Modelling Civic Problem-Solving in Smart City Using Knowledge-Based Crowdsourcing

Syed M. Ali Kamal, Nadeem Kafi, Fahad Samad, Hassan Jamil Syed, Muhammad Nauman Durrani
k173025@nu.edu.pk , nadeem.kafi@nu.edu.pk , fahad.samad@nu.edu.pk , hassan.jamil@nu.edu.pk , muhammad.nouman@nu.edu.pk
National University of Computer and Emerging Sciences, Karachi Campus, Pakistan

Summary
Smart City is gaining attention with the advancement of Information and Communication Technology (ICT). ICT provides the basis for smart city foundation; enables us to interconnect all the actors of a smart city by supporting the provision of seamless ubiquitous services and Internet of Things. On the other hand, Crowdsourcing has the ability to enable citizens to participate in social and economic development of the city and share their contribution and knowledge while increasing their socio-economic welfare. This paper proposed a hybrid model which is a compound of human computation, machine computation and citizen crowds. This proposed hybrid model uses knowledge-based crowdsourcing that captures collaborative and collective intelligence from the citizen crowds to form democratic knowledge space, which provision solutions in areas of civic innovations. This paper also proposed knowledge-based crowdsourcing framework which manages knowledge activities in the form of human computation tasks and eliminates the complexity of human computation task creation, execution, refinement, quality control and manage knowledge space. The knowledge activities in the form of human computation tasks provide support to existing crowdsourcing system to align their task execution order optimally.

Key words:
Human Computation; Machine Computation; Crowdsourcing; Knowledge Space; Hybrid Model; Smart City.

1. Introduction

In this growing digital world of smartphones, media and Internet, the crowd has become more active, responding to any event or action instantly occurring in the environment. The activeness of crowds has made the researchers think in the area of human computation and has led to the foundation of crowdsourcing. With the advancement of information technology, Crowdsourcing has got an explosive succession and variations in number of applications and business needs. Crowdsourcing is a fancy term, which refers to an online distributed and problem-solving model utilizing the collaborative and collective intelligence of connected group of people (communities) to solve proposed problem [1]. Crowdsourcing model has benefited in a range of areas from medicine [2], machine learning [3], linguistics [4], and software development [5], automation and testing [6] and other various fields. Crowdsourcing becomes the only tool that can mobilize huge crowds to accomplish a task at global scale. Using smart technologies, the information from the crowd can play a vital role in solving various related problems.

By 2050, about 70% of the people around the world will migrate to and live in cities as reported by United Nations Children's Fund (UNICEF). This huge transition will eventually create many challenges in various domains like natural resources and energy management, transport and mobility, infrastructure, environmental management, public health and safety, economy, governance and municipality. In order to overcome these challenges, cities are equipping smart technologies in their infrastructural, healthcare, educational, industrial and other various social activities. This equipment of smart technologies turned the cities into smart cities. However, the meaning of the word “Smart” in Smart City varies from context to context. In the marketing domain, smart is centric to worker perspective [7], which reflects intelligence of workers, having a quick mind and responsive to feedback. In urban development planning, the term “Smart” refers to the strategic planning, decisions and directions for government and public agencies to make new development programs, strategies and public policies in order to introduce and maintain sustainable development, economic and social growth and quality life of their citizens [8]. In the context of information technology, which implies automatic computing entities, computing systems, artificial intelligence and IoTs (internet of things) [9] [10]. Autonomous computing principles like self-healing, self-protection and self-optimization are also considered as a part of smartness in information technology [11]. The idea of a smart city is simple. It is armed with the latest intelligent technologies, which helps in improving the quality of services given to citizens as well as makes all processes efficient and beneficial. A smart city covers the entire human ecosystem. Its main focus is to provide those services that improve economic growth of citizens, increasing social benefits, creating new opportunities for crowd citizens and increasing their quality of living [12].

Manuscript received August 5, 2023
Manuscript revised August 20, 2023
https://doi.org/10.22937/IJCSNS.2023.23.8.18

On the other hand, Information and Communication Technology (ICT) provides a basis to smart city foundation, enabling us to interconnect all the actors of a smart city [13] and by supporting the provision of seamless ubiquitous services [14].

Using the power of human computation, benefits of crowdsourcing and the utilities of smart cities we have proposed a Crowdsourced human computation model (hybrid-model) which is a compound of human computation, machine computation and citizen crowds. The hybrid-model consist of four phases; data sensing, data transformation into human computation tasks (task formation), task execution and task validation. The hybrid-model captures data using a crowd sensing model, identifies and transforms crowd sensed data into human computation tasks using crowdsourced feedback systems, executes and validates human computation tasks through crowdsourcing. Hybrid-model will not only help in tackling challenges that occurs when human and machine are engaged to solve complex civic problems in smart city but also capture problem semantics that will be used as a solution to cater future similar problems using the initiatives of smart cities. Hybrid-model also empowers common citizens for their socio-economic welfare which will not only satisfies citizen needs but will also open new possibilities to improve the quality of their living, improve socio-economic welfare of crowd citizens as well as creates opportunity for humans and machines. Informed participation of citizen crowd either individual or as whole (community) creates democratic shared knowledge space, which not only provides strategic planning, decisions and directions to the government and public agencies to make new development programs, strategies and public policies in to order to introduce and maintain sustainable development, economic and social growth, and quality life of their citizens as well as provides solution to natural resources and energy management, transport and mobility, infrastructure, environmental management, public health and safety. The democratic knowledge space created through the intelligent abilities, cognitive, learning and problem-solving skills of the citizen crowd also provides service-wide solutions to Artificial Systems of smart cities by teaching new ethical scenarios in real time and limits their decision making in situations involving human life and environment. Furthermore, this democratic knowledge provisions human intensive solutions to human centric and human intensive problems and similar types of other problems in future.

2. Related Work

Smart city cover the entire human ecosystem. In the past decade, many attempts have been made using crowdsourcing approaches to exploit services in various aspects to improve economic growth of citizens, increase social benefits, reduce life threat, create new opportunities for crowd citizens and increase their quality of living in a smart city.

For sharing good practices in local planning and sustainable development, a platform which used emotional mapping was proposed by Pánek, Jiři, 2018 [19]. In order to collect data related to emotions different crowdsourcing techniques were used by this platform. A single page application was built to record data from the crowd. The crowds were asked to mark certain areas on the map that they think are dangerous, interesting or relaxed. The data in the electronic map was then visualized on screen. Each data is marked with a specific color to highlight the specific categories (homeless; alcohol and drugs; traffic) and contribution of crowd workers.

Kandappu, Thivya, et. al. [40], proposed a crowd-sourcing platform to monitor municipal resources in smart cities. It launched in “citizen-controlled” urban areas where people actively report on the status of different community resources for example individual users (or workers) voluntarily select and perform a set of location-specific tasks, such as logistics or package delivery. The proposed model comprises (a) a client facing mobile App called Smart City, and (b) a backend server that includes a mobility prediction engine, task generator and recommender system. Using the data of the user collected in the form of a database is used to show their result and conclusion.

Alvear Oscar, et al, [2] in his study proposed crowdsourcing architecture for the analysis of candidate technologies, which aims to use air-monitoring capabilities to empower users. Further, from the perspective of crowd sensing which deals with the identification of fundamental tasks performed differently by sensors, this paper caters to the need of embedded mobile sensors along with analysing the protocols and architecture of the internet of things. This shows that crowdsourcing has become a trending topic in smart city to solve problems related to smart environment, smart transport, smart grid and smart government, which will eventually improve the quality of human life and reduce risk factors.

With the help of famous micro task crowdsourcing platform Abbas, Tahir, et. al. [1] aims to discover the potentials of sourcing scenarios related to Internet of Things (IOTs) and evaluate these scenarios with respect to its practicality and originality. This research work aids the end users of IoT by providing automated leverage of crowdsourced user scenarios. Through Amazon Mechanical Turk (MTurk) a crowdsourcing platform, they researched whether by combining the given devices, an unidentified crowd could aid smart home people in the making of more meaningful, creative and diverse scenarios or not. Further to assess the creativity they have used binary measures and used the Linguistic Inquiry and Word Count (LIWC) tool for computing text metrics like words per sentences, word count, long words (> 6 letters) and number of unique words. Finally, the results are represented in the form of bar charts.

In case of crowd sensing through mobiles in smart cities, contribution-based Incentive Design (COIN) proposed by Chen et al, 2013 [11] served as a guide for nascent developers. Maintaining an up to date knowledge database by assigning different tasks to crowd workers, which in turn contribute to the smart parking system. The system used mobile-based applications to engage drivers, who seek for parking or drive away, in highlighting the vacant spots, and then respond to their queries by suggesting the most suitable place. The application used the Markov model to predict the next vacancy of a parking spot as well as interpreting the data collected from the crowd in the parking lot. They aim to propose a crowd sourced based system and have eventually proposed 3 new features i-e multiple choice of task, focus of mining valuable data source and differentiated service.

To provide disable peoples with access to urban environments, Chouikh, Arbi. "HandYwiN:2018 [12] came up with a solution. A platform known as "HandYwiN", presented to add value to smart cities by catering to the needs of disables. The objective of the research is to find and map the accessibility of private and public spaces for individuals on wheelchairs. HandYwiN is developed on android and it has the following features: it uses Google Maps to display and save the places in the database; it detects the users position through the GPS; once investigated, the places are stored in the database; Any place can be reinvestigated if any user thinks that some answers are not correct; Besides the answers, the photos of the place can be stored in the database; and The photos, the colour, the service category and the accessibility details are displayed as newsfeed on the map. The finding is that the concepts of "mobility" and "accessibility" exist; however, there is not a clear analysis given in this paper.

To warn drivers approaching unsafe zones, different feedback conditioned multimodal was proposed by Dunlop, Mark D., et al, 2016 [15]. According to them, crowdsourcing possesses an edge over smart-city approach in terms of coverage benefits and cost. However, a sudden brake detection model was proposed that collects raw accelerations, smoothing and speed data using mobile accelerometer sensors. Using the mobile data log, they have interpreted results.

Harish, Kumar, Manoj, and Gupta [21], proposed an approach that emphasizes on advancement and smartening of the transport system, for the sake of this innovation different crowdsourcing techniques have been employed to strengthen the structure of the transport system. Further to classify the data into different categories content analysis has been performed. The URL based forms were distributed through social media, public forums and blogging sites to anonymous user and asked them for the collection of data. Content analysis is a text analysis method of social investigation, which was used for the interpretation of analysis of content data.

The researchers have discussed sensing citizens' crowd data and developing systems using crowdsourcing to improve citizens' healthcare style as well as identify possible challenges during this process. Many attempts have been taken in optimizing and controlling healthcare related issues with different systematic methodologies.

PlateMate [16] was introduced in order to record accurate food logging easily and cost effectively. PlateMate uses crowdsourcing to outsource photographs of meals for nutrition analysis on Amazon Mechanical Turk. PlateMate provides users with a platform which can suggest nutrition estimates based on the diet photographs that the user has uploaded. PlateMate suggests estimates which consist of a list of foods depicted in photographs with their appropriate protein, fat, calories, and carbohydrate and serving sizes of each item in the food list.

PlateMate poses significant challenges in workflows and tasks design when crowdsourcing photographs of meals for nutrition analysis. There can be danger of formulating unreliable estimates as most of the workers are inexperienced. Similarly, since most of the tasks are modest, tasks like nutrition analysis are some of the complex tasks to which many of the workers are unaccustomed. On the other hand, some individuals may find difficulty recognizing certain diets in the photograph or they may be biased in their estimates.

Keeping appropriateness and correctness of data, the study [17] proposes a novel way of accumulating information of medical symptoms. In order to integrate it with the social health website, Games with A Purpose (GWAP) based on human computation was used. Also, to generate new collections of interesting data, the template was designed to integrate different GWAP games as well as reining existing information related to the medical field or task that often flops because of scalability.

CrowdMed [18] is a platform which accepts cases from a patient or medical detective and based on the user preference, through its rewarding systems sets the compensation for the experts involved to solve the case. CrowdMed connects each patient with rare or mysterious diseases to a network of experts who compete to solve cases for cash and gamified rewards. At the end, patients receive detailed reports containing diagnostic suggestions to discuss with their physicians and fill out surveys about their outcomes.

The existing research work lacks an architecture and a feasible as crowdsourced human computation task for modelling civic problem-solving in a smart city environment.

3. Motivation Scenario and Requirements

In this paper, we have proposed a healthcare problem of "Aligning Medical Treatment by Developing

Evidence Based Guidelines on Medication" as our knowledge creation opportunity using citizen workers. The key issue is "How to employ and utilize the available information by sensing citizen's healthcare data directly or indirectly in such a way that both healthcare professionals as well as citizens can take advantage of their treatment and improve medical services and clinical guidelines while cost remains intact". The goal is to find the group of citizens having similar healthcare problems and align their treatment and medication to reduce fatal complications by sensing their healthcare data (semantics) at different intervals. The possible model is to use crowd sensing to collect various data from the citizen crowd directly or indirectly and identify and make human computation tasks while considering the citizen crowd in a loop. These human computation tasks are then outsourced to a crowd of citizens having various skill sets for their feedback in iterative fashion either sequential or parallel. In each iteration, the task is refined by crowdsourcing to one level up skilled crowds until it reaches an optimal form. The knowledge produced during this knowledge activity enables healthcare professionals to systematically improve the quality of care, timely align guidelines and make strategic planning and decisions to maintain health related policies. As this problem is treated as complex problem, it consists of various human computation tasks at different intervals: (i) Capturing problem through mobile crowd sensing (ii) Transformation of problem i-e removing irrelevant and duplicates details through feedback from a group (community) of civic crowd workers (iii) Take expert opinion on those feedbacks from another community of experts in order to find problem rationales, causes of occurrence and precautions (iv) Interactions between various level of crowd worker to identify optimal problem solution space through feedbacks and (v) Finally solution is revised by healthcare professionals and government stakeholders to make strategic planning and decisions support for public health and safety.

3.1 Motivation of Aligning Medical Guideline for Improved Health Care

Delivering proper care to patients is the primary aim of any health care organization and health care professional. However, health care organizations and professionals are influenced by various factors for delivering proper care to patients. Improvement motivation is one way of comparing performance between peers of health care professionals. Clinical practice guidelines, collaborative procedural pathways and interactive protocols can be used to optimize and improve patient care, clinical practices and protocols and make it more consistent around a definition of best practice.

Guideline developers use different consensus methods to develop evidence-based clinical practice guidelines. Previous research suggests that existing guideline development techniques are subject to methodological problems and are logistically demanding. Guideline developers appreciate new methods that facilitate a systematic methodology based on sound decision-making processes. Systems that aggregate knowledge while participants actively participate is one class of human computation applications. Researchers have already proven that this active participation with a purpose is effective in building common sense knowledge databases. These active knowledge databases can be used to build and align best guidelines that can be improved systematically over time.

Despite the fact that medical related information is nowadays readily available in computer readable formats, it still poses significant challenges in employing and utilizing this information for the enhancement of the quality of medical services. The available information needs to be presented and utilized in such a way that healthcare professionals can utilize this information to improve patient treatment and citizens can get benefits timely in their treatment. Available data on various health care database records can also be presented and aligned in a way that even citizens can make decisions according to their expertise. But the decision making also needs an appropriate guideline and common consensus method to develop evidence based clinical practice for the healthcare professionals. Human computation as a backbone can be used to build such a system that aggregate and align knowledge while citizens actively participate in providing and solving simple tasks and getting incentives. Existing clinical knowledge, best practices by health care professionals, evidence collected from reliable sources like research and successful treatment history of patients if combined and aligned timely may provide potential aid in reducing high cost.

3.2. Integration of Evidence based Medicine

The knowledge space produced from the workflow of a series of crowdsourced human computation tasks helps in aligning Evidence Based Medicine (EBM). In 1991, Gordon Guyatt proposed a term *Evidence Based Medicine* emphasizing the inclusion of new evidence in clinical practice. Primary the term EBM is defined as "conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients" [22]. Sackett DL [23] revised and improved EBM further as "a systematic approach to clinical problem-solving which allows the integration of the best available research evidence with clinical expertise and patient values". The primary goal of Evidence-based Medicine (EBM) is the use of current best evidence from various practitioners and medical guidelines in formulating the decision regarding a patient's personal health care. Furthermore, it also stresses that the patients should not be kept aloof from the decision-making process about their own treatment.

Masic et. al. [24] describe a 5-step systematic approach for Evidence Based Medicine. Each step of the systematic model described above can be formulated as an activity of human computation tasks. These activities in the form of human computation tasks are then outsourced to citizen crowds having particular skill sets using crowdsourcing systems in the form of human computation workflows. These workflows consist of a series of different human computation activities (tasks) that capture and combine relevant information from the various different skilled crowd workers and generate democratic knowledge spaces. This democratic knowledge space provides clinical problem-solving solutions created from the integration of the best available evidence from the clinical experts and patient past experiences. Furthermore, besides utilizing the current best evidence from expert crowds, the decision-making process also keeps patients in the loop about their own treatment.

3.3 Opportunity of Human Computation

The scenario of the health care problem discussed earlier captured a workflow of a series of human computation tasks. A possible abstract workflow of our scenario is described in details below. A diagrammatic representation is shown in Figure 1.

1. The scenario assumed citizen as a problem reporter or as a crowd worker or both signup for crowdsourcing.
2. The citizen as a problem reporter creates a problem related to health care by uploading text, images, voice or video. Reporters can also attach extra details (necessary for the problem) in the form of description and problem related tags (from Tag Pool).
3. The citizen, as a crowd worker, after registration, completes their profile by adding their skill tags, education, professional qualification and previous work experience in order to execute human computation tasks.
4. The knowledge-based crowdsourcing application (KBCA) parses the reported problem by extracting tags and descriptions reported by the citizen. The extracted tags is then used to extract questions from the Question Pool (relevant to the problem) by matching problem tags with question tags using an computer algorithm (i-e similarity algorithm etc) based on predefined similarity measure threshold criteria and creates a new human computation task (HC-Task).
5. The workers are recruited based on the skill tags attached with the HC-Task, their availability and subscription package. Anyone from the pool of crowd workers can also participate voluntarily based on his or her skill set matching the HS-Task. A Community of Citizen Worker is built upon each task from recruited crowd workers based on problem domain using computer algorithm i-e community builder algorithm etc.
6. Community builder algorithm parses each HC-Task, extract skill tags and problem domain and recruit crowd workers by matching profile information and send them task invitation requests. The crowd workers accepting the requests are included in the community using some community size threshold measure. Anyone from the citizen crowd worker with matching their profile can also participate voluntarily.
7. The HC-Task is then crowdsourced to the community of citizen crowd based on distribution criteria fixed by the KBCA admin for optimal outcome. Distribution criteria define the execution order of task by a community of crowd workers which can be either sequential or parallel.
8. The community of citizen crowd perform many human computation activities like critical evaluation of HC-Task (appropriateness, quality, problem applicability, reliability and importance), new tags suggestion, assigning new questions relevant to problem, mark HC-Task for further improvement (requires more crowdsourcing iterations) and recommending it to more appropriate citizen crowd workers.
9. When HC-Task are properly executed by all the community members, the solutions of each question in HC-Task are compiled based on distribution criteria defined in point 7. In case of sequential distribution, results are compiled normally as each task is improved over the solution submitted by previous crowd worker but in case of parallel distribution, results are aggregated by taking mode as the same HC-Task is distributed to different crowd workers.
10. Finally, a single aggregated result in the form of a report is created which is called knowledge outcome. This knowledge outcome can be used by healthcare professionals and concerned organizations to take appropriate decisions and align guidelines for a cause.

4. Research Problem and Proposed Architecture

In this research paper we have provided an architecture as crowdsourced human computation task for modelling civic problem-solving in smart city and a feasible solution framework using knowledge base crowd-sourcing in hybrid fashion. We have addressed healthcare related medication issues for better treatment in the smart city. A key issue is how to systematically improve and align medical treatment, the quality of care, timely align guidelines and make strategic planning and decision to maintain health related policies directly or indirectly so that healthcare professionals can improve medical treatment as well as create awareness regarding harmful chronic diseases. The possible mechanism is to use crowdsourcing to identify, characterize and input various data from citizens with their suggested medication and plan through a participatory process by engaging civic crowds. We defined these civic problems as a human centric and human intensive problem. Human centric requires citizens to actively report and vote on their healthcare issues. These huge reported data in the form of texts and images need to be aligned according to the standard guidelines in order to find the problem domains and common point of interest. On the other hand, as civic problems are recursive in nature, there is no single reason for their occurrence. Human intensive solutions are required to find the contextual knowledge of the occurrence of healthcare problems and create appropriate and optimal conclusions to the medical practitioner, hospitals, citizens, pharma companies and local health care agencies in the smart city and also cater similar problems in future.

5. Penta-Process Model for Knowledge-based Crowdsourcing

Due to the complex nature of the civic problem, elicitation of knowledge by traditional civic engagement directly will not produce optimal outcome so, in order to gain optimal outcome, we have proposed a systematic process model called Penta-Process Model, that will ensure the capturing of relevant problem domain, problem causes, problem semantics, problem rationales and provides ability to draw optimal solution (solution optimization elicitation) while discard irrelevant information. Figure 2 shows the states of the proposed process model, which consist of five states; Problem Learning, Problem Definition, Problem Formulation, Problem Solution and Problem Optimization. Each state is dependent on its previous state. Each individual state functions as a separate elicitation of knowledge and is responsible for creating and maintaining a separate knowledge space. This knowledge space will not only help in developing and maintaining systematic Evidence-Based Guidelines for our proposed research problem but also provision a wide spectrum of systematic solutions to other civic problems in future. Function of each state in Penta-Process Model is described below.

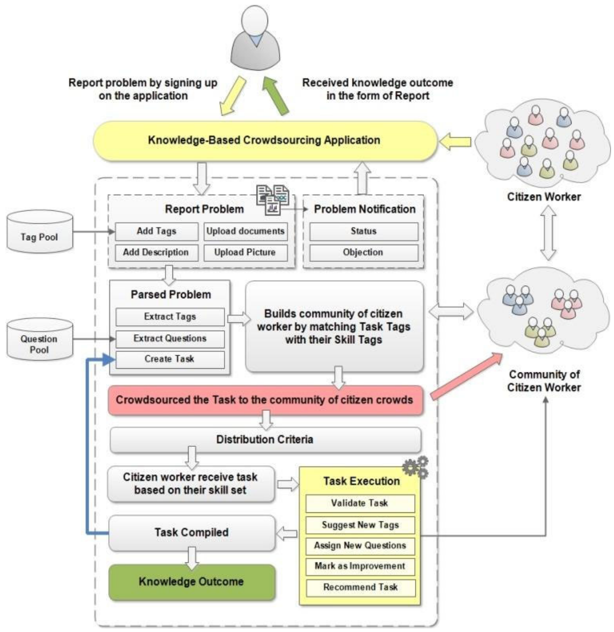


Figure 1: Scenario Workflow

1. Problem Learning

Problem learning is the first state of the penta-process model in which, initial problem is captured in the form of an actual problem. Any local civic problem is reported in the form of snaps because we think that taking snaps is the fastest and easiest way to report any type of problem. However other mediums may also be used to report civic problems. Exact location, date and time of the problem are also captured as it may be necessary to find different ways to solve the problem. Few other attributes for specific information related to problem in the form tags for example problem type (in the form of tags and description), tags for problem related to authorities (optional in this stage), severity level, and time (from when the problem exists).

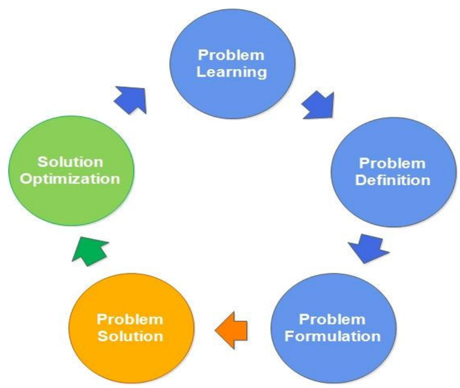


Figure 2: Penta-Process Model

2. Problem Definition

After capturing the actual problem (problem semantics) in this state, we transform the actual problem into problem definition. Problem definition is necessary in order to keep the domain of the problem focused and discard irrelevant details which will affect problem solution optimality. In this state, the captured data in the form of human computation tasks will be outsourced to the citizen crowd based on their skill set, location and time or to those who voluntarily participate. The human computation task in this state includes marking tasks as duplicate and irrelevant. Additional attributes like reasoning tags (reason of problem occurrence), optional notes, problem severity level, problem affiliation tags and problem rating were also captured.

3. Problem Formulation

This state will combine and formulate all the definitions (tasks) in previous states into one. Also, it will capture problem rationales, problem impact (positive and negative) in the form of notes and tags and reasoning tags for problem cause will also be revised.

4. Problem Solution

After formulating a problem in problem formulation state, in this stage, different types of solutions will be captured in the form of tags and suggestions. Depending upon the problem complexity, tasks will be revised iteratively in this state. Problem size (how much time it will take to solve) and type of solution methodology will be used. Suggestions and pre-existing solutions will also be captured regarding the problem solution.

5. Solution Optimization

In this stage, problem formulation filtration is captured in order to provide a correct and focused solution. Revision of every point in the problem solution state will be done here. More ever an aggregated result in the form of solution knowledge space will be presented for further optimization.

5.1 Penta-Process Model as a Democratic Knowledge Space

Interaction between different communities for solving a particular civic problem enables transfer of expertise across communities of government and non-government organizations. An interactive transfer of expertise model for knowledge acquisition in each state of the penta-process model is shown in Figure 3. In this model, users can report or discuss any civic issue in the form of snaps and tags by interactive through a web/mobile application and get responses either directly from the expert citizen community or from solutions (answers) of previously asked questions. This interactive transfer of expertise model will both create knowledge as well as utilize pre-existing knowledge to guide the knowledge acquisition process of penta-process model.

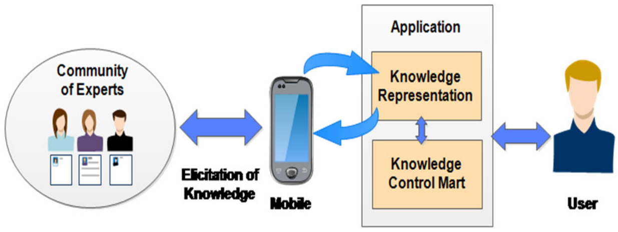


Figure 3: Knowledge Acquisition using Interactive Transfer of Expertise

Problem Learning, Problem Definition and Problem Formulation states of the Penta-Problem Process Model described previously will produce different variations of knowledge space that will provide useful insights of the local civic problems. These insights will highlight different aspects of the reported problem like problem context, problem semantics, problem rationale and focused problem and helps in shaping decisions made by the local government. Figure 4 shows the Venn diagram of problem motivation knowledge space. On the other hand, refined solution space can also be produced using the interaction of problem solution and solution optimization as shown in Figure 5.

5.2 Penta-Process Model as a Crowdsourced Human Computation System

In order to solve civic problems in smart city, we have proposed a hybrid architecture which is composed of human computation, machine computation and citizen crowd. The proposed hybrid architecture will provide a significant platform for citizens to come together to create solutions for the local civic problems of their own city. This hybrid platform will focus on civic engagement and community value in order to capture collective knowledge to come up with an optimal solution and draw appropriate conclusions. Civic engagement will ensure sharing of common points of interest among the citizen workers while the collaboration, communication and active participation will increase the community value. Community pool, bounties and knowledge solution space will be managed separately. This hybrid architecture covers all types of civic related problems as mentioned in previous sections. In this paper, we have considered health care problems as a civic problem, also discussed briefly in the previous section. Figure 6 shows an abstract view of proposed hybrid architecture, which ensures systematic solutions to various civic problems. The hybrid

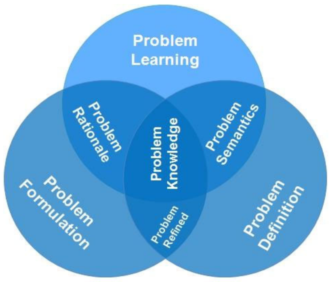


Figure 4: Problem Motivation Knowledge Space

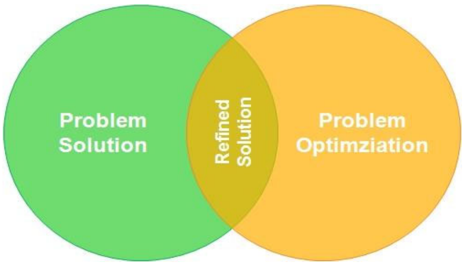


Figure 5: Refined Solution Space

architecture is composed of 8 layers that is Data Sensing Layer; Citizen Worker Integration Space; Citizen Worker Profile Manager; Task Generator; Task Controller; Task Recommender; Control Mart; Citizen Worker Pool Manager; Each layer is described in details below.

1. **Data Sensing Layer**

A local civic problem can be reported in many forms for example text, video and audio etc. and through any medium for example mobile phones, IoTs and social networking websites (Facebook, Twitter, Instagram etc.). Data sensing layer will collect the problem data from these different sources and depending upon the problem severity, social network will also be used for sensing of information relevant to the problem.

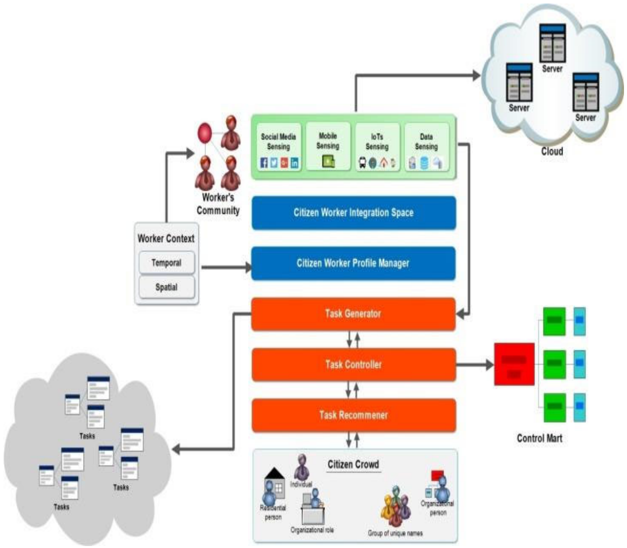


Figure 6: Hybrid Architecture

2. Citizen Worker Integration Space

Citizen worker integration space will maintain and keep up to date cognitive responses from the citizen workers related to the particular civic problem. Pre-existing responses of similar types of problems can also be included as a suggestion. These cognitive responses will create democratic knowledge space around a specific civic problem that can be used to provision human intensive solutions to human intensive problems as well as caters for similar problems in future.

3. Citizen Worker Profile Manager

Citizen worker profile manager is responsible for managing worker profiles who are voluntarily participating in solving the civic problem. Managing worker profile helps in forming a community of workers that have expertise in solving civic problems from their past experiences. This community of workers can also be used in future similar problems and also fulfils the required skill sets to solve a particular civic problem.

4. Task Generator

As civic problems are complex in nature, the task generator will generate a set of simple tasks using a data sensing layer related to civic problems. By using a citizen worker profile manager, these simple tasks then be outsourced to the community of workers having similar expertise to execute tasks. Community based crowdsourcing will ensure the transparency and correctness of data collected from multiple workers having different expertise levels. This creates a shared knowledge space also said as democratic shared knowledge space that will not only be used to solve civic problems but also improve other worker skill-set levels.

5. Task Controller

Workflows are created in order to manage these simple tasks in task controller layer. Task division, task forwarding, task tracking and task aggregation are done in the form of task workflows. Task controller is also responsible for dividing a complex task into subtasks and tracking each task status and performing task aggregation to formulate a combined result. Various task distribution strategies can be used for distribution and aggregation for example map reduces strategy.

6. Task Recommender

Task recommender layer uses citizen worker profile manager layer and other sources suggested by citizen worker for forwarding of simple tasks in workflows. Tasks are recommended to different crowd workers based on their skill set and past experience as well as their subscription model will be used for recommending the task to the appropriate citizen worker with subscription packages. Tasks can also be forwarded by any crowd worker on its social network based on skill sets as well as any citizen can also voluntarily participate in this democratic knowledge activity.

7. Control Mart

Task controller (workflow) uses control mart for recording the state of each forwarded task and keeping track of each task. Control mart also captures knowledge produced at a certain point in time.

8. Citizen Worker Pool Manager

Citizen worker pool manager is a database of citizen workers having a set of expertise. Information about signing up citizen for performing any task is stored here. Depending upon the citizen skill set and past experiences, tasks are forwarded to them. On the other hand, a signed-up worker's friend list from either their email or social account will also be used for marketing and sign up suggestions.

11. Execution of Knowledge-based Human Computation Workflow

This section will elaborate the methodology of our research proposal step by step. We will show how a proposed hybrid model (crowdsourced human computation) can solve human intensive problems (civic problem) in a smart city. We will show that active participation of the citizen crowd combined with crowdsourcing using hybrid architecture based on the penta-process model can be used to solve complex civics problems that machines cannot or are not cost effective and accurate. We will use the health care use case discussed in previous section as a civic problem to describe our methodology. Human computation tasks are essential and must be identified and captured accurately in order to represent and execute complex civic problems in optimal fashion. The knowledge-based crowdsourcing captures a series of human computation tasks as workflow using proposed hybrid architecture as a base model. Below are the detailed steps of each human computation task. A tabular representation of human computation tasks is shown in Table 1.

1. The use case assumed citizen and healthcare professional like doctor as crowd worker for crowdsourcing. The hybrid architecture categorizes crowd workers into three categories non-experts, semi-experts and experts. Non-experts are common citizen that are either involved as problem reporter or perform simple tasks like knowledge extraction (step 3) and filtration (step 4). Semi-experts are those that have partial knowledge about the problem or previously performed some semi-expert tasks like x-rays finding, patient history making etc. These semi-experts include staff, medical officers, nurse etc. Experts are healthcare professional's i.e. Doctors that have complete domain knowledge of specific case.
2. The citizen can enter his personal profile information after signing up to the forum. The citizen reports health related problem in the form of text, images, voice or video. The citizen can assign initial tags related to their problem and also upload supporting documents like medical prescription, test reports and past records.
3. The row information is crowd sourced in the form of initial task to the community of non-experts (having basic skills like translation, writing, vocabulary etc.) in order to extract information and remove errors. The community of non-experts performs many basic human computation activities like voice and text translation, video spot detection, image identification and tagging. Based on the expertise or availability, non-expert can also optionally forward the task to their connection which keeps the size of community intact.

Table 1: Human Computation Tasks

#	Opportunity for Human Computation Tasks	Community
Task 1	Reports health related problem in the form of tags, text, images, voice or video and also upload supporting documents like medical prescription, test reports and past records.	Non-Experts
Task 2	Extract information and remove errors. The community of non-experts performs many basic HC activities like voice and text translation, video spot detection, image identification and tagging. Also recommend HC task to their connection.	Non-Experts

Task 3	Filters and aggregate data by removing duplicate entries, remove noises and errors. Also record narrative feedbacks.	Non-Experts
Task 4	Validation of case information. Ask for more information from the reporter (if incomplete). Information to case conversion. Split case (iterate from Task 2).	Semi-Experts
Task 5	Recommendation and suggestion for treatment and case management. Ask to suggests doctor for relevant domain.	Non-Experts, Semi-Experts
Task 6	Evaluation of diagnosis, identify problem gap, recommend medication plan and formulate or approve diagnosis.	Experts
Task 7	In the last step, the case will be voluntarily assigned to any Doctor and a complete statistic from this knowledge activity is formed.	Experts

4. The Automatic aggregated algorithm will be transformed information and then forwarded to other community of non-experts for marking duplicated data, remove noises and errors from data. The community of non-expert can also mark the inappropriateness of data by giving feedback.
5. Semi-expert validates the information or asks for more information from the reporter. They also give their feedback and recommend for any urgent treatment. After validation, the semi-expert changes the information into a case. Semi-expert can also link other similar cases with it or split the case into multiple case types. They also suggest doctor of similar domain.
6. At this point, an automatic diagnosis algorithm will run, which will make a complete diagnosis with medication using case tags, textual description, images and reports using knowledge pool of past successful completed cases. Algorithm will also suggest doctors having similar past records and case specific experience.
7. The algorithm will also ask other reporter having similar problem to recommended medication they are using, recommendation for the doctor and diet they are following by notifying them directly by email/SMS or by indirectly on any social forum.
8. For final diagnosis, community of expert like doctor will evaluate the automatic diagnosis and feedbacks of crowd workers and give negative and positive feedback on diagnosis and recommended medications, identify possible causes of problem occurrence, precaution plan etc. the doctors can also merge the spitted case in step 5 and suggest single diagnosis.
9. In the last step, the case will be voluntarily assigned to any Doctor and a complete statistic from this knowledge activity is formed.

12. Towards Implementation Architecture

The number and sequence of human computation tasks are not fixed. They may vary depending upon the complexity of the problem. The human computation tasks are also dynamic and polymorphic in nature. It means they cannot be constant to cater similar problems in future as the context of the civic problem varies from time to time. Since the sequence of task execution is not fixed, workflows are necessary for managing the tasks execution order as well as capturing knowledge space from these human computation tasks. In order to synchronize both polymorphic behaviour of human computation tasks and workflow, we have proposed a crowdsourced human computation framework that is responsible of human computation tasks creation, execution, refining and filtration, quality controlling, task aggregation and managing knowledge space as depicted in Figure 6. The crowdsourced human computation framework is capable of catering any type of civic problem. The explanation of working of framework is described in details below.

13. Framework Explanation (A Scenario)

Assuming a scenario in which a user voluntarily participates for a cause. The user through any mobile device can either upload image, audio or give description about his concern in the form of text or by annotating through tags or can leverage all the options.

For a given case, a user provides his case history in the form of a single image and does not bother to leverage other options, leaving them empty. The input is then stored in the data store. Now the task generator process will fetch this data and extract tags, but in this use case it will remain empty and so it will skip the remaining process. After the task generating process, the task generator pushes the data to the task services component through API. Task service component will use the data and create a single page application and return restful URL to the task generator component. Workflow manager will create workflow from URL (in this case consist of only a single task).

Workflow manager is based on iterative design patterns, each time it iterates and creates new tasks if the previous task needs some improvement also known as progressive framework. Workflow manager stores each new task or updated task in its workflow repository. Using workflow repository community of citizen crowd manager starts its citizen crowd recruitment process by extracting each task from workflow (1), extracts tags from task (in this case empty tags) (2), extract workers form citizen worker pool (by matching citizen worker's tags with extracted tags form tasks) or (3), citizen worker can voluntarily participate. These extracted citizen workers are saved in citizen worker database. This community of citizen crowd managers use these saved crowd workers and forms a community which is stored in a community repository.

Task control system distributes tasks to this community with specified completion time. Using the criteria of workflow manger, it asks the community to identify the task by tagging the task, by assigning a short description which is optional. Additional details are also required by the crowd worker such as any improvement, input on relevancy of the assigned task according to his profile. Task control system has few other optional components for example task recommendation, task monitoring, task validation and task quality control component. Task recommendation component enables community of crowd workers to recommend tasks to other workers in their connection (based on subscription package). Task monitoring system will monitor the status of the distributed task and also notify the crowd worker about its pending status. Task validation component uses task quality control component to validate the task based on the quality control design pattern scheme. Possible design pattern schemes are iterative improvement or redundancy improvement. In iterative improvement tasks are distributed to the crowd in linear fashion, that is one task is distributed to one community worker at a time with specified time frame. After the task performed by the previous worker then this task with its feedback is forwarded to the next community worker and the chain continues until all workers receive this task. In case of unavailability of workers or workers decline, the task will be forwarded to the next worker. The task aggregation process of iterative improvement is based on the common feedback and similarity measure.

In redundancy improvement the task is forwarded to all the community workers at once and the task aggregation process compiles the result. During aggregation of results if the majority crowd workers recommend for improvement then the workflow manager will create a new task using a task generator and the whole process continues again on the other hand if the majority of crowd workers do not recommend for improvement the aggregate result will be stored as a knowledge outcome. Knowledge analytics models can be applied on these knowledge outcomes in order to derive statistically significant results. In the assumed case the later tasks will be added which will includes the questions of medication suggestions for the said symptoms which in the end will be aggregated to form a knowledge outcome in the form of most common medication preferred among experts.

14. Discussion

This section discusses the utilities of hybrid model as a knowledge creation opportunity in context of proposed use case “Aligning Medical Treatment by Developing Evidence Based Guideline on Medication” described under research problem sections as well as limitations of proposed architecture and framework. Hybrid model not only provides ways to capture, process and execute civic problems in the form of human computation tasks but also provides a systematic model to capture and refine knowledge in democratic knowledge space. On the other hand, it also introduces knowledge acquisition processes and support for existing crowdsourcing systems to obtain knowledge in new ways.

Interactive Transfer of Expertise Empowering Exciting Crowd Sourcing System

Interaction between citizen crowds ensures collective and collaborative intelligence in the form of communities to produce civic innovation hence provides solutions not only to human intensive problems, but also covers a wide spectrum of civic problems. Hybrid model also teaches and develops new ethical scenarios when human-human interac and human-machine interact not only within a community but also across the community by interactive transfer of expertise. Crowdsourced human computation framework is proposed, due to task’s polymorphic nature of problem, which proves that task can now be automated by the crowd itself also. Using interaction space, the crowd can create, tune, execute and evaluate the tasks hence eliminates the complexity of making, managing and executing workflows. Furthermore, it also automates the management activities of workflow such as what tasks are to be included, which tasks are valid, which tasks need to be forwarded to citizen workers and what tasks should be combined to obtain optimal results. Existing crowdsourcing systems can use the knowledge of task workflows to align their task execution order in a more optimized and controlled way.

15. Conclusion

Initiative of information and communication technology in smart city provisions the ability to citizen crowd to participate in sharing their knowledge for the social and economical development of the city. Hybrid model consist of knowledge-based crowdsourcing captures collaborative and collective intelligence of the citizen crowds forming a democratic knowledge space which provides a robust solution to civic problems in smart city. The hybrid model not only provides solution to complex problems but also enable citizen crowd to participate in knowledge creation activity through knowledge based crowdsourcing framework. This knowledge based crowdsourcing framework eliminates the complexity of human computation task creation, execution, refinement. Quality control and manage knowledge space hence provisions support to existing crowdsourcing system to align their task execution order optimally.

17. Future Work

The paper proposed a conceptual hybrid model for modelling civic problem-solving in smart city using knowledge-based crowdsourcing. Hence, a physical implementation in the form of application is required that uses proposed human computation framework for creating, executing and capturing knowledge space by making human computation tasks at different stages of complex problem using penta-process model. On the other hand, the aggregated results captured during different intervals need be analysed and align with existing solution to come up with a unified solution.

References

[1] Abbas, Tahir, et al. "How creative is the crowd in describing smart home scenarios?." *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, 2018.

[2] Alvear, Oscar, et al. "Crowdsensing in smart cities: overview, platforms, and environment sensing issues." *Sensors* 18.2 (2018): 460.

[3] Ambati, Vamshi, Stephan Vogel, and Jaime Carbonell. "Collaborative workflow for crowdsourcing translation." *Proceedings of the ACM 2012 conference on Computer Supported Cooperative Work*. ACM, 2012.

[4] Ambati, Vamshi, Stephan Vogel, and Jaime Carbonell. "Collaborative workflow for crowdsourcing translation." Proceedings of the ACM 2012 conference on Computer Supported Cooperative Work. ACM, 2012

[5] Ambati, Vamshi, Stephan Vogel, and Jaime Carbonell. "Collaborative workflow for crowdsourcing translation." *Proceedings of the ACM 2012 conference on Computer Supported Cooperative Work*. ACM, 2012.

[6] Doan, Anhai, Raghu Ramakrishnan, and Alon Y. Halevy. "Crowdsourcing systems on the world-wide web." *Communications of the ACM* 54.4 (2011): 86-96.

[7] Attenberger, Andreas. "Collecting and Enriching Medical Information Through Human Computation."

[8] Brabham, Daren C. "A model for leveraging online communities." *The participatory cultures handbook* 120 (2012).

[9] Chamoso, Pablo, et al. "Tendencies of technologies and platforms in smart cities: A state-of-the-art review." *Wireless Communications and Mobile Computing* 2018 (2018).

[10] Chang, Joseph Chee, Saleema Amershi, and Ece Kamar. "Revolt: Collaborative crowdsourcing for labeling machine learning datasets." *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. ACM, 2017.

[11] Chen, Xiao, Elizeu Santos-Neto, and Matei Ripeanu. "Smart parking by the coin." *Proceedings of the third ACM international symposium on Design and analysis of intelligent vehicular networks and applications*. ACM, 2013.

[12] Chouikh, Arbi. "HandYwiN: a crowdsourcing-mapping solution towards accessible cities." *Proceedings of the 19th Annual International Conference on Digital Government Research: Governance in the Data Age*. ACM, 2018.

[13] Dinkins, J. M. "Beliefs and attitudes of Americans towards their diet-insight# 19. Washington (DC): Center for Nutrition Policy and Promotion." *US Department of Agriculture* (2000).

[14] Dumitrache, Anca, et al. "Dr. Detective: combining gamification techniques and crowdsourcing to create a gold standard for the medical domain." (2013).

[15] Dunlop, Mark D., et al. "Using smartphones in cities to crowdsource dangerous road sections and give effective in-car warnings." *Proceedings of the SEACHI 2016 on Smart Cities for Better Living with HCI and UX*. ACM, 2016.

[16] Noronha, Jon, et al. "Platemate: crowdsourcing nutritional analysis from food photographs." *Proceedings of the 24th annual ACM symposium on User interface software and technology*. ACM, 2011

[17] Attenberger, Andreas. "Collecting and Enriching Medical Information Through Human Computation."

[18] Meyer, Ashley ND, Christopher A. Longhurst, and Hardeep Singh. "Crowdsourcing diagnosis for patients with undiagnosed illnesses: an evaluation of CrowdMed." *Journal of medical Internet research* 18.1 (2016).

[19] Kandappu, Thivya, et al. "A Feasibility Study on Crowdsourcing to Monitor Municipal Resources in Smart Cities." *Companion of the The Web Conference 2018 on The Web Conference 2018*. International World Wide Web Conferences Steering Committee, 2018.

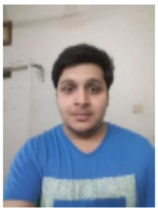
[20] Pánek, Jiři. "Emotional Maps: Participatory Crowdsourcing of Citizens´ Perceptions of Their Urban Environment." *Cartographic Perspectives* 90 (2018).

[21] Kumar, Harish, Manoj Kumar Singh, and M. P. Gupta. "Smart mobility: Crowdsourcing solutions for smart transport system in smart cities context." *Proceedings of the 11th International Conference on Theory and Practice of Electronic Governance*. ACM, 2018.

[22] Sackett DL, Rosenberg WM, Gray JA, Haynes RB, Richardson WS. Evidence based medicine: What it is and what it isn't. Br Med J 1996;312(7023):71-2

[23] Sackett DL, Strauss SE, Richardson WS, Rosenberg W, Brian Haynes RB. Evidence-based medicine: How to practice and teach EBM. London: Churchill-Livingstone, 2000.

[24] Masic, Izet, Milan Miokovic, and Belma Muhamedagic. "Evidence based medicine–new approaches and challenges." *Acta Informatica Medica* 16.4 (2008): 219.



Syed Muhammad Ali Kamal received the BS and MS degrees in Comptuer Science from FAST National University of Computer and Emerging Sciences, Karachi in 2016 and 2019 respectively. Currently, he is working for a renowned digital e-commerce company named ekuep of Saudi Arabia as a Software Engineer.

Nadeem Kafi Khan is an Assistant Professor in the Department of Computer Science, FAST National University of Computer and Emerging Sciences, Karachi. He has received his Ph.D (EE) from FAST NUCES in 2020. He is a member of the Systems Research laboratory. His research interests include Software Defined Networks, Parallel/Distributed Computing and Crowdsourced Human Computations.

Fahad Samad received his Ph.D. from RWTH Aachen University Germany in 2011. He is working as an Assistant Professor in the FAST School of Computing since 2017. His research interests include Network Analysis through Crowdsourcing, Network Security, Software Defined Networks and Internet of Things. Additionally, he has a number of international publications in different IEEE and ACM conferences and journals.

Hassan Jamil received the B.E. degree in electrical engineering from the Quaid-e-Awam University of Engineering, Science, and Technology, Nawabshah, Pakistan, in 2003, the master's degree in personal mobile and satellite communication from the University of Bradford, England, U.K in 2008, and the Ph.D. degree in computer science from the University of Malaya, Malaysia in 2019. He is currently serving as an Assistant Professor with the Department of Computer Sciences, National University of Computer and Emerging Sciences, Karachi, Pakistan. During his career, he supervised several post-graduate thesis and final-year projects, and taught courses in the Electronics, Telecommunication, and Computer Science Departments. His research interests include performance analysis, stability, reliability, scalability of the cloud, and the Internet of Things.

Nouman M. Durrani is an Assistant Professor in the Department of Computer Science, FAST National University of Computer and Emerging Science, Karachi. He has received his Ph.D. (CS) from FAST NUCES in 2017. He is a member of Systems Research Laboratory and Center for Research in Ubiquitous Computing (CRUC), and Co-PI at the HEC National Center in Big Data and Cloud Computing (NCBC), Smart Video Surveillance Lab FAST-NUCES. His research interests include Heterogeneous Devices Volunteer Computing, Distributed Systems, IoTs, Computer Vision, and Big Data Analytics.