each scenario is described with interacting agents and multiple communication path among them. Role identification of agent is represented using sequence diagram in PASSI[3].An agent may participate in different scenarios with different roles. Each object is represented as *<role-name>:<agent-name>* .

Consider the scenario where mother is under stress because something goes wrong while handling cash on work desk in bank. The lady is not able to tally the cash for 2 hours. After sometime her BP shoots up and she starts

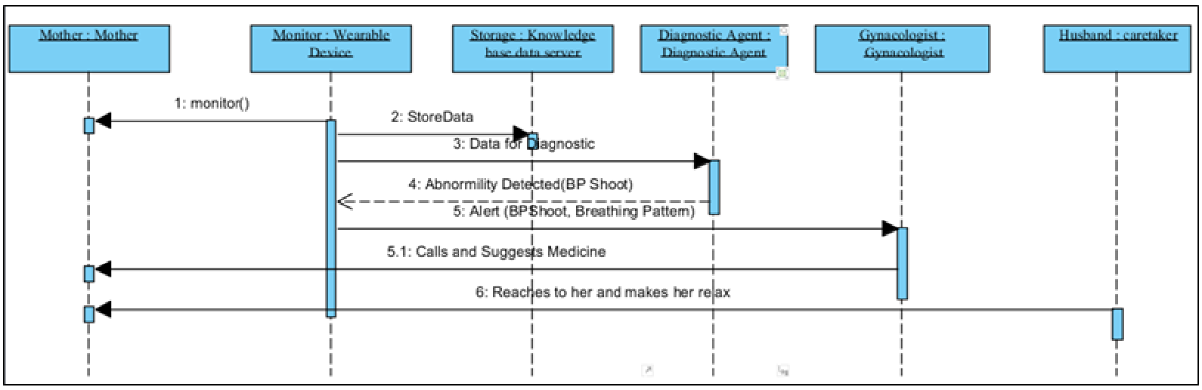

Figure 9: Role Identification Model for Scenario 2

feeling dizziness and uncomfortable. She has faced such technical problem earlier, hence ignores the dizziness and focuses on resolving the issue. She misses to relate such stress with her current physical situation. The MAA-FMS wearable agent detects high BP and immediately generates and sends alert message for caretaker as well as gynecologist. The system searches for similar scenario in case base. Similar scenario was recorded hence specific measures are informed to mother till she gets treatment from gynecologist. The gynecologist's assistant calls the lady and suggests the medicine. This scenario is shown in figure 9 to describe role of MAA-FMS wearable device, diagnostic agent and caretakers and case base.

3.4 Task Specification Phase

Task is the collection of some actions which forms logical unit of work. For task specification model, activity diagram is drawn specific to agent. The task specification model represents agents' capabilities. Relationships among activities signify messages among activities or interactions among tasks or agents [3]. Consider the task specification model for wearable agent for MAA-FMS. It is shown in figure 10.

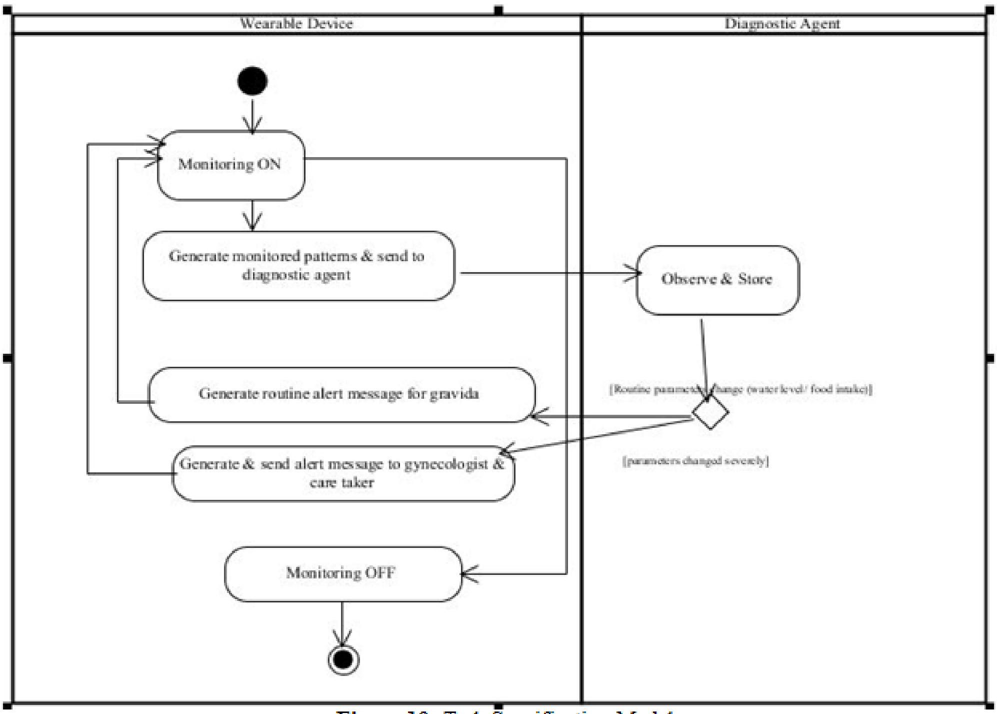

Figure 10: Task Specification Model

IV. Design Phase- Implementation Of Requirements Model:

The domain requirements models are implemented for agent society modeling phase i.e. designing phase using PASSI for multi-agent autonomic software. Agent society models are created with the help of domain ontology description. The ontologies represent knowledge about agents and scenarios of the system. The ontology is used to support the interaction among the agents i.e. at run-time through reasoning. Roles description phase is used to represent dependencies among agents which identifies communication capabilities of agents. Further, task specification phase is tested and implemented for protocols description of system where agent interaction protocols are formed using FIPA. The current requirements models are implemented in CASE tool Visual Paradigm. The requirements models and ontologies for agent society will be implemented in PASSI toolkit, hence iterations according to change in requirements can be incorporated easily. These models can be used for direct implementation to generate code for the system.

V. Conclusion

The purpose of this study is to propose Multi-Agent Autonomic- Fetus Monitoring System to monitor fetus movements, water and food intake of pregnant woman when she is engrossed in her work. The body parameters are monitored and stored for further reference of gynecologist. Here requirements models are proposed for analysis of the system. The system becomes self-adaptive or autonomic due to use of case base with MAPE-k loop. The next step of the study is to design ontology for agents and roles of agents for the system. Incorporating sophisticated diagnostic methodologies into MAA-FMS can effectively enhance the functionality of wearable device and diagnostic agent.

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