ISSN. 0377 - 2969
Vol. 48(4), Dec. 2011

PROCEEDINGS
OF THE PAKISTAN ACADEMY OF SCIENCES

Pakistan Academy of Sciences,
Islamabad, Pakistan

PAKISTAN ACADEMY OF SCIENCES

Founded 1953

PROCEEDINGS OF THE PAKISTAN ACADEMY OF SCIENCES, published since 1964, is quarterly journal of the Academy. It publishes original research papers and reviews in basic and applied sciences. All papers are refereed externally. Authors are not required to be Fellows or Members of the Academy, or citizens of Pakistan.

Annual Subscription for 2011: **Pakistan:** Institutions, Rupees 2000/-; Individuals, Rupees 1000/-
Other countries: US$ 100.00 (Price includes air-lifted overseas delivery)

HEC Recognized, Category X

Published by **Pakistan Academy of Sciences**, 3 Constitution Avenue, G-5/2, Islamabad, Pakistan
Tel: 92-5 1-9207140 & 9215478; **Fax:** 92-51-9206770; **Website:** **www.paspk.org**

Printed at **PanGraphics (Pvt) Ltd.,** No. 1, I & T Centre, G-7/l, Islamabad, Pakistan
Tel: 92-51-2202272, 2202449 Fax: 92-51-2202450 E-mail: pangraph@gmail.com

Proceedings of the Pakistan Academy of Sciences, 48 (4): 197-199 (2011)

ISSN: 0377 - 2969

Pakistan Academy of Sciences

Original Article

Brooks & Corey Model and Extended Analysis to Develop a New Correlation

Muhammad Khurram Zahoor*

Department of Petroleum and Gas Engineering,
University of Engineering and Technology, Lahore, Pakistan

Abstract: Capillary pressure correlation was developed by Brooks and Corey, which is frequently used to study and analyze the capillary pressure behavior in porous media, including hydrocarbon bearing formations. It was proposed more than 40 years ago and since then has been implemented during various studies in different ways. This paper gives a brief overview of Brooks and Corey correlation and its usage, which shows its significance in reservoir engineering studies. Also, in this study a correlation has been proposed between reservoir characteristic constant and change in maximum displacement pressure.

Keywords: Bubbling pressure, characteristic constant, maximum displacement pressure

INTRODUCTION

A relationship between pressure differential (capillary pressure) and effective saturation was developed by Brooks and Corey [1]. They conducted a number of drainage experiments by using different porous media and proposed the following empirical correlation:

$$P_c = P_b S_e^{-1/\lambda} \tag{1}$$

Where, P_b is the bubbling pressure and "λ" is referred to as the pore-size distribution index or reservoir characteristic constant.

DISCUSSION

Equation (1) has strong experimental validation [2]. Therefore, it has been widely accepted and implemented in presenting the displacement behavior of one fluid by another, while including the effect of pore-size distribution. Bubbling pressure term in the above equation refers to the minimum existing pressure during the drainage process. It is the pressure at which displacement process initiates and is also referred as displacement pressure (P_d). Therefore, equation (1) can also be re-written in the following form, which is more commonly used in the literature [3-5]:

$$P_c = P_d S_e^{-1/\lambda} \tag{2}$$

Reservoir characteristic constant is a parameter which qualitatively expresses the uniformity in pore size distribution. Greater the value of "λ", refers to the higher degree of uniformity, while the smaller value represents the vice-versa situation, i.e., higher degree of non-uniformity in pore size distribution [3]. Pore size distribution has strong influence on displacement pressure as well as on the shape of the capillary pressure curves [5, 6].

Effective saturation, in the above mentioned equations is expressed in terms of a ratio of change in saturation to the maximum displaceable saturation available before the displacement process, initiates. Mathematically, it can be expressed as follows, for the drainage process [1]:

$$S_e = \frac{S_w - S_{wr}}{1 - S_{wr}} \tag{3}$$

Received October 2011, Accepted 2011
*Email: mkzahoor@yahoo.com

While, the proposed correlation by Brooks and Corey has also been used for imbibition process by representing the effective saturation equation [7], in the following manner:

$$S_e = \frac{S_w - S_{wr}}{1 - S_{wr} - S_{nwr}} \qquad (4)$$

RECENT DEVELOPMENTS

Based on the above discussion, theoretically, Brooks and Corey model can be applied when wetting phase is mobile. So, the effective saturation or normalized saturation correlation was later presented in terms of mobile (displaced/ displacing) phase saturation in the following manner [8]:

$$S_e = \frac{S_{displaced} - S_{rdisplaced}}{1 - S_{rdisplaced}} \text{ and/or,} \qquad (5)$$

$$S_e = \frac{S_{mp1} - S_{rmp1}}{1 - S_{rmp1} - S_{rmp2}} \qquad (6)$$

EFFECT OF NON-UNIFORM PORE-SIZE DISTRIBUTION

Petroleum reservoirs generally have non-uniform pore size distribution. A number of studies and discussions are available in the literature, showing the effect of heterogeneities and pore-size distribution on displacement behavior and/or on de-saturation curve [6, 9, 10]. Different porous mediums, for example, cores having different pore-size distribution will present distinct capillary pressure curves. At the same time can also have different displacement or entry pressure values [8, 9]. However, in this paper, capillary pressure curves have been generated by using Brooks and Corey correlation, while keeping the displacement pressure, constant. Because this will help in signifying the effect of "λ", while maintaining the same starting point (displacement pressure).

The displacement pressure value used to generate capillary pressure curves in this study is the one which represents the entry pressure of the de-saturation curve for one of the oil reservoir. The Fig. 1 shows the effect of characteristic constant on P_c data generated by Brooks and Corey correlation. The curves are generated by increasing the value of pore-size distribution index from 4 to 16, in increments.

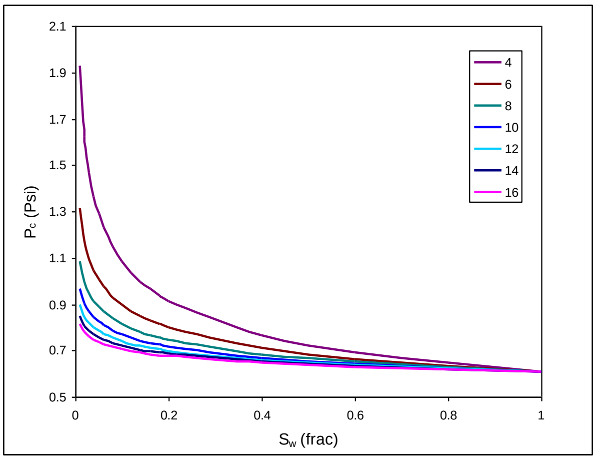


Fig. 1. Effect of characteristic constant on data generated by Brooks and Corey correlation.

Furthermore, the effect of characteristic constant on the change in capillary pressure corresponding to immobile saturation of the displaced phase can be demonstrated with the help of following Fig. 2.

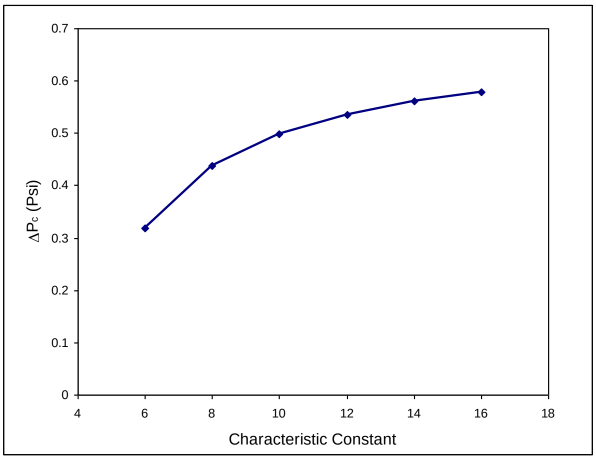


Fig. 2. Effect of characteristic constant on change in maximum displacement pressure w.r.t. $P_{c,max}$ for $\lambda = 4$.

The Fig. 2 shows that as the characteristic constant increases, its corresponding effect on maximum capillary pressure value decreases. Furthermore, based on this study, it has been observed that the effect of "λ" on change in maximum displacement pressure (with reference to base case, $\lambda = 4$) can be expressed in the form of following relationship:

$$\Delta P_{c,max} = \Delta P_{c,Swir} = -3.93\times10^{-5}\,\lambda^4 + 0.002\,\lambda^3 - 0.0399\,\lambda^2 + 0.3783\,\lambda - 0.892 \qquad (7)$$

CONCLUSIONS AND RECOMMENDATIONS

Brooks and Corey model is of great interest in the petroleum industry. To increase its applicability, different modifications have been incorporated in it. In this study, a correlation between characteristic constant and a change in maximum displacement pressure has also been developed, providing an opportunity to directly analyze the effect of pore-size distribution index on maximum capillary pressure values. The proposed correlation can be further modified with future studies.

NOMENCLATURE

P_b	Bubbling pressure
P_c	Capillary pressure
S_e	Effective saturation
S_{mp1}	Saturation of mobile phase 1
S_{nwr}	Residual saturation of non-wetting phase
S_{rmp1}	Residual saturation of mobile phase 1
S_{rmp2}	Residual saturation of mobile phase 2
S_w	Wetting phase saturation
S_{wr}	Residual saturation of wetting phase

REFERENCES

1. Brooks, R.H. & A.T. Corey. Hydraulic properties of porous media. *Hydrology Papers,* Paper no. **3:** (1964).
2. Skjæveland, S.M. Physically-based Capillary Pressure Correlation for Mixed-Wet Reservoirs from a Bundle-of-Tubes Model. *SPE/DOE Symposium on Improved Oil Recovery,* Tulsa, Oklahoma (2004).
3. Dandekar, A.Y. *Petroleum Reservoir Rock and Fluid Properties.* CRC Press, Taylor & Francis Group, Florida (2006).
4. Thomas, C.J., N. Kent, R. Jay Alan & B.T. Alwin. A Comparative Study of Capillary-Pressure-based Empirical Models for Estimating Absolute Permeability in Tight Gas Sands. *SPE Annual Technical Conference and Exhibition,* Anaheim, California, USA (2007).
5. Manthey, S. Two-phase flow processes with dynamic effects in porous media – parameter estimation and simulation. *Eigenverlag des Instituts fur Wasserbau der Universitat Stuttgart* (2006).
6. Hamouda, A.A., O. Karoussi & E.A. Chukwudeme. Relative permeability as a function of temperature, initial water saturation and flooding fluid compositions for modified oil-wet chalk. *Journal of Petroleum Science and Engineering,* 63: 61-72 (2008).
7. Li, K. & R.N. Horne. Steam-Water Capillary Pressure. *SPE Annual Technical Conference and Exhibition,* Dallas, Texas (2000).
8. Zahoor, M.K., M.N. Derahman & M.H. Yunan. WAG process design - an updated review. *Brazilian Journal of Petroleum and Gas,* 5: 109-121 (2011).
9. Killins, C.R., , R.F. Nielsen & J.C. Calhoun. Capillary desaturation and imbibition in porous rocks. *Producers Monthly,* 18: 30-39 (1953).
10. Ataie-Ashtiani, B., S.M. Hassanizadeh & C. A. Michael Effects of heterogeneities on Capillary pressure–saturation–relative permeability Relationships. *Journal of Contaminant Hydrology,* 56: 175-192 (2002).

Proceedings of the Pakistan Academy of Sciences, 48 (4): 201-204 (2011)

ISSN: 0377 - 2969

Pakistan Academy of Sciences

Original Article

Development of a Software to Evaluate Faculty Performance

Muhammad Khurram Zahoor[1*] and Sana Zahoor[2]

[1]Department of Petroleum and Gas Engineering,
University of Engineering and Technology, Lahore, Pakistan
[2]Institute of Industrial Biotechnology, Government College University, Lahore, Pakistan

Abstract: Since the last few years, emphasis has been placed on evaluating the performance of teaching faculty of educational institutions. This evaluation is normally carried out manually, by distributing printed questionnaires to the students, where they convey evaluations based on their thinking and understanding. In this case, handling enormous data and further summarizing the conducted surveys regarding the teacher's evaluation, could be quite massive. To ease this situation, a software has been designed, which can be conveniently used by students to rank their teachers. By using this in-house developed software, any chance of computational errors in finalizing such surveys in a timely manner can be avoided. In addition, it provides multidimensional survey analysis facilities to the survey conducting authorities.

Keywords: Software, teacher's evaluation, faculty performance, educational system betterment

INTRODUCTION

To improve educational standards at university level, different programs have been announced from time to time. These programs include higher education, training of teaching faculty from abroad, encouraging and facilitating them to attend international conferences, etc.

As a result of these efforts, the standard of education at higher degree awarding institutions is improving. Since the recent past, evaluation of teaching capabilities of the faculty members by their students has started gaining attention in the developing countries as well, though in the developed countries, like USA, it has been a routine practice since the last about 50 years [1]. The objective of this evaluation exercise is to get an idea about the faculty members' competence as a teacher and to arrive at the means of improving educational standards [2,3,4]. In addition, in some institutions, these evaluations are used as one of the criteria, to provide some financial incentive to the teachers with higher ranking [2].

CONVENTIONAL TEACHERS' EVALUATION PROCESS (CTEP)

Currently, at various universities in the developing countries, surveys for evaluating teachers' competence and proficiency are usually conducted by distributing a printed questionnaire among the students, once in a year or in a semester. This questionnaire would contain a number of questions, which are answered by the students by giving marks to the respective teacher's (who taught them during that semester/year), based on the experience with the teacher and his/her perceptions.

Once the marks are assigned, the bundle of collected questionnaire is forwarded to the University's concerned authorities, where all the questionnaires for a teacher are processed, to arrive at his/her overall ranking(s).

This procedure is not only cumbersome but also is prone to errors. Also, it provides lesser chances for the students to analyze/ re-consider their evaluation, because normally they assign marks question by question and are not able to visualize the overall picture of the teacher ranking/standing based on total marks, especially when the list of teachers is huge. The entire process of conducting faculty evaluation surveys can also be explained with the help of the following flow chart shown in Fig. 1.

Received October 2011, Accepted December 2011
*Corresponding author: Muhammad Khurram Zahoor; Email: mkzahoor@yahoo.com

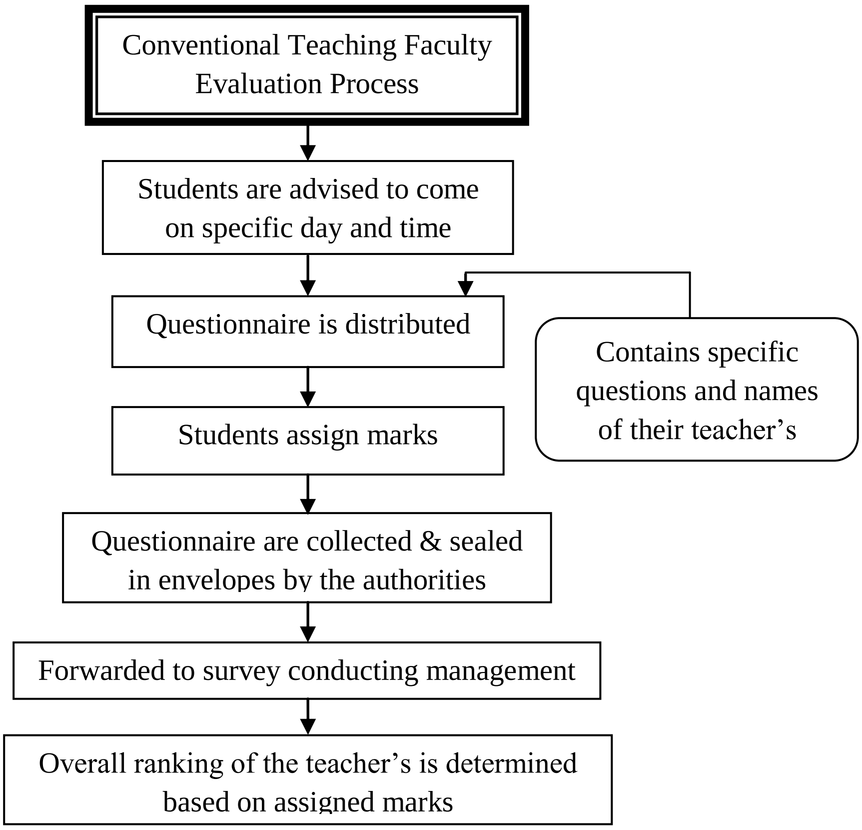


Fig. 1. Procedure for conducting CTEP.

To make this faculty teachers (F.T) evaluation process faster, with increased accuracy of the final results, a software has been developed, which is described below:

DEVELOPED SOFTWARE FOR CONDUCTING TEACHERS’ EVALUATION SURVEYS

A software has been developed using state-of-the-art algorithms in Visual Basic [5,6,7]. This program offsets the need of having piles of questionnaire and makes the entire evaluation process faster with increased accuracy. The overview of the developed software named as “F.T Evaluator”, is shown in Fig. 2 and its working is explained with the help of flow chart as shown in Fig. 3. The software generates output file(s) in specified form with extension “.fte”, in which any number of data sets can also be appended without opening the file, providing immense ease of data saving.

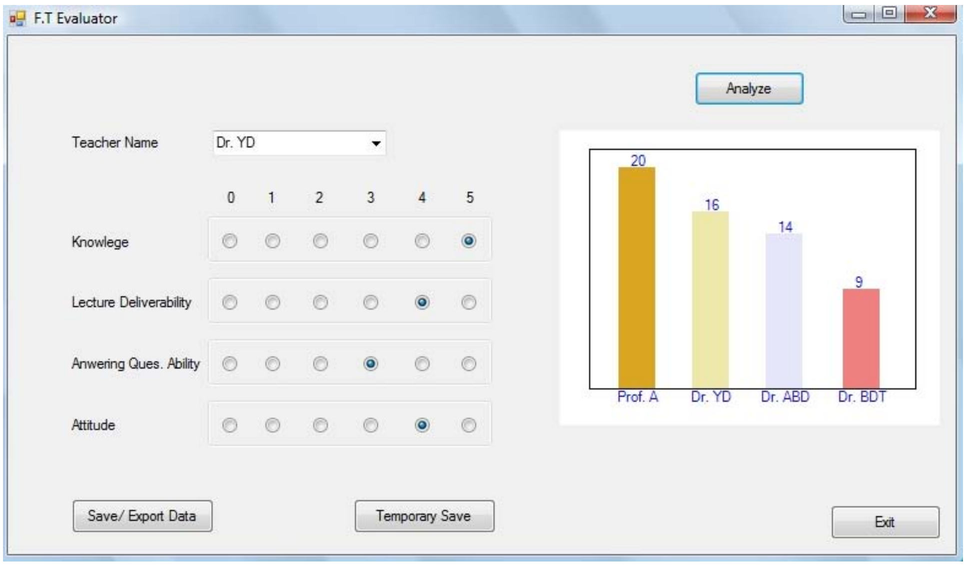


Fig. 2. Overview of the developed software.

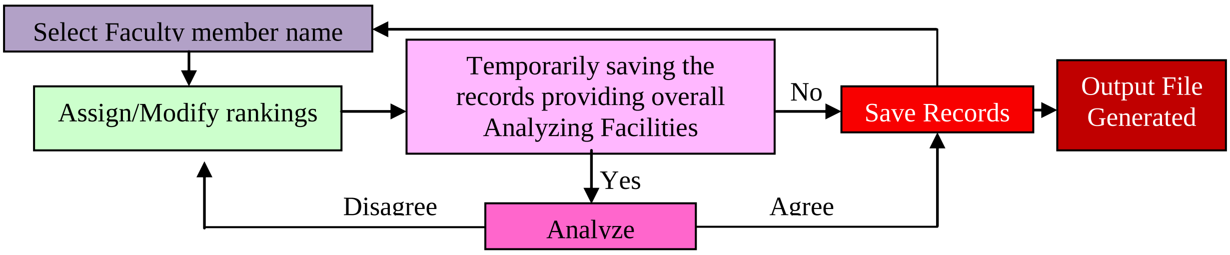


Fig. 3. Working of the developed software/program.

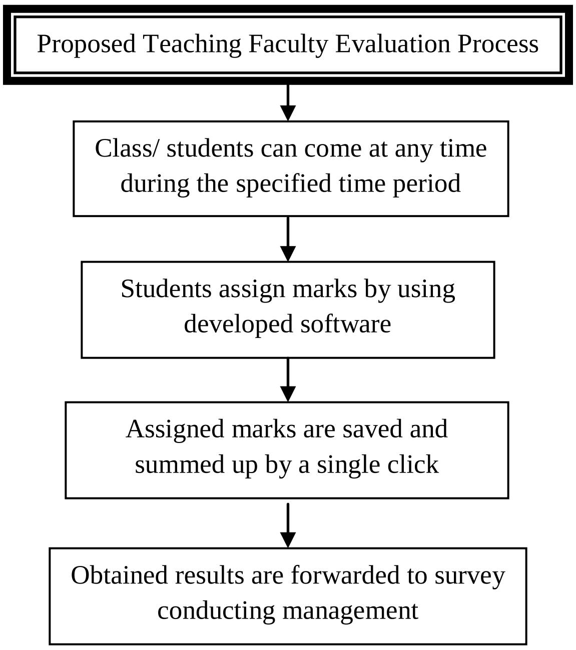


Fig. 4. Proposed procedure for conducting teachers' evaluation.

The entire process of conducting teachers' evaluation surveys by using the developed software can be explained with the help of Fig. 4, showing an immense ease in conducting such surveys as compared to accomplishing them in a conventional manner (Fig. 1).

ADVANTAGES OF DEVELOPED PROGRAM OVER CTEP

Followings are benefits of using the developed software over conventional teachers' evaluation procedure:

1) F.T. Evaluator provides an option to the students for overall analysis of the assigned rankings, prior to data saving.
2) Possibility of correcting the entered values without overwriting (making it difficult to read the entered values later on), as in case of conventional procedure.
3) Faster and error free compilation of the entered data.
4) Easier analysis of the teachers' overall ranking based on all questions, providing better evaluation of teachers' competence.
5) More economical, as it saves cost of printing questionnaires required for CTEP.
6) Saves time required to distribute, collect and handling of the questionnaires conducting CTEP.

CONCLUSIONS

The developed software and the proposed teachers' evaluation process provides a faster, error-free and broader analysis facility for in-depth scrutiny of the conducted surveys as compared to the conventional method of carrying out teachers' evaluation. Thus, the proposed system may be adopted, as a cost- and time-saving method for teachers' performance evaluations by students.

REFERENCES

1. Huemer, M. Students evaluation: a critical review – Part 1. *The Beacon* 3 (2006).
2. Peterson, K.D. *Teacher Evaluation - A Comprehensive Guide to New Directions and Practices*. Corwin Press, California, USA (2000).
3. Cohen, S. How valid are student evaluations of instruction? *The Beacon* 3 (2006).
4. Shinkfield, A.J. & D.L. Stufflebeam *Teacher Evaluation: Guide to Effective Practice*. Kluwer Academic Publishers, USA (1995).
5. Utley, C. *A Programmer's Introduction to Visual Basic(R).Net*. Sams Publishing, USA (2002).
6. Deitel, P. J. & H.M. Deitel. *Visual Basic 2008 - How to Program*. Pearson Education, New Jersey (2009).
7. Zak, D. *Programming with Microsoft - Visual Basic 2008, 4th ed.,* Course Technology, Cengage Learning, Boston (2010).

Proceedings of the Pakistan Academy of Sciences, 48 (4): 205-220 (2011)

ISSN: 0377 - 2969

Pakistan Academy of Sciences

Original Article

Investigating the Performance of Key Based Broadcast Routing Protocol

Nancy Alhamahmy[1] and Haseeb Zafar[1,2*]

[1]Department of Electronic & Electrical Engineering,
University of Strathclyde, Glasgow, UK
[2]Department of Computer Systems Engineering,
University of Engineering & Technology, Peshawar, Pakistan

Abstract: Wireless Sensor Networks (WSNs) are Mobile Ad Hoc Networks (MANETs) where the nodes are sensors usually with limited capabilities. These are often mobile, and are used to gather data about their environment and relay the date to a larger central node. They are often used in industrial applications or in dangerous areas. In this paper, the Key Based Broadcast Routing (KBBR) protocol is investigated. KBBR is a simple secure routing protocol designed for wireless sensor networks. KBBR aims to make efficient use of broadcasting by limiting the number of broadcast packets as well as providing security functions. The performance differentials are investigated using Network Simulator-2 (NS-2). Results demonstrate the merits of KBBR when compared with competing schemes.

Keywords: Wireless sensor networks, mobile ad hoc networks, key based broadcast routing, network simulator-2

INTRODUCTION

Mobile Ad Hoc Networks (MANETs) [1] are wireless networks formed by several nodes communicating on a peer-to-peer basis without being connected to any fixed infrastructure. These nodes could be laptop computers, personal digital assistants, mobile phones or sensors dispersed in an area to measure certain data and send the information to a larger node. Where a source node and a destination node are not within direct range, they communicate through multi-hop routing, i.e. nodes in between them relay messages between source and destination.

Routing protocols in MANETs are responsible for deciding on the best (multi-hop) paths to send data across from source to destination. The most widely used categories of MANET routing protocols are proactive, reactive (on-demand) and broadcast-based routing [2-6].

In proactive routing protocols, each node in the network attempts to keep track of all other nodes in the network, even if it does not need to communicate with them. This is achieved by exchanging periodic "hello" or beacon messages, which are used to update the nodes' routing tables. Proactive routing protocols are generally inefficient, because a lot of messages are exchanged and a lot of resources used to maintain information that may not be used, but they allow sending nodes to start transmitting data straight away as required, rather than waiting while a route to the destination is found.

In reactive routing protocols, nodes discover routes only when required. This introduces additional delay as a route has to be found before data transmission can begin, but avoids overloading the network and using resources unnecessarily. The Ad Hoc On-Demand Distance Vector (AODV) routing protocol [7] is a widely used reactive routing protocol for MANETs. A brief overview of AODV will be presented in the next section since it is used in the experiments.

Received November 2011, Accepted December 2011
*Corresponding author: Haseeb Zafar, Email: haseeb@eee.strath.ac.uk

Broadcast-based routing protocols try to modify the simple flooding approach to increase its efficiency while maintaining simplicity. In the simple flooding routing protocol used in this paper, Flood, a node receiving a packet checks whether it has received the same packet before (by checking the packet's unique ID and source node address), and whether the hop count (Time To Live field in the IP header) is greater than 0. If the packet is not a duplicate and the hop count is greater than 0, the node decrements the hop count and broadcasts the packet, so that all other nodes within range receive it. Broadcast-based routing protocols, like Key Based Broadcast Routing (KBBR) protocol [8], try to restrict the number of broadcast packets but without introducing additional complexity. The operation of KBBR will be covered in detail in the next sections.

MATERIALS AND METHODS

Ad Hoc On-demand Distance Vector (AODV) Routing Protocol

AODV [7] is a reactive routing protocol where nodes exchange periodic “Hello” packets to update their routing tables. Routing tables include the neighbors the node is aware of, and the next hop to each of them. AODV does not support multipath routing, so only one next-hop can be stored for each destination. AODV uses sequence numbers to identify the latest routing information, and assigns expiry times to routing table entries to avoid routing packets based on outdated data [2-7].

To send a packet, a source node would first check its routing table for the next hop to the destination, if it does not find an appropriate entry it broadcasts a route request (RREQ) packet. Nodes receiving an RREQ determine whether it is a duplicate RREQ, and forward it if it is not. Once the RREQ reaches the destination, the latter replies with a route reply (RREP) packet which traverses the reverse path, hop by hop, to the source. Every node along the path updates its routing table accordingly. Nodes inform each other of a broken link using route error (RERR) packets, which are used to update routing tables [2-7].

Key Based Broadcast Routing (KBBR)

Key Based Broadcast Routing (KBBR) is a broadcast-based routing approach proposed in [8]. It is designed for sensor networks, where nodes have very limited capabilities. The operation and features of KBBR are presented in this section.

Operation of KBBR

Being a broadcast-based protocol means minimizing the number of broadcast packets is key to good performance. In KBBR, two authentication levels are used to limit the number of broadcast packets and to provide secure data transmission. Nodes in the network are divided in to a number of groups and nodes of the same group have the same Message Integrity Checksum (MIC), so that they can re-broadcast packets they receive from nodes within the same group. However, having the correct MIC does not allow a node to access the packet payload, it simply allows it to forward the packet to all nodes within range. Furthermore, data payload is encrypted and nodes in KBBR networks have a second set of authentication keys which allows the intended recipient(s) only to decrypt the payload. Nodes receiving packets for which they do not have the correct MIC will simply drop them. The operation of KBBR is further illustrated in Fig.1.

As shown in Fig. 1, when a node in a KBBR network receives a packet, it first checks whether the MIC computes correctly and drops the packet if it doesn't. Next, the node checks whether it has received the same packet before and whether the hop count is greater than 0. The node then decrements the hop count by 1 and checks whether it is the only recipient, in which case it does not need to re-broadcast it and instead attempts to decrypt the packet payload using the decryption keys it has. If this node is not the only recipient, it queues the packet for re-broadcast in addition to attempting to decrypt it. To decrypt the packet, the node uses the decryption keys it has, one at a time, until the correct one is found. If none of the keys it has are suitable, it discards the packet.

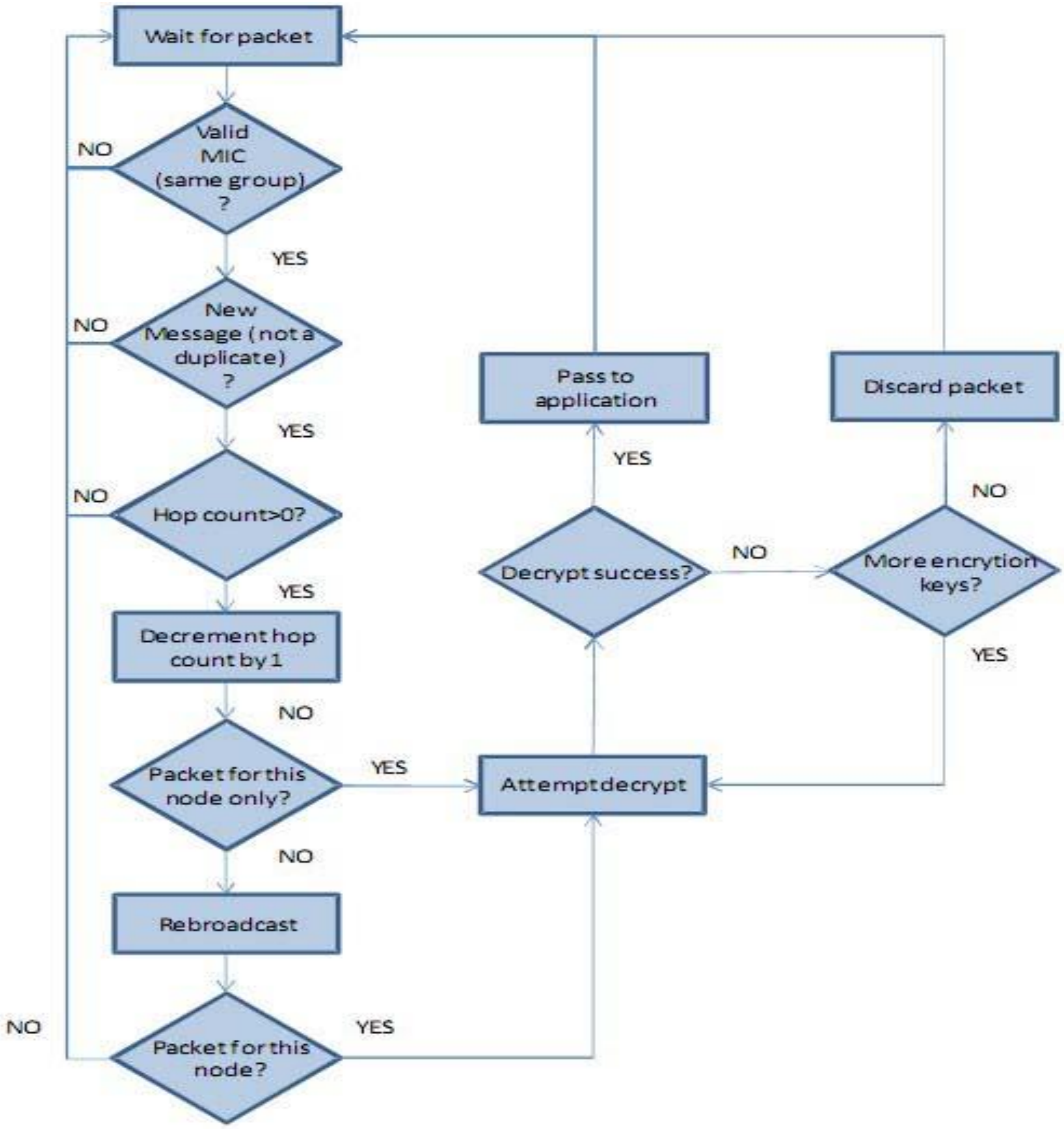


Fig. 1. Operation of a node in a KBBR network [8].

KBBR was implemented in hardware [8]. The nodes used in the test bed were stationary, but the effect of movement was emulated by having some nodes switch off at different times, effectively changing the distance between online nodes. Also, Zigbee – IEEE 802.15.4 was used instead of Wireless LAN – IEEE 802.11 as is the case in this paper. The advantage of simulating KBBR in software is that more scenarios can be tested while avoiding the cost, time and complexity of hardware tests.

Advantages of KBBR

Being simple devices with low processing power and limited battery life, the simplicity of KBBR can be very advantageous in sensor networks. KBBR becomes even more powerful in multicasting scenarios. Furthermore, since the nodes move around, no transmission bandwidth, processing or battery life is wasted on maintaining routing tables and keeping track of other nodes. The MIC, which ensures that only nodes of the same group can forward packets, prevents a flood storm or unnecessary congestion from occurring. While the encryption keys ensure that only the authorized nodes can process a packet.

Limitations of KBBR

Because of its broadcast nature, flood storms can occur in KBBR networks if the number of groups is not selected properly. The number of nodes in each group has to be large enough to ensure packets can find a path from source to destination, but at the same time small enough to minimize the number of packets broadcast unnecessarily. Furthermore, the area the network covers has to be appropriate for the expected load on the network. Factors such as packet size, transmission rate and number of active (transmitting) sources all contribute to the load on the network. With packets being broadcast, if the area is too small the network will get congested and very few packets will be delivered. So configuration of the KBBR network is very important. The first two sets of experiments presented in the next section investigate the behavior of KBBR as the number of groups and the network area (node density) are varied, respectively.

Operation of KBBR

The key point in the operation of KBBR is whether a node receiving a packet decides to re-broadcast it, or does nothing about it. The security features (encryption/decryption) will not impact the performance metrics used here (detailed in next section). In other words, since all nodes within range would receive a transmitted packet and then decide whether to rebroadcast it or not, whether or not the receiving node can access the packet payload (i.e., whether it can decrypt it) will not affect performance in terms of packet delivery fraction, end to end delay and normalized broadcast load and so can be excluded from the Network Simulator 2 (NS2) [9] model. This greatly simplifies the task of modeling KBBR in NS2, since encryption/decryption functions are not part of NS2, and would be difficult to develop, unnecessarily complicating the model.

So, the NS2 model of KBBR is simplified to a modified flooding protocol where nodes rebroadcast received packets if they received them from nodes of the same group, and do nothing about them if they are sent by nodes from a different group. The code for a simple flooding protocol, Flood, was obtained from public domain code website http://www.sce.carleton.ca/wmc/ code.html and modified to model KBBR.

To avoid having to make modifications to main NS2 component code, such as mobilenode.cc, nodes are not explicitly assigned to certain groups. Instead, the number of nodes in the simulation and the number of groups are specified, and the nodes distributed equally among the groups. For instance, in a simulation that includes 60 nodes and 3 groups, nodes 0 to 19 are assigned to the first group, nodes 20 to 39 are assigned to the second group and nodes 40 to 59 belong to the third group. This way, a node can tell if another node belongs to its group by comparing the difference between their node IDs to the number of nodes in each group. When a source node broadcasts a packet, the receiving node checks to see if the source node's ID is within the same group and acts accordingly. Randomness is introduced through the location and movement of each node, which is determined by the mobility file.

The main advantage of this scheme is its simplicity, and the fact that it does not involve major changes to main NS2 component programs, particularly considering the interdependencies within NS2 component code and the likelihood of such changes resulting in errors or unexpected behavior, and given the time frame for this work. On the other hand, the disadvantage is that the number of nodes in the network and the number of groups has to be explicitly defined in the C++ code of the routing protocol, kbbr.cc, which means that every time either numbers is changed NS2 has to be recompiled. Provided the code is error-free, recompiling NS2 takes a few minutes to complete, which is a reasonable price to pay for avoiding the complications of modifying main NS2 code.

Traffic File

The default Constant Bit Rate (CBR) generating file included in NS2, cbrgen.tcl, takes in the date type(CBR or TCP), the number of nodes, maximum number of sources, the simulation time, the packet sending rate (for instance 10 packets per second) and a seed for the random number generator. It then generates a file that lists out the connections to be created over the duration of the simulation. The nodes connect to each other in the order of their node IDs, but the time at which the connection occurs is randomly selected between 0 and 90 seconds (this range can be modified easily). For instance, node 0 connects to node 1 at time=50 seconds, Once established, the CBR connection continues at the rate specified for the duration of the simulation.

This file had to be modified so that the source and destination belong to the same group. The modified CBR generation file, cbrgenkbbr.tcl, accepts the number of groups in the simulation as an argument in addition to the input arguments mentioned above. To make sure that connections are established within as many of the groups as possible depending on the maximum number of connections, the program starts by establishing one connection within each group, then, once it reaches the last group, it establishes a second connection within the first group, a second connection in the second group and so on. The simulation time used in all experiments is 600 seconds, and since CBR connections are established at random times between 0 and 90 seconds, this gives the network enough time to operate at steady state so that performance can be evaluated more accurately. However, it is important to note that after 90 seconds the total load on the network comprises of the specified rate of packets per second, multiplied by the maximum connections and the packet sizes.

Mobility File

The mobility file generates a text file that details a scenario for the movement of the nodes for the duration of the simulation. The default NS2 mobility file, setdest (version 1), was used without any modification. It takes the number of nodes, the area of the simulation, the simulation run time, the maximum speed and the pause time to generate a random mobility "plan" for each node using the random waypoint model. In the random waypoint model each node chooses the coordinates of its next position randomly, and then moves to that point in a straight line at a random speed less than the maximum speed specified. The node remains in its new position for the duration of the specified pause time, and then picks a new point and moves towards it. Even though nodes of the same group are numbered sequentially, the randomness of location ensured by the mobility file ensures that the sequential numbering of the nodes does not affect the performance, and simulations remain "random" in nature.

Packet Size

KBBR is designed for sensor networks, where mobile nodes usually send a few small packets of data every once in a while. As a result, packet sizes can be smaller than those of MANETs. Packets used throughout the experiments presented in the next section are 64 bytes in size, plus 20 bytes for the IP header.

Number of Groups

As mentioned earlier, the number of groups the nodes are divided into affects the performance of a KBBR network. If there are too few nodes in a group the probability of packets getting dropped b becomes higher, as it becomes less likely to find a path from source to destination. On the other hand, if there are too many nodes in a group congestion may result as a result of too many broadcasts. Simple flooding is the extreme case where there is only one group in the network. In the first set of experiments presented in the next section, the effect of varying the number of groups is investigated.

Simulation Area

The area of the simulation affects the performance of a communication network significantly. An area that is too large is more likely to make the network too sparse, increasing the probability of nodes getting out of range of other nodes, or node partitioning. Coupled with slow speeds, this means parts of the network may be dysfunctional for long periods of time, affecting the overall performance. On the other hand, since nodes within range compete for the shared transmission medium, air, a small simulation area increases the chances of collisions and congestion of the network. So the area has to be appropriate for the number of nodes and their transmission ranges. The second sets of experiments presented in the next section investigate the performance of KBBR within networks of varying areas.

RESULTS AND DISCUSSION

The first two experiments investigate how the performance of KBBR is affected by varying network configuration; namely the number of groups and the area of the network. For all experiments, each point on the graph represents the average of the results of 10 runs. It is necessary to repeat simulations to make sure the results are not based on one particularly "lucky" or "unlucky" combination of traffic and mobility patterns.

Simulations are time-consuming, and their duration increases depending on the protocol, the simulation time and the complexity of the scenario because the number of events increases. The simulations were run on a Dell PowerEdge 2900 server and a Toshiba Satellite A300 laptop. To measure the time it takes for a sample simulation, a test run was performed using KBBR where the default parameters are used and the number of sources is increased from 1 to 19 with a step of 2 sources. The test simulations were not repeated. The test run took about 1.5 hours on both the server and the laptop. So, if each run is repeated 10 times for accuracy, then each set of experiments takes approximately 15 hours for each protocol. Determining the number of times to repeat each simulation involves a trade-off between making results as accurate and consistent as possible, and investigating more scenarios. Ten runs are sufficient to ensure results are reasonably consistent, while allowing sufficient experimentation.

The default settings which apply for experiments, except where the particular parameter is being tested, are given in Table 1. The number of nodes is chosen to be 60 because it is a convenient number divisible by 2, 3, 4, 5 and 6, which simplifies the allocation of nodes to different numbers of groups in KBBR. The simulation areas are chosen initially keeping in mind that the transmission range of each node is 250m. So the areas have to be large enough to allow multi-hop routing without being too sparse. The effect of varying simulation areas is explored in the second set of experiments. The remaining default parameter values are chosen to match values widely used in published research.

Table 1. Default simulation parameters used in the experiments.

Simulation Parameter	**Default value**
No. of nodes	60
Simulation Area	1000mx700m, 700mx500m
Simulation Time	600 seconds
Pause time	30 seconds
Data Rate	4 packets / second
Max node speed	5 m/s
Number of sources	10 nodes
Transmission range	250 meters

Performance Metrics

The performance metrics considered in the following experiments were[10]:

- Packet Delivery Fraction (PDF): This is the ratio of packets received to the packets sent.
- Average end-to-end delay: A measure of the average time it takes for a packet to travel from source to destination.
- Normalized Broadcast load: This is a measure of how many times packets have to be broadcast relative to the number of packets that successfully reach their destinations. Dividing the forwarded packets by the received packets, not the sent packets, factors in the packet loss.

Effect of Varying the Number of Groups

The first set of experiments investigated the performance of the 60-node network as the number of groups is varied. The simulations are run with the 60 nodes in the network divided into 3, 4, 5 and 6 groups respectively. In other words, each group consists of 20, 15, 12 and 10 nodes, respectively. The network area in the simulations is 1000m x 700m. Fig. 2 shows the effect of changing the number of groups on the PDF as the number of sources is increased, while Fig. 3 shows the effect on average end-to-end delay and finally Fig. 4 shows the effect on the normalized broadcast load.

As shown in Fig. 2, while the load on the network is low, i.e. small number of sources, a network with a fewer number of groups seems to have better performance in terms of PDF. That is because at lower loads, the network can support a larger number of broadcasts without getting congested, thus increasing the PDF. On the other hand, when the number of sources increases, the network performs better with a larger number of groups because less packets are broadcast, reducing the chances of collisions during transmission and network congestion.

Fig. 3 shows that the networks with fewer nodes in each group have lower average end-to-end delay, which is expected because fewer nodes in each group results in fewer packets being broadcast. In the networks with 3 and 4 groups, the average end to end delay remains reasonably low while the number of sources is low, and then increases significantly when the load on the network becomes too high, so that too many collisions occur and packets take longer to get to the destination. The average end to end delay for the networks with 5 and 6 groups remains low even with all 19 sources transmitting simultaneously. The sudden surge in delay that occurs in KBBR with 3 groups beyond 13 sources is not readily explained by the other results.

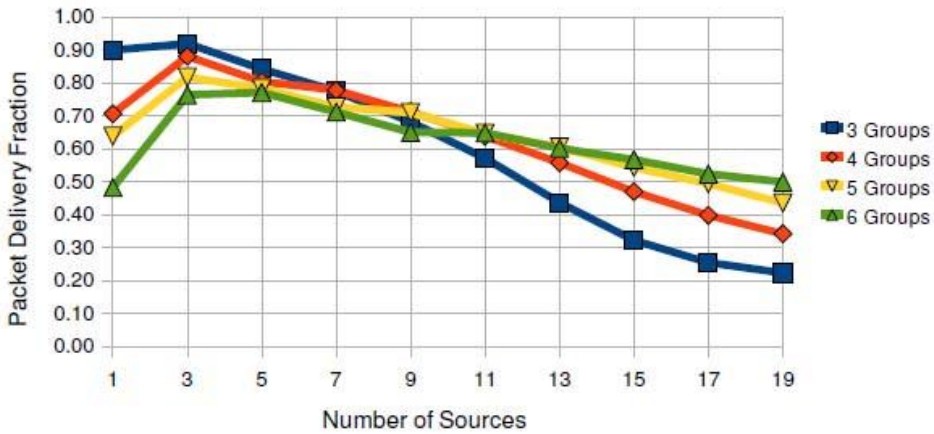


Fig. 2. Plot of PDF against the number of sources for a 60 node KBBR network with 3, 4, 5 and 6 groups.

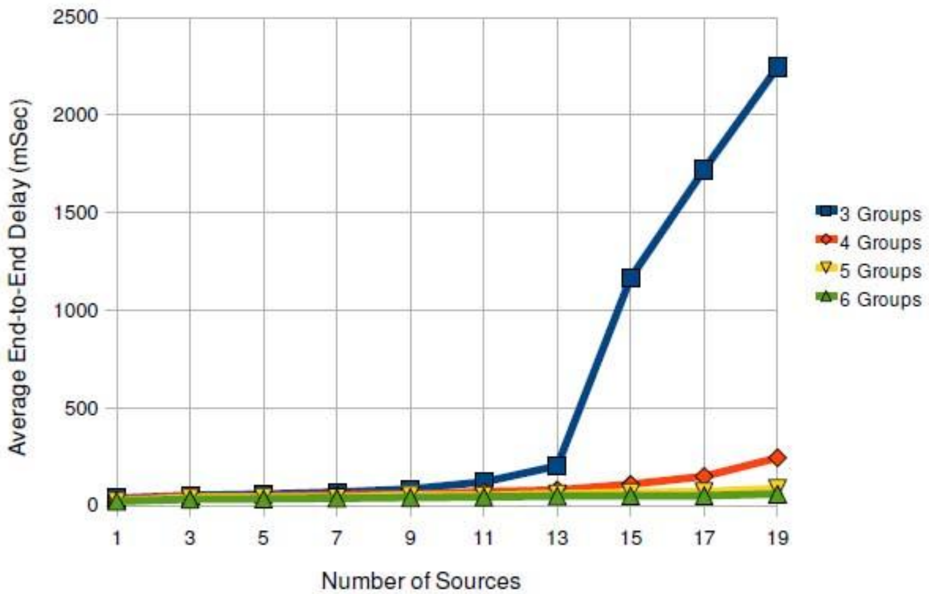


Fig. 3. Plot of average end-to-end delay (mSec) against the number of sources for a 60 node KBBR network with 3, 4, 5 and 6 groups.

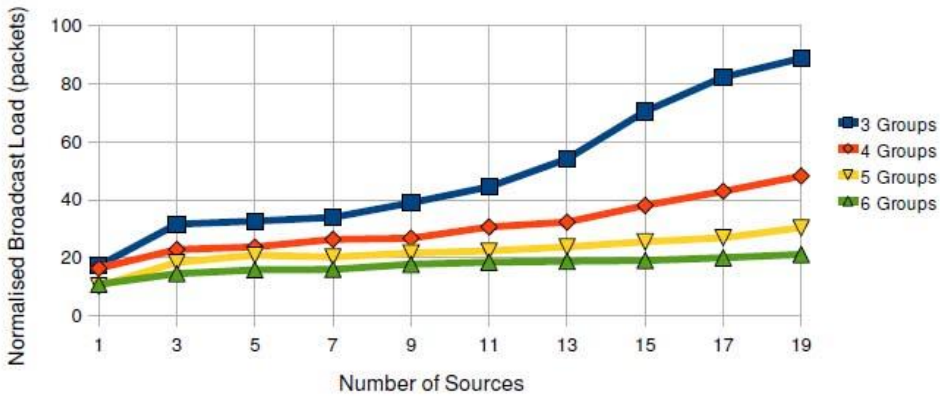


Fig. 4. Plot of the normalized routing load against the number of sources for a 60 node KBBR network with 3, 4, 5 and 6 groups.

Fig. 4 illustrates that the normalized broadcast load increases as the number of groups decreases, a direct result of the fact that less packets are broadcast when the group has fewer nodes.

So, based on the above results, it can be concluded that to select a suitable number of groups, the expected load on the network has to be considered. If the load is likely to be low, a smaller number of nodes per group can be selected to limit the number of broadcast packets, while maintaining a reasonable PDF and average end-to-end delay. On the other hand, if the load on the network is expected to be high, then a larger number of nodes per group would offer better performance in terms of PDF, end-to-end delay and normalized broadcast load. In all cases selecting the number of nodes per group involves a trade-off between PDF and the normalized broadcast load, i.e. increasing the number of nodes per group would improve the PDF, but is likely to increase the normalized broadcast load as well. However, it should be noted that if the broadcast load becomes too high, it might cause congestion and increased packet loss, degrading the overall performance of the network.

For the remaining experiments, a 60-node network with 4 groups will be used, since this configuration is expected to provide reasonable performance at all loads considered.

Effect of varying the terrain size

In the second set of experiments, the performance of KBBR was investigated for different terrain sizes as the number of sources was increased. Here, the 60 nodes which make up the network are divided into 4 groups and the areas used are 500mx500m, 700mx500m, 1000mx700m, 1000mx900m and 1200x900m. To determine an appropriate network area, the transmission range of the nodes must be considered, as well as the number of nodes, the number of sources, the data rate and the packet size. The transmission range of the nodes used is 250 meters. So, in the smallest network considered, 500m x 500m, the maximum possible distance between any two nodes, which occurs if they are located in diagonally opposite corners of the network, is 707.1m (using Pythagoras' theorem), which is less than 3 times the transmission range. This is the worst possible case, but most packets would have to travel a shorter distance between source and destination.

The performance in terms of PDF, average end-to-end delay and normalized broadcast load is shown in Fig. 5, 6, and 7, respectively.

As shown in Fig. 5, the performance at all considered terrain sizes exhibits similar trends. At lower loads, the PDF is higher, but it decreases significantly as the load is increased. However, the PDFs of the different area networks seem to converge when the number of sources is 17-19, such that the network area that exhibits the highest PDF at lower loads also exhibits the steepest decrease in PDF as the number of sources is increased, while the network area that exhibits low PDF at lower network loads seem to less affected by the increasing network load. This maybe because there are two factors contributing to packet loss in these experiments; high network load and large network area that makes it less likely to find a path for packets within each group from source to destination. In the smaller networks, packet loss is mainly a result of the network load being too high (either because there are too many sources transmitting simultaneously, or because the network area is small, so that collisions are more likely to occur, causing delays and packet loss), which is why the PDF decreases significantly as the load is increased. On the other hand, in the larger networks, packet loss is mainly caused by the nodes of the same group being too far apart, which is why the larger networks appear less affected by increasing the network load.

Fig. 6 shows that the average end-to-end delay is nearly the same for networks of all sizes considered up to 7 sources. For the smaller networks which have the highest PDFs, i.e. 500m x 500m, 700m x 500m and partly 1000m x 700m, at higher network loads the smaller the network the lower the delay. However, the largest two networks, which have the lowest PDFs have the lowest average end-to-end delay, which indicates that packets are either delivered to their destinations quickly if that is possible, or if they can not be delivered they are dropped, in which case they do not add to the average end-to-end delay.

As shown in Fig. 7, networks of all sizes considered exhibit increasing normalized broadcast load as the number of sources is increased. At lower loads, the normalized broadcast load of all networks is very close. At higher loads, the larger networks, namely 1000mx 900m and 1200m x 1000m exhibit relatively low normalized broadcast load, although the low PDF of these networks – and thus the low number of received packets - at higher loads would contribute to higher normalized broadcast loads. This could be due to the fact that larger networks have lower node density, so when a node broadcasts a packet there are few nodes in its vicinity to receive and re-broadcast it. In the remaining three networks, as the network load is increased, the smaller networks with the higher PDFs exhibit lower normalized broadcast load.

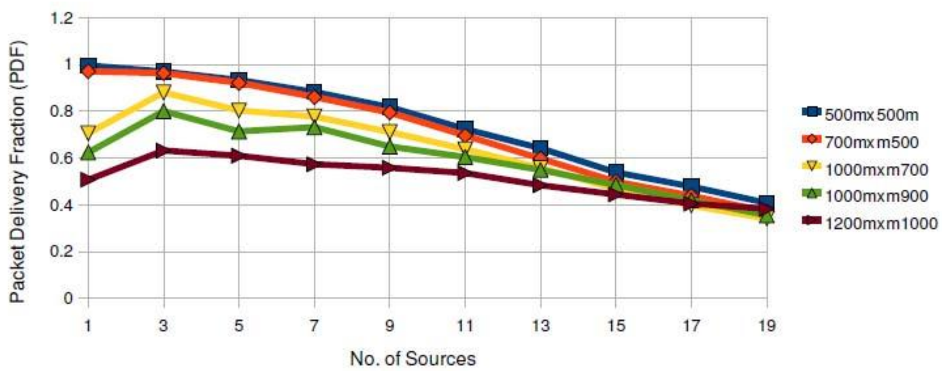


Fig. 5. Plot of PDF against number of sources for different terrain sizes.

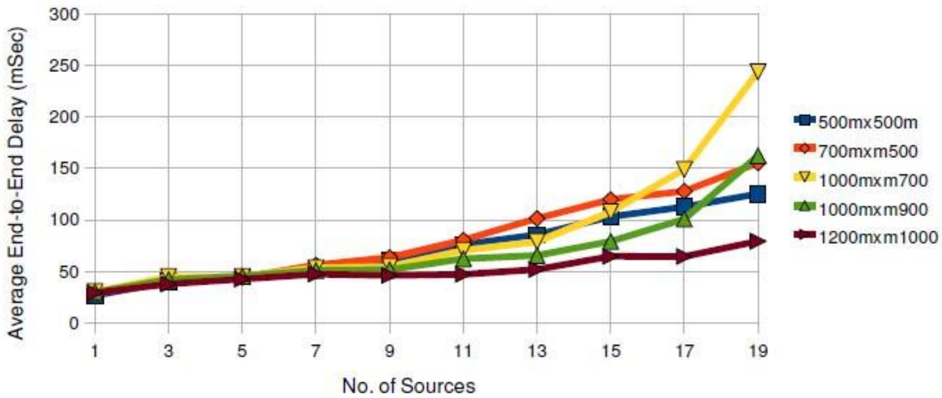


Fig. 6. Plot of average end-to-end delay against number of sources for different terrain sizes.

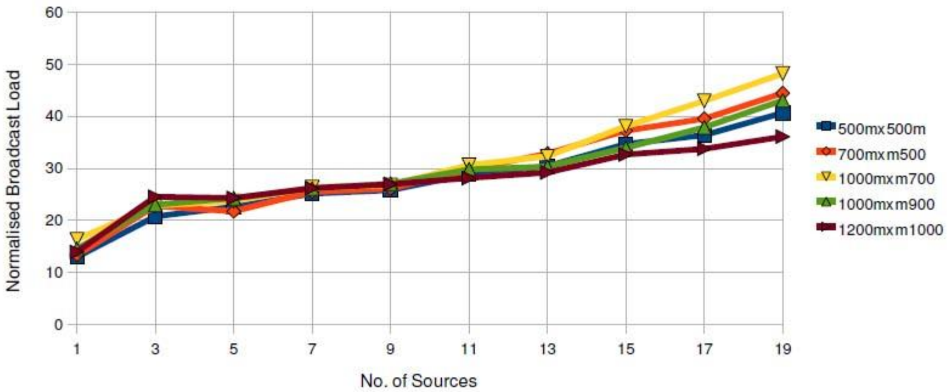


Fig. 7. Plot of normalized broadcast load against number of sources for different terrain sizes Based on the above results, a simulation area of 700m x 500m is selected for the remaining experiments.

.

Comparing Performance of KBBR and Other Protocols

To put the above results in context, it is important to compare the performance of KBBR to that of other protocols. In this paper, KBBR is compared to Flood, a simple flooding protocol, whose code is the basis for KBBR, and AODV, one of the most widely used reactive MANET routing protocols, to which a lot of the newer protocols are compared.

The performance of all three protocols is compared first as network load (number of sources) is increased with the nodes moving at a maximum speed of 5m/s. Then the number of sources is fixed at 10 sources, and the speed is varied.

Varying network load

In the following set of experiments, the number of sources is increased incrementally from 1 to 19, while the nodes move through an area of 700m x 500m at a maximum speed of 5m/s. In KBBR, the 60 nodes are split into 4 groups. The PDF, average end-to-end delay and normalized broadcast load for the three protocols are shown in Fig. 8, 9 and 10. For AODV, instead of the normalized broadcast load, the normalized routing load is used, which measures the number of routing packets for every packet received. The broadcast load and the routing load both measured in packets.

Fig. 8 shows the PDF performance of KBBR, Flood and AODV as the number of sources is increased from 1 to 19. AODV maintains a near one PDF throughout, while KBBR's PDF remains between 100% and 80% for up to 9 sources, beyond which the PDF falls with an increasing number of sources. At low network loads, Flood is able to deliver most packets, but as the load on the network (number of sources) increases, its performance degrades drastically as broadcast packets congest the network, so that very few packets are actually delivered.

Fig. 9 shows the average end-to-end delay of experienced by nodes in all 3 protocols as the load on the network is increased. In terms of average end-to-end delay, the performance of all three protocols is quite close when there are less than 9 nodes transmitting simultaneously. Beyond that, Flood's delay increases significantly. KBBR experiences increasing delays as the number of sources is increased but overall the end-to-end delay remains less than 160 mSec as the number of sources reaches 19.

In Flood and KBBR, the normalized broadcast load measures the number of packets forwarded for every packet received, so in addition to accounting for the broadcast packets, the number of packets received (or the PDF) is factored in as well. Fig. 10 shows that, as expected, Flood has a much higher broadcast load throughout, which increases sharply at higher network loads when less packets are delivered. KBBR maintains a reasonable broadcast load throughout, with a minimum of about 13 packets broadcast for every packet delivered when one node is transmitting and a maximum of about 45 broadcast packets for every packet received when 19 sources are transmitting simultaneously. AODV maintains the least normalized routing load throughout.

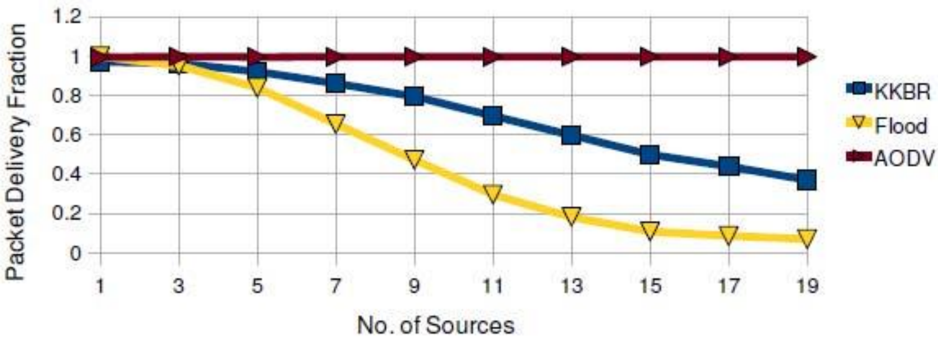


Fig. 8. Plot of PDF against number of sources for KBBR (4 groups), Flood and AODV.

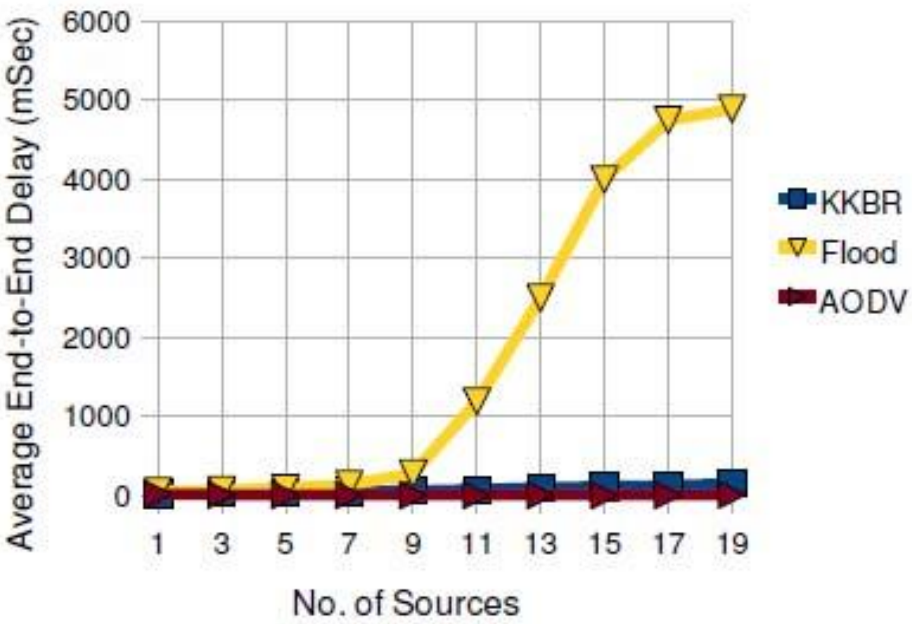


Fig. 9. Plot of average end-to-end delay against number of sources for KBBR (4 groups), Flood and AODV.

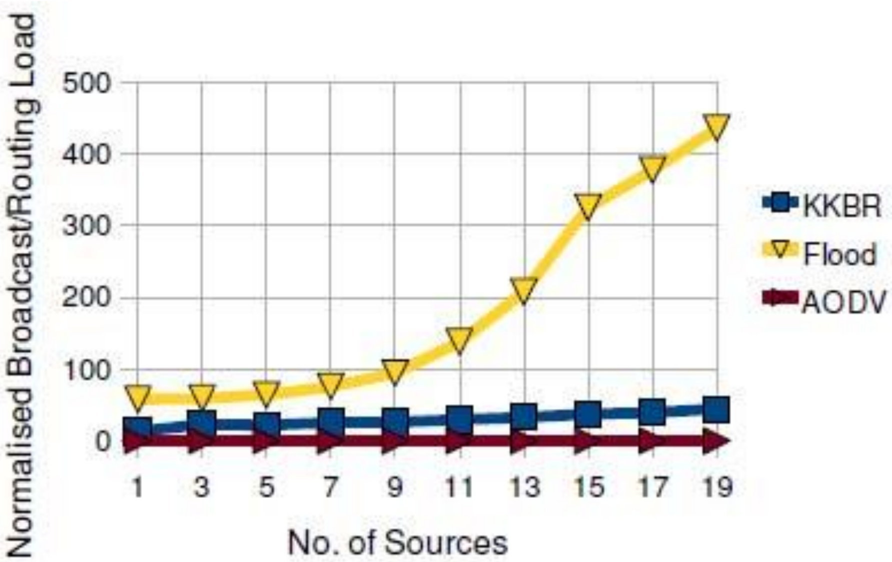


Fig. 10. Plot of the normalized broadcast load for Flood and KBBR, and normalized routing load for AODV against number of sources.

Varying node speed

In the following set of experiments the data rate is fixed at 4 packets per second and the number of sources transmitting in each network is fixed at 10 nodes, while the maximum speed is varied from 0.1m/s to 25m/s. The area of the networks used is 700 m x 500 m and the simulation time is 600 seconds with a 30 second pause time. Figs. 11, 12 and 13 shows the PDF, average end-to-end delay and normalized broadcast / routing load, respectively, for Flood, KBBR and AODV.

As shown in Fig. 11, both KBBR and AODV appear unaffected by increasing node mobility up to a maximum speed of 25 m/s. KBBR's PDF, which varies between 0.73 and 0.75, is in line with the PDF shown in Fig. 2 for 9 and 11 sources. AODV delivers nearly all packets at all speeds, while Flood drops most of them.

As shown in Figs. 11, 12 and 13, the performance of Flood seems consistent in terms of PDF, average end-to-end delay and normalized broadcast load as the node speed is increased. While performance (i.e. PDF or the inverse of delay or the inverse of broadcast load) starts off at its lowest when the speed is 0.1m/s, it improves significantly until it reaches a peak at 2m/s, after which it degrades gradually with increasing node speed. This behavior could be a result of the network being too small for the number of nodes and their transmission ranges, so that at the lowest speed very few connections are broken and the network gets saturated quickly. Another explanation might be that when nodes move slowly, then a node going out of range at some point in time is less likely to move back in to range of its neighbors within a certain time, and so it is more likely for packets to be dropped. This might seem to contradict the first explanation because the former implies the network area is too small and so most nodes are within range, while the latter implies that the network is large enough for nodes to move out of their neighbors' ranges for a long time. Both effects may occur at the same time if most nodes are gathered in one part of the network wile a few wander out of range.

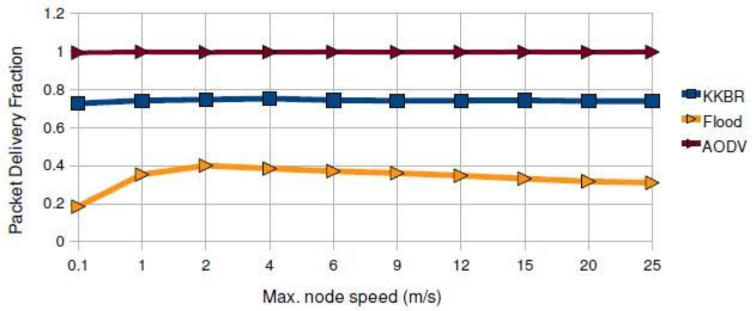


Fig. 11. Plot of PDF against node speed with 10 sources transmitting simultaneously for Flood, KBBR and AODV.

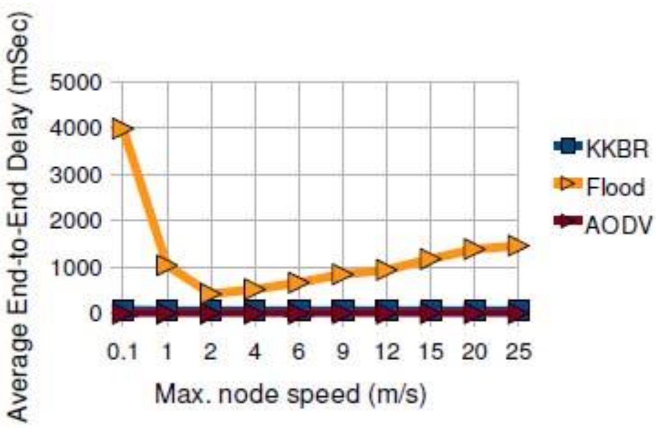


Fig. 12. Plot of average end-to-end delay against maximum node speed for KBBR (4 groups), Flood and AODV.

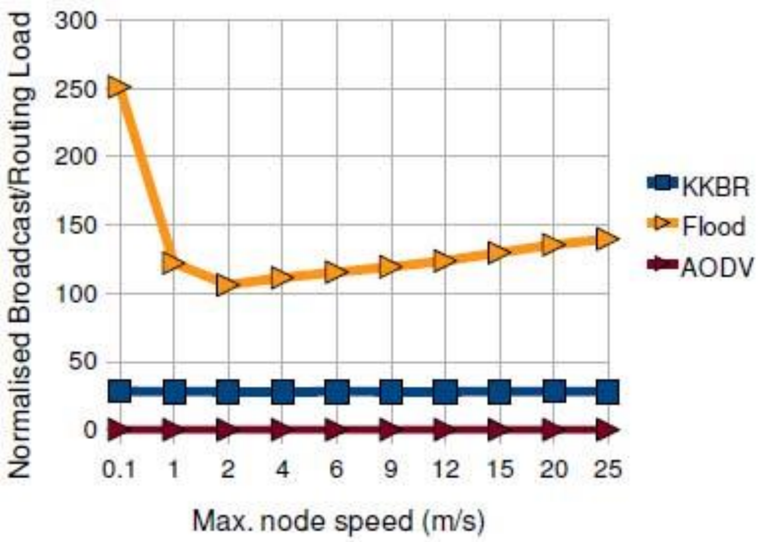


Fig. 13. Plot of normalized broadcast / routing load against maximum node speed for an area of 700mx500m.

KBBR seems nearly unaffected by increasing node speeds, particularly in terms of average end-to end delay. This is due to the fact that KBBR does not do any extra work if nodes move faster, i.e. it does not maintain routing tables or establish routes between nodes which are more likely to be broken with increasing node speed. KBBR nodes simply broadcast packets if they belong to the same group, and as long as there are nodes of the same group between the source and destination the packets will be received successfully.

AODV exhibits the highest PDF, and lowest delay and routing load throughout, although its average delay seems to fluctuate slightly as the node speed is increased.

The results above seem to indicate that although nodes move around at increasing speeds, very few connections are broken because the area is small enough (or the node transmission range is large enough) to maintain connectivity even as the nodes move around. To test whether this is the case, the experiment is repeated with a larger area, 1000mx700m. The area is intentionally rectangular to force the formation of longer multi-hop routes through the network. The PDF, average end-to-end delay and normalized broadcast/routing load for all three protocols are shown in Figs. 14, 15 and 16 respectively.

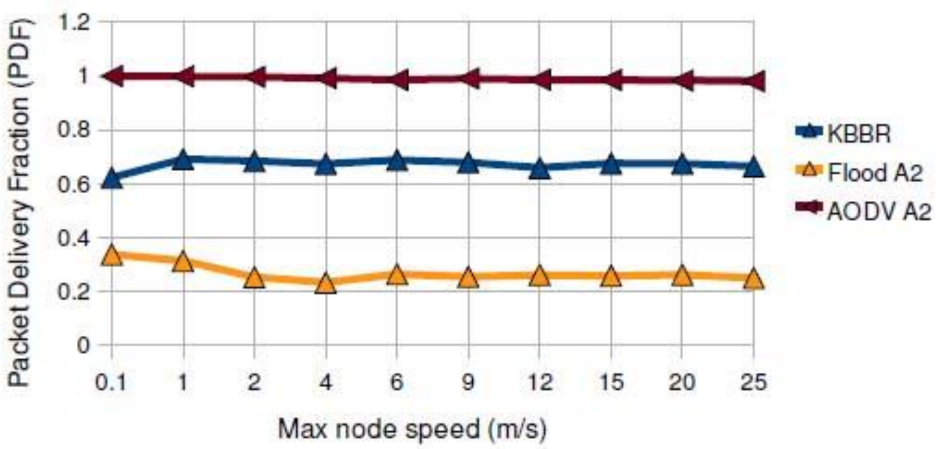


Fig. 14. Plot of PDF against maximum node speed with a larger area.

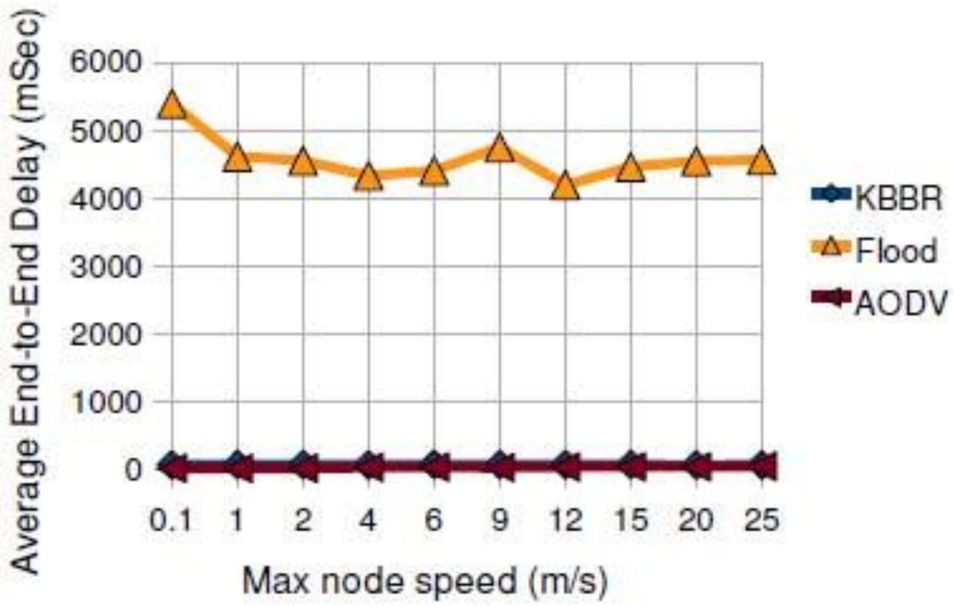


Fig. 15. Plot of average end-to-end delay against maximum node speed for KBBR (4 groups), Flood and AODV as the area is increased.

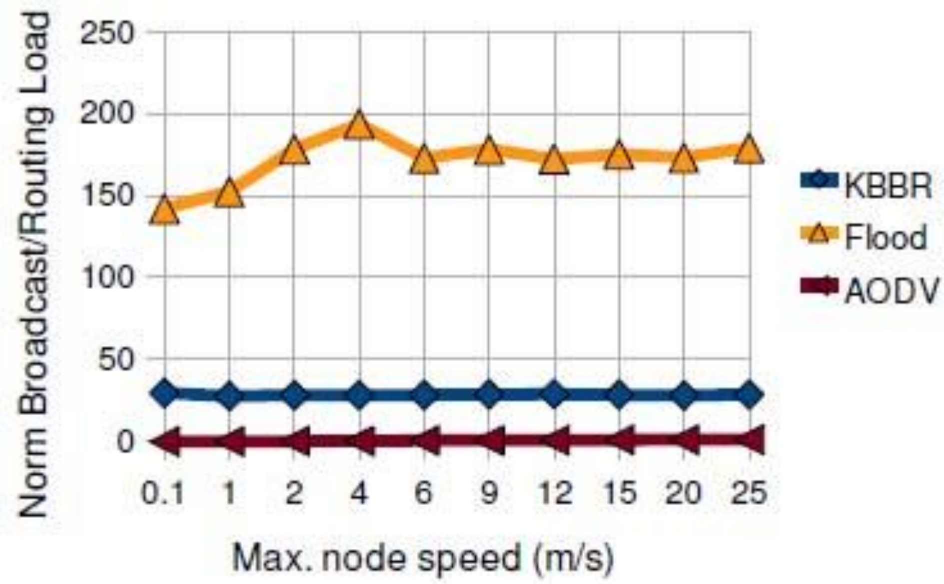


Fig. 16. Plot of the normalized broadcast load for Flood and KBBR, and normalized routing load for AODV against maximum node speed as the area is increased.

In the Flood network, all three performance metrics fluctuate less than they did for the smaller network, which indicates that the significant fluctuations exhibited in the previous experiments are more likely to be due to the network size being too small and resulting in congestion. Except for the lowest speed, PDF drops as the network size is increased. Average end-to-end delay increases significantly at most speeds, but seems to decrease slightly with increasing node speeds. Again, except for the least speed, normalized broadcast load increases as a result of the increased network size. The reduced PDF, increased average end-to-end delay that result from using a larger network may indicate that the degrading performance is a result of nodes getting out of range. But considering the increasing broadcast load indicates that this is not the case, because with fewer nodes in the vicinity less packets are broadcast. So rather than being a result of a too-sparse network, the degraded performance is most likely a result of the higher broadcast load, which leads to congestion, increasing delay and reducing the PDF.

In the KBBR network, the increasing network area results in a slightly lower PDF, which is lowest at the slowest speed where nodes which move out of range are likely to remain so for longer. However, KBBR manages to maintain a consistent PDF with varying node speed. Meanwhile, the average end-to-end delay is reduced when the network size is increased, although it fluctuates slightly more as node speed increases, although there is no particular trend (i.e. the delay does not increase or decrease with increasing node speed). Again, this fluctuation may smooth out with more simulation runs. Normalized broadcast load does not seem significantly affected by increasing the network area. This indicates that although less packets are delivered, they are delivered quicker and at nearly the same broadcast load.

In the AODV network, nearly all packets are delivered at all speeds. But the PDF shows signs of very slight decrease at higher speeds. The effect of the larger network area is clearer on average end-to-end delay, which remains the lowest, but clearly increases with increasing speed. This is a result of an increasing route discovery delay at the beginning of data transmissions. With nodes moving at higher speeds, source nodes may first start transmitting based on outdated entries in their routing tables, then receive route errors, then attempt to find new routes. The same effect appears in the normalized routing load, which increases from 0.04 when maximum node speed is 0.1m/s to 1.2 when maximum node speed reaches 25m/s. Although this is much lower than the broadcast load of KBBR and Flood, the increase reflects the effect of nodes losing connectivity as nodes move faster. The dip in average end-to-end delay at 9m/s is not readily explained by the results. However, the results of the 10 simulation runs seem to vary significantly, from a minimum of 9.8 mSec to a maximum of 40.14 mSec. This could be due to variations in performance as a result of differing scenarios, in which case they would be smoothed-out by repeating the simulation for more runs which was not possible due to time constraints.

Using the larger network, 1000mx700m, helps illustrate the real effect of nodes losing connectivity as they move around the network. Further experimentation can be carried out to further investigate this point.

The networks used in this research were designed to be similar to wireless sensor networks, with small packet sizes and low data loads (maximum of 19 nodes transmitting simultaneously in a network consisting of 60 nodes). However, the constant bit rate traffic model used, where transmitting nodes start transmission at a random time between 0 and 90 seconds and continue to transmit at a constant bit rate until the end of the simulation, is not commonly used in wireless sensor networks. Instead, sensors usually remain in sleep mode until they are required to take a reading or gather some information, which they transmit and switch off or return to sleep mode to conserve energy. This means that in wireless sensor applications network load may be even lower than that considered here. This issue may be addressed in further work by modifying the CBR generation file of NS2.

Since energy consumption is a crucial issue in wireless sensor networks, it would also be useful to investigate the performance of KBBR in different situations in terms of energy consumption. Further experimentation can also investigate the effect of varying the network diameter used, which determines the Time to Live (TTL) field of the IP header and consequently, the maximum number of times a packet can be re-broadcast.

Finally, this research did not study the performance of KBBR in multicasting applications, where it is expected to be more efficient since the broadcast load will be shared among several destination nodes.

CONCLUSIONS

The Key Based Broadcast Routing (KBBR) protocol is a simple and secure routing protocol designed for wireless sensor networks. It is based on dividing the nodes into groups, and ensuring that only nodes of the same group re-broadcast each other's packets whose payload is encrypted for added security. Only the authorized nodes would have the decryption key necessary to decrypt the encrypted packet payload. Despite its simplicity, KBBR aims to make efficient use of broadcasting by limiting the number of broadcast packets, as well as providing security functions.

REFERENCES

1. IETF Mobile Ad-hoc Networks (MANET) Working Group, http://www.ietf.org/html.charters/manet-charter.html (2011).
2. Perkins, C.E. *Ad hoc Networking*, Addison-Wesley (2001).
3. Murthy, C.S. & B.S. Manoj, *Ad hoc Wireless Networks Architectures and Protocols*. Prentice Hall, NJ, USA (2004).
4. Boukerche. *Algorithms and Protocols for Wireless and Mobile Ad Hoc Networks*. John Wiley & Sons, Hoboken, New Jersey (2009).
5. Spaho, L. Barolli, G. Mino, F. Xhafa, V. Kolici & R. Miho. Implementation of CAVENET and its usage for performance evaluation of AODV, OLSR and DYMO protocols in vehicular networks. *Mobile Information Systems*, 6(3): 213–237 (2010).
6. Kulla, M. Hiyama, M. Ikeda, L. Barolli, V. Kolici & R. Miho. MANET performance for source and destination moving scenarios considering OLSR and AODV protocols. *Mobile Information Systems*, 6(4): 325–339 (2010).
7. Perkins, C.E., E.M. Royer & S. Das, Adhoc On-demand Distance Vector (AODV) Routing. *RFC 3561* (2003).
8. Jamieson, A.G. A novel systems design approach to wireless sensor networks for industrial applications. *PhD. thesis*, Department of Electrical & Electronic Engineering, University of Strathclyde, Glasgow (2008).
9. Network Simulator (NS2), http://www.isi.edu/nsnam/ns/ (2009).
10. Zafar, H., D. Harle, I. Andonovic & Y. Khawaja. Performance evaluation of shortest multipath source routing scheme. *IET Communications*, 3(5), 700–713 (2009).

Proceedings of the Pakistan Academy of Sciences, 48 (4): 221-232 (2011)

ISSN: 0377 - 2969

Pakistan Academy of Sciences

Original Article

Morpho-anatomical Studies on Two Peculiar Brown Algae from Karachi Coast of Pakistan

Alia Abbas[1*] and Mustafa Shameel[2]

[1]Department of Botany, Federal Urdu University of Arts, Science and Technology, Gulshan-e-Iqbal, Karachi-75300
[2]Department of Botany, University of Karachi, Karachi -75270, Pakistan

Abstract: Two dictyolean brown algae, *Padina antillarum* (Kützing) Piccone and *Stoechospermum ploypodioides* (J. V. Lamouroux) J. G. Agardh, were collected from Manora, Hawksbay and Buleji, the coastal areas near Karachi during March 2007-May 2010 and investigated for their morphology, anatomy and reproductive structures. This is the first detailed study of these species from the coast of Pakistan. The present specimens were investigated in detail for the measurement, size and shape of surface cells, presence and absence of intercellular spaces, cell-wall thickness *etc*.

Keywords: Marine algae, Phaeophycota, Dictyotales, *Padina*, *Stoechospermum*, morphology, anatomy, reproduction

INTRODUCTION

Although the occurrence of the algal genera, *Padina* Adanson and *Stoechospermum* Kützing were first reported from the coast of Karachi Pakistan very early [1], but only a few studies were made on the taxonomy of their various species [2-4]. Only recently attention has been paid on this aspect, and a taxonomic survey of their species growing in the coastal waters of Karachi was carried out [5-8]. In this connection two peculiar species were collected, which were not described earlier. They have now been investigated in detail for their morphology and anatomy.

MATERIALS AND METHODS

The specimens were collected from Manora, Hawksbay and Buleji, the coastal areas of Karachi (Pakistan) during March 2007 and May 2010, and preserved in 4 % formaldehyde-seawater solution. In order to study internal structures, cross sections (C.S.) were obtained by freehand cutting with shaving blades, which were stained with aniline blue and mounted in glycerine. The semi-permanent slides were sealed with nail polish and examined under microscope (Nikon PFX, Japan). The photographs were taken by Nikon F 601 camera and developed in a photolab with *hp* scanner. The photographic plates were prepared in Adop Photoshop 7.0 with the help of a computer. The herbarium sheets of the materials are deposited in the herbarium (FUU-SWH), Department of Botany, Federal Urdu University of Arts, Science & Technology, Karachi, Pakistan.

RESULTS

The general observation and microscopic examination of the collected specimens indicated following characters of the two investigated species.

1. *Padina antillarum* Kützing Piccone 1886: 36

Basionym

Zonaria antillarum Kützing 1859: 29.

Received October 2011, Accepted December 2011
*Corresponding author: Alia Abbas; Email: abbasalia@yahoo.com

Synonym

Padina tetrastromatica Hauck 1887: 43.

References

Børgesen 1935: 35, 1939: 80, Anand 1940: 5, Durairatnam 1961: 36, Salim 1965: 195, Misra 1966: 158, 1967: 233, Krishnamurthy & Joshi 1970: 11, Saifullah 1973: 140, Islam 1976: 41, Jaasund 1976: 45, Shameel & Afaq-Husain 1987: 295, Silva *et al*. 1987: 79, 1996: 601, Begum & Khatoon 1988: 298, Shameel *et al*. 1989: 179, 2000: 84, Shameel & Tanaka 1992: 39, Ormond & Banaimoon 1994: 117, Shaikh & Shameel 1995: 22, Shameel 2000: 51, Nizamuddin & Begum 2006: 231, Begum 2010: 242, Aisha & Shameel 2010: 330 [3, 4, 6, 7, 9-27].

Morphological characters

Thalli olive green or dark green in colour, dichotomously or irregulary branched; margins smooth or slightly undulate, apex enrolled, surface smooth; sporangia present in double sporangial lines, sporangial lines and hair lines alternate to each other; attached with the help of a small, compact, holdfast, 0.5 – 1.5 cm broad and 0.7 – 2.0 cm long; thallus dived into many lobes, upto ¾ part of the thallus, many clefts present on the thallus; thalli 7 – 15 cm long, 7 – 12 cm broad at the apex, 10 – 12 cm broad at the middle and 7.5 – 10.0 cm broad at the base (Fig. 1).

Anatomical features

In surface view: thalli dark brown, peripheral cells cubical or rectangular, 7.5 – 20.0 µm in length and 7.5 – 15.0 µm in breadth; double sporangial lines present at specific intervals (Fig. 2), sporangial lines alternate with the hair lines (Fig. 3).

In the apical portion: thallus consists of 2 – 3 layers *i.e.* upper and lower peripheral layers and one layered cortex; peripheral cells cubical or squarish, thin walled, cell size more or less equal, with dense phaeoplasts, 17.5 – 25.0 µm in length and 20 – 25 µm in breadth (Fig. 4); cortical cells large, rectangular or slightly cubical, thin walled, poor in contents, intercellular spaces absent, 25.0 – 32.5 µm long and 12.5 – 25.0 µm broad (Fig. 5).

In the middle part: thallus consists of 3 – 4 layers; upper and lower peripheral layers composed of cubical or quadratic, thin walled cells, with dense phaeoplasts, peripheral and cortical cells more or less equal in size, 17.5 – 27.5 µm in length and 17.5 – 22.5 µm in breadth; two layered cortex composed of cubical or squarish, thin walled cells, inter-cellular spaces absent, poor in contents, 15 – 25 µm long and 12.5 – 15.0 µm broad (Fig. 6).

In the basal portion: thallus composed of 4 (-5) layers; upper and lower peripheral layers consist of cubical, thin walled cells, with dense phaeoplasts, 12.5 – 25.9 µm in length and 10.0 – 22.5 µm in breadth; 2 (-3) layered cortex consists of squarish or cubical cells (Fig. 7), inter-cellular spaces absent, poor in contents, 12.5 – 25.0 µm long and 10.0 – 27.5 µm broad, cells thick walled (Fig. 8).

Reproductive structures

Sporangia non-indusiate, dark brown or reddish brown, stalked, arise from peripheral cells, 20 – 60 µm in length and 15 – 35 µm in breadth (Fig. 9); tetrasporangia found in sori, sporangial lines present on both surfaces of the thallus (Fig. 10).

Type locality

Locality not specified: (*Padina tetrastromatica* = Meith (Maydh), Somalia*)*.

Habitat

Collected as drift material or benthic in shallow sandy pools at Manora (*Leg*. Alia Abbas 6-4-2009); Goth Haji Ali, Buleji (*Leg*. Alia Abbas 17-3-2007, 18-3-2008, 24-1- & 31-3-2009).

Local distribution

Karachi: Manora, Hawksbay, Buleji and Paradise Point; Balochistan: Sonmiani, Sur Bunder and Gawader.

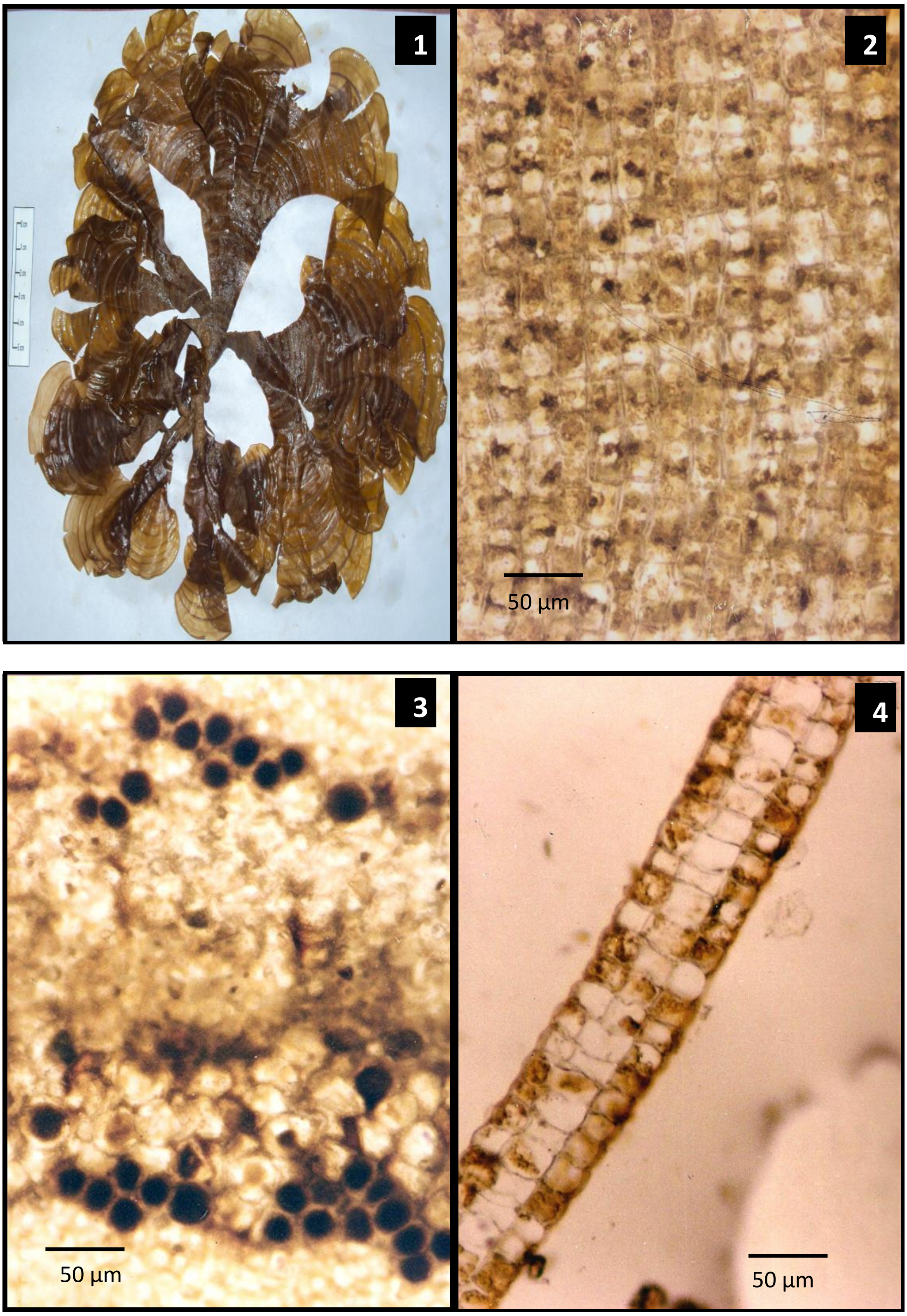


Fig. 1-4. *Padina antillarum*: **1.** Habit of the thallus, **2.** Surface view of thallus, **3.** Sporangial lines on the surface, **4.** C.S. of apical portion of thallus.

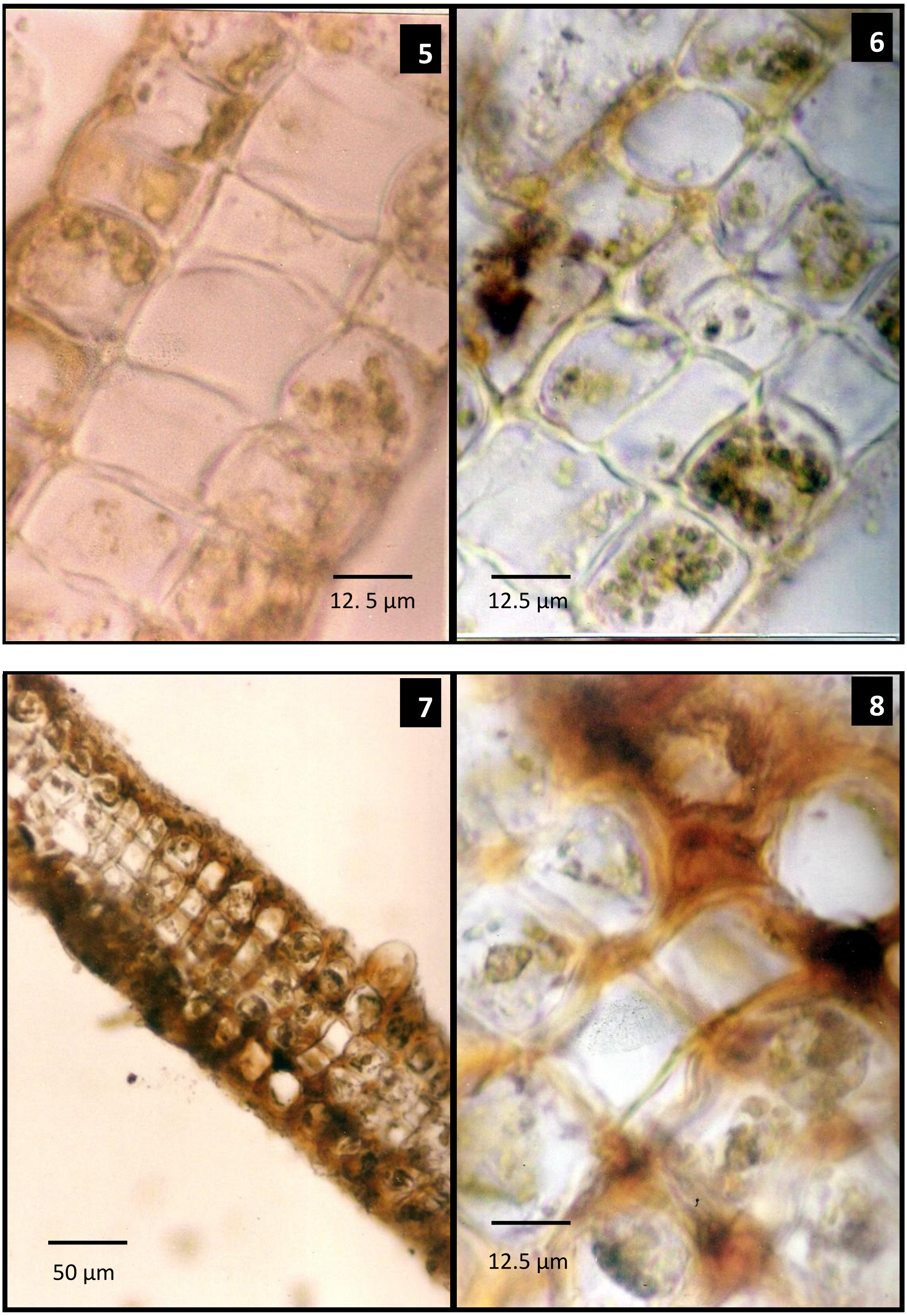


Fig. 5-8. *Padina antillarum*: **5.** Enlarged view of apical portion, **6.** C.S. of middle part of thallus, **7.** C.S. of basal portion, **8.** Thick walls present in the basal part.

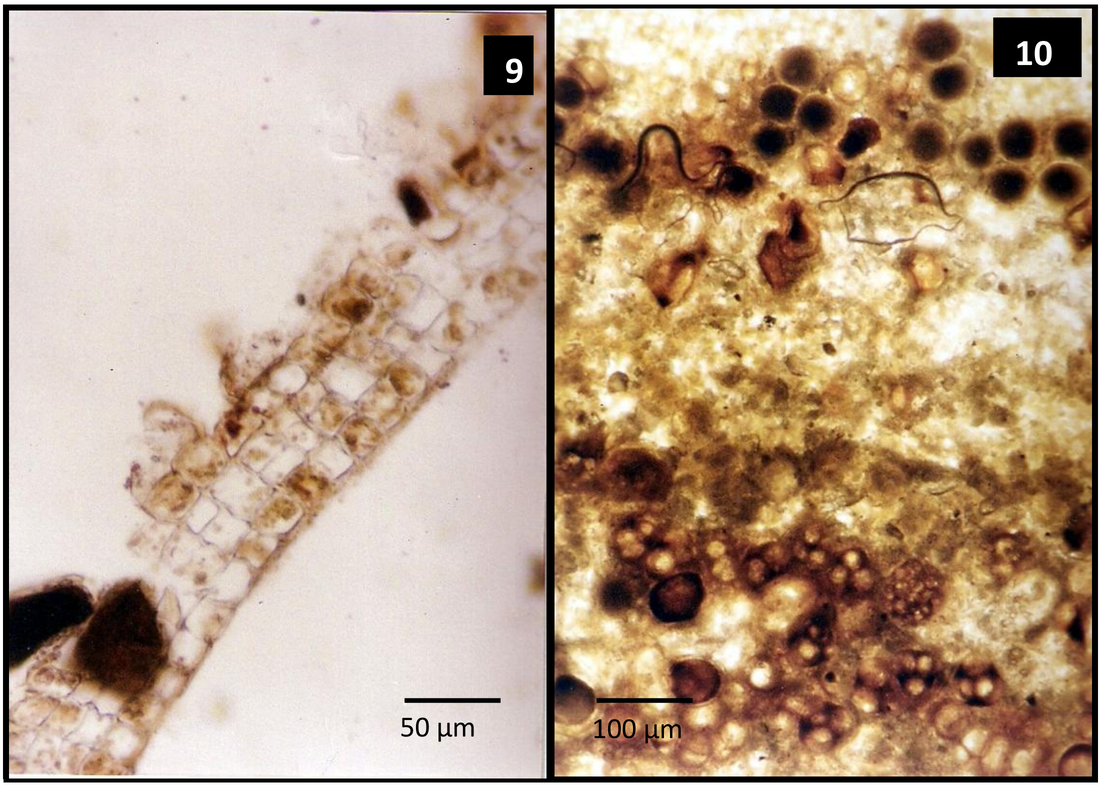


Fig. 9-10. *Padina antillarum*: **9.** Sporangia arising from peripheral cells, 1**0.** Tetrasporangia in sori.

Distribution in the Indian Ocean

Andaman Islands, Diego Garcia Atoll, India, Indonesia, Iran, Kenya, Kuwait, Laccadive Islands, Malaysia, Nicobar Islands, Pakistan, Seychells, Singapore, Somalia, South Africa, Sri Lanka, Tanzania and Yemen.

2. *Stoechospermum polypodioides* (J. V. Lamouroux) J. G. Agardh 1848: 100

Basionym

Dictyota polypodioides G. V. Lamouroux 1809: 44.

Synonyms

Zonaria polypodioides (Lamour.) C. A. Agardh 1820: 136, *Zonaria marginata* C. A. Agardh 1824: 266, *Dictyota marginata* (C. A. Agardh) Greville 1830: x1iii, *Dictyota maculata* J. G. Agardh 1841:446, *Stoechospermum marginatum* (C. A. Agardh) Kützing 1843: 339, *Stoechospermum maculatum* (J. Agardh) J. G. Agardh 1848:99, *Stoechospermum patens* Hering *ex* J. G. Agardh 1848: 99.

References

Børgesen 1934: 28, Durairatnam 1961: 33, Misra 1966: 161, 1967: 233, Krishnamurthy & Joshi 1970: 11, Jaasund 1976: 45, Nizamuddin & Perveen 1986: 124, Shameel 1987: 513, 2000: 52, Shameel & Afaq-Husain 1987: 295, Begum & Khatoon 1988: 299, Shameel *et al.*1989: 179, 1996: 227, 2000: 85, Shameel & Tanaka 1992: 39, Ormond & Banaimoon 1994: 117, Shaikh & Shameel 1995: 25, Silva *et al.* 1996: 610, De Clerck & Coppejans 1997: 338, Abbas & Shameel 2008: 2567, Begum 2010: 272 [1-6,11-15, 18-26, 28-31].

Morphological characters

Thalli greenish brown in colour, erect, tufted, linear, ligulate; 5 - 26 cm in height, attached with rhizoids emerging from holdfast up to 1 cm broad (Fig. 11); fronds flat, 0.3 – 1.5 cm broad at the apex, 1 – 2 cm broad at the middle and 2 – 5 mm broad at the base; dichotomously branched, dichotomy at 2.0 – 6.5 cm apart, attenuated, cuniate below; lateral margins of branches entire, apical margins involute, surface smooth; growth of thalli by means of marginal meristem; sporangial sori arranged in longitudinal rows along the margins; distance of sori from margins 1 – 2 mm, sori 1 – 3 mm broad (Fig. 12).

Anatomical features

In surface view: surface cells small and quadratic, polygonal, dark brown, thin walled; group of cells arranged in different manners, 7.0-22.5 µm in length and 5-20 µm in breadth (Fig. 13).

In the apical portion: thallus consists of 6 – 7 layers including upper and lower peripheral layers; peripheral cells are small, quadratic with dense phaeoplasts, enclosing 4 – 5 layered cortical cells. Cortical cells are more or less isodiametric and equal in size, poor in contents, thin walled, 12.5 – 47.5 µm long and 10.5 – 40.5 µm broad (Fig. 14).

In the middle part: thallus consists of 11 – 12 layers, cells of peripheral layers are small, rectangular, compact, have no intercellular space with dense phaeoplasts, 12.5 – 25.0 µm in length and 12.5 – 25.0 µm in breadth; the 9 – 10 layered cortical cells are present at the central portion of the thallus; in the central region of cortical cells 9 - 10 layers are large, polygonal or rectangular with intercellular spaces, poor in contents, 75.0 – 87.5 µm long and 25.0 – 42.5 µm broad (Fig. 15). Number of layers gradually decreases from centre to margins; only 3 layered cortex is present at the dichotomy, the cortical cells present at the dichotomy are divided into two portions: central portion with large, elongated cells, 150 – 200 µm in length and 67.5 – 100 µm in breadth, and on either side of central cells are narrow, elongated cells, 75 – 130 µm long and 25 – 62 µm broad (Fig. 16).

In the basal portion: 10 – 12 layers are present including single layered peripheral cells, which are small, slightly elongated or quadratic, with dense phaeoplasts, 15 – 25 µm in length and 10.0 – 17.5 µm in breadth (Fig. 17); they enclose 8 – 10 layered cortical cells, which are polygonal, large, parenchymatous, poor in contents, 25 – 125 µm long and 25 – 75 µm broad, thick walled (Fig. 18); cell-wall thickness is 7.5 – 17.5 µm (Fig. 19).

Reproductive structures

Thalli monoecious, reproductive bodies occurring in the form of marginal sori; antheridia cylindrical, dark brown, 17.5 – 12.0 µm in length and 12.5 – 37.5 µm in breadth (Fig. 20); oogonia club-shaped, dark brown, 25 – 75 µm long and 12.5 – 30.0 µm broad, associated with hairs; hairs distributed among oogonia, 75.0 – 137.5 µm in length and 12.5 – 50.0 µm in breadth, tips of hairs in 3 – 4 different shapes: swollen, curved and bifurcated (Fig. 21); tetrasporangia dark brown, globular, stalked, large, 22.5 – 37.5 µm long and 17.5 – 30.0 µm broad; hairs also distributed among tetrasporangia (Fig. 22).

Type locality

Locality unknown: (*Zonaria marginata*= “Ex coll. Forskåhleana”, Red Sea).

Habitat

Collected as drift material from the sandy beach at Manora (*Leg.* Alia Abbas 6-4-2009); Hawksbay (*Leg.* Alia Abbas 14-4-2010); Goth Haji Ali, Buleji (*Leg.* Alia Abbas 17-3-2007, 15-3- & 24-7-2008, 31-3-2009, 12-2-, 24-3-, 22-4- & 19-5-2010).

Local distribution

Karachi: Manora, Hawksbay, Buleji, Paradise Point, Cape Monze, Goth Mubarak, Goth Manjar; Balochistan: Gadani, Sonmiani, Miani Hor, Ras Malan, Sur Bunder, Gawadar and Jiwani.

Distribution in the Indian Ocean

Australia, Egypt, Eritrea, Ethiopia, India, Indonesia, Iran, Kenya, Madagascar, Mauritius, Mozambique, Oman, Pakistan, Red Sea, Somalia, South Africa, South-East Arabian Coast, Sri Lanka, Tanzania and Yemen.

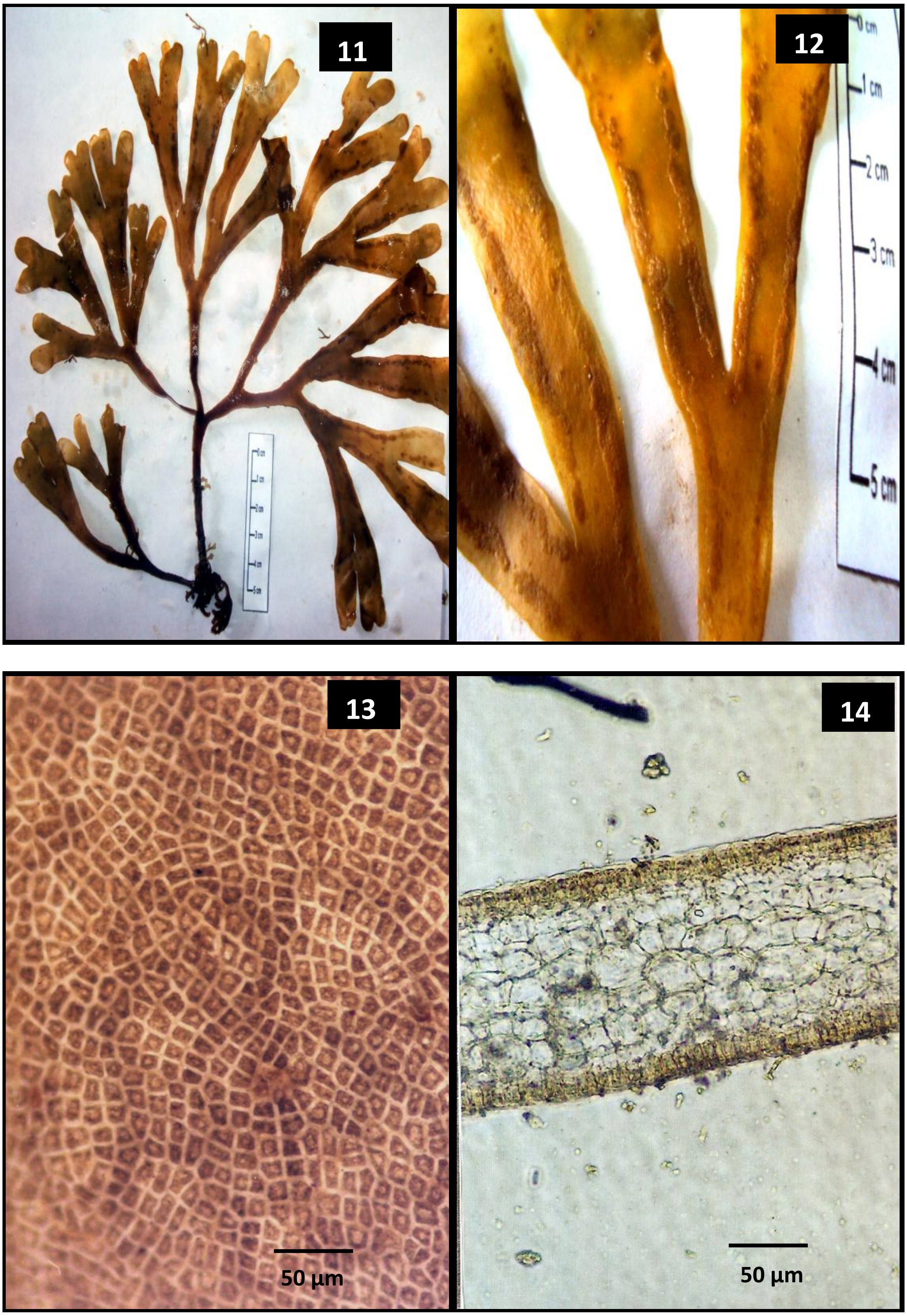


Fig. 11-14. *Stoechospermum polypodioides*: **11.** Habit of the thallus, **12.** Thallus with sporangial sori, **13.** Surface view of thallus, **14.** C.S. of apical portion.

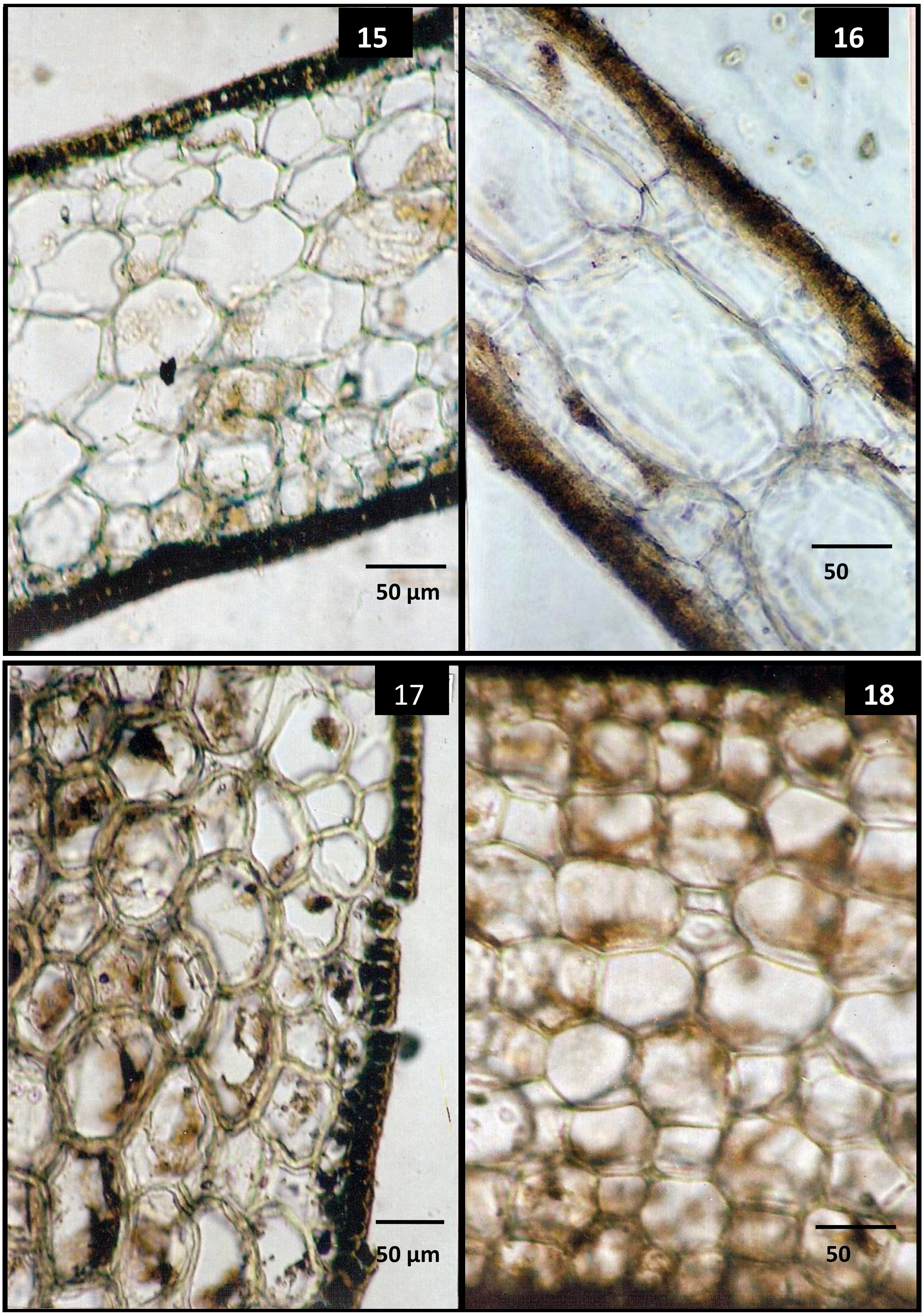


Fig. 15-18. *Stoechospermum polypodioides*: **15.** C.S. of middle part of the thallus, **16.** C.S. at 3-layered dichotomy, **17.** C.S. of basal portion showing peripheral cells, **18.** 12-layered thallus at the basal part.

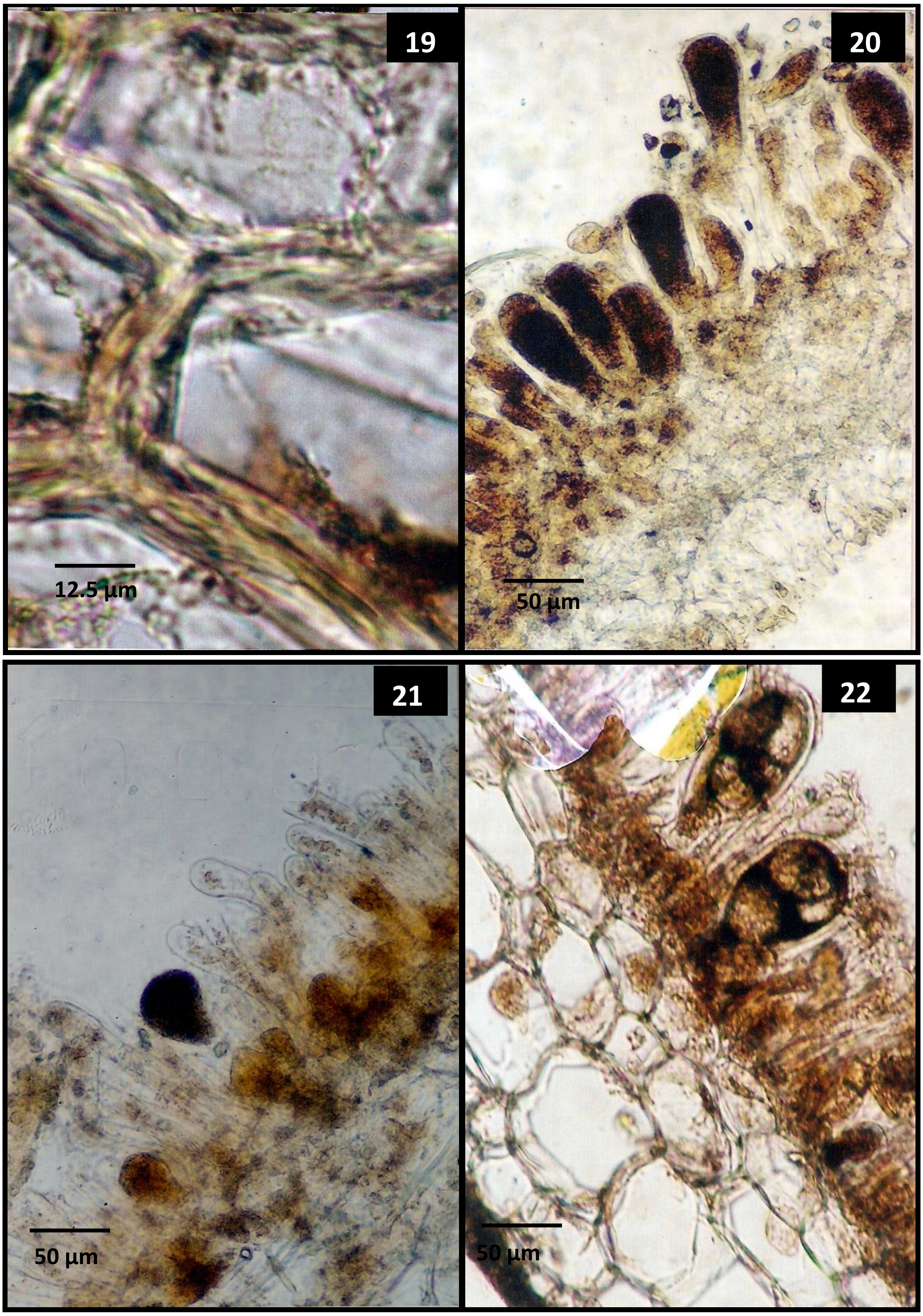


Fig. 19-22. *Stoechospermum polypodioides*: **19.** Cell-wall thickness at basal portion of thallus, **20.** C.S. of thallus showing antheridia, **21.** Oogonia associated with Hairs **22.** Tetrasporangia associated with hairs.

DISCUSSION

Padina antillarum and *Stoechospermum polypodioides* are marine algae of the family Dictyotaceae (order Dictyotales, class Dictyophyceae, phylum Phaeophycota [32]. The population of *P. antillarum* growing at the coast of Pakistan was initially considered as *P. tetrastromatica* [3, 4, 9]. The present specimens were investigated in detail for the measurement, size and shape of surface cells, presence and absence of intercellular spaces in the peripheral and cortical cells, cell-wall thickness *etc*. All these characters were not described by the previous workers [4, 27]. Wynne argued that *P. tetrastromatica* is a synonym of the earlier *P. antillarum* [33]. It was observed in the recent studies [6, 7] that the Karachi specimens are quite different from Wynne's illustrations, therefore these workers considered the specimens as *P. tetrastromatica*. But our material showed a resemblance, therefore the present specimens have been treated as *P. antillarum.* Prof. Dr. Gerald T. Kraft agreed with this treatment (pers. comm.). However, molecular analysis using *rbcL* and mitochondrial *COX*3 genes as molecular markers may confirm the identification of this species, as has recently been carried out on several species of *Padina* from Japan [34, 35].

Stoechospermum Kützing is now a monospecific genus, which was based on the type species *S. marginatum* (C. Agardh) Kützing. Gradually its four more species were reported: *S. maculatum* J. Agardh, *S. patens* Hering *ex* J. Agardh, *S. polypodioides* (Lamouroux) J. Agardh and *S. suhrii* Kützing. But *S. suhrii* was transferred to the genus *Dictyota* [36], *S. maculatum* and *S. patens* were reduced to synonyms of *S. marginatum* [37]. Recently, the examination of type specimen of *S. polypodioides* revealed it to be conspecific with *S. marginatum*, and the anteriority of *Dictyota polypodioides* Lamouroux on *Zonaria marginata* C. Agardh (the basionyms of the two mentioned species) resulted in *S. marginatum* to be a synonym of *S. polypodioides* [31].

This is the first study made on the specimens of *S. polypodioides* growing in the coastal waters of Pakistan. All the reports and investigations carried out in the past on Pakistani specimens of *S. marginatum* [*e.g.* 2-30, 38] should now be considered as about *S. polypodioides*. Absence of hairs in the sporangial sori were reported in the specimens of *S. marginatum* from Sri Lanka [11], whereas occurrence of hairs was described only in the oogonial sori in the Indian specimens [13]. In the specimens of *S. polypodioides* from Pakistan the hairs are present among oogonia and tetrasporangia both. Our specimens are characterised by the presence of hairs of 3 – 4 different shapes in the reproductive organs, 9–10 layered and very thick-walled cortical region in the basal portion of the thallus and a 3-layered cortex of very large central cells at dichotomy. These characters were not observed previously [2 & 4].

Previously the peripheral cells were measured in *S. marginatum* as 5 – 18 µm long and 8 – 12 µm broad, cortical cells as 28 – 188 µm in length (breadth was not mentioned) and sporangia as 65 – 115 µm long and 15 – 60 µm broad [2]. But in our specimens peripheral cells were observed as 15 – 25 µm in length and 10.0 – 17.5 µm in breadth, cortical cells as 25 – 200 µm long and 25 – 75 µm broad and sporangia as 22.5 – 37.5 in length and 17.5 – 30.0 µm in breadth. Rows of sori were not measured previously but peripheral cells were reported in *S. marginatum* as 13 – 17 µm in length and 10 – 14 µm in breadth, and cortical cells as 68 – 102 µm in diameter in cross section [4]. Our specimens differed from both these previous studies. The thalli of *S. polypodioides* growing on a shallow reef flat in the southern Red Sea (Eritrea) were found to exhibit highly seasonal pattern of growth and reproduction related to the seasonal variation in the environment, especially temperature [39].

REFERENCES

1. Børgesen, F. Some marine algae from the northern part of the Arabian Sea with remarks on their geographical distribution. *Kongelige Danske Videnskabernes Selskab, Biologiske Meddelelser*, 11 (6): 1 –72 (1934).
2. Nizamuddin, M. & S. Perveen. Taxonomic studies on some members of Dictyotales (Phaeophyta) from the coast of Pakistan. *Pakistan Journal of Botany*, 18: 123– 135 (1986).
3. Begum, M. & N. Khatoon. Distibution of and some ecological notes on Phaeophyta from the coast of

Karachi. *Pakistan Journal of Botany*, 20: 291-304 (1988).

4. Shaikh, W. & M. Shameel. Taxonomic study of brown algae commonly growing on the coast of Karachi, Pakistan. *Pakistan Journal of Marine Science*, 4: 9- 38 (1995).
5. Abbas, A. & M. Shameel. Anatomical studies on *Stoechospermum marginatum* (Phaeophycota) from the coast of Pakistan. *Pakistan Journal of Botany*, 40: 2567-2572 (2008).
6. Begum, A. Taxonomic study of Phaeophycota from Karachi coast. *Karachi University Seaweed Biology & Phycochemistry Thesis*, 12: 1-375 **(**2010).
7. Aisha, K. & M. Shameel. Occurrence of the genus *Padina* (Dictyophyceae, Phaeophycota) in the coastal waters of Karachi. *Pakistan Journal of Botany*, Sp. Issue (S.I. Ali Festschrift), 42: 319-340 (2010).
8. Abbas, A. & M. Shameel. Occurrence of *Padina gymnospora* (Phaeophycota) at the coast of Karachi. *Pakistan Journal of Botany*, 43: in press (2011).
9. Anand, P. L. *Marine Algae from Karachi:* I. *Chlorophyceae*. University of Punjab, Lahore (1940).
10. Børgesen, F. A list of marine algae from Bombay. *Kongelige Danske Videnskabernes Selskab, Biologiske Meddelelser*, 12 (2): 1-64 (1935).
11. Duraitranam, M. Contribution to the study of the marine algae of Ceylon. *Fisheries Research Station of Ceylon Bulletin*, 10: 1-181 (1961).
12. Salim, K. M. The distribution of marine algae along Karachi coast. *Botanica Marina*, 8: 183-198 (1965).
13. Misra, J. N. *Phaeophyceae in India.* Indian Council of Agricultural Research, New Delhi (1966).
14. Misra, J. N. The Phaeophyceae of the west coast of India. In: *Proceedings of the Seminar on Sea, Salt and Plants.* Krishnamurthy, V. (Ed.), Bhavnagar, India, p. 227-233 (1967).
15. Krishnamurthy, V. & H. V. Joshi. *A Check-List of Indian Marine Algae.* Central Salt & Marine Chemical Research Institute, Bhavnagar (1970).
16. Saifullah, S. M. A preliminary survey of standing crop of seaweeds from Karachi coast. *Botanica Marina*, 16: 139 – 144 (1973).
17. Islam, A. K. M. N. Contribution to the study of the marine algae of Bangladesh. *Bibliotheca Phycolgica*, 19, 1-253 (1976).
18. Jaasund, E. *Intertidal Seaweeds in Tanzania*. Tromsø University, Norway (1976).
19. Shameel, M. & S. Afaq-Husain. Survey of algal flora from Lasbela coast. In: *Modern Trends of Plant Science Research in Pakistan.* Ilahi, I. & F. Hussain (Eds.), University of Peshawar, p. 292-299 (1987).
20. Silva, P. C., E. G. Meñez & R. L. Moe. *Catalogue of the Benthic Marine Algae of the Philippines.* Smithsonian Institute Press, Washington D. C. (1987).
21. Silva, P. C., P. W. Basson & R. L. Moe. *Catalogue of the Benthic Marine Algae of the Indian Ocean.* University of California Press, Berkeley (1996).
22. Shameel, M., S. Afaq-Husain & S. Shahid-Husain. Addition to the knowledge of seaweeds from the coast of Lasbela, Pakistan. *Botanica Marina*, 32:177-180 (1989).
23. Shameel, M., S. H. Khan & S. Afaq-Husain. Biodiversity of marine benthic algae along the coast of Balochistan, Pakistan. *Pakistan Journal of Marine Biology*, 6: 69-100 (2000).
24. Shameel, M. & J. Tanaka. A preliminary check-list of marine algae from the coast and inshore waters of Pakistan. In: *Cryptogamic Flora of Pakistan.* Vol.1. Nakaike, T. & S. Malik (Eds.), National Science Museum, Tokyo, p. 1-64 (1992).
25. Ormond, R. F. G. & S. A. Banaimoon. Ecology of intertidal macroalgal assemblages on the Hadramout coast of southern Yemen, an area of seasonal upwelling. *Marine Ecology Progress Series*, 105: 105 – 120 (1994).
26. Shameel, M. Biodiversity of the seaweeds growing along Balochistan coast of the northern Arabian Sea. In: *Proceedings of National O.N.R. Symposium in Arabian Sea as a Resource of Biological Diversity.* Ahmad, V. U. (Ed.), H. E. J. Research Institute of Chemistry, University of Karachi, p. 45-64 (2000).
27. Nizamuddin, M. & M. Begum. Studies on the genus *Padina* Adanson 1763. *International Journal of Biolology & Biotechnology*, 3: 215 – 236 (2006).
28. Shameel, M. A preliminary survey of seaweeds from the coast of Lasbela, Pakistan. *Botanica Marina*, 30: 511-515 (1987).
29. Shameel, M. & S. Afaq-Husain. Survey of algal flora from Lasbela coast. In: *Modern Trends of Plant Science Research in Pakistan.* Ilahi, I. & F. Hussain (Eds.), University of Peshawar, p. 292-299 (1987).
30. Shameel, M., K. Aisha & S. H. Khan. A preliminary survey of seaweeds from the coast of Makran, Pakistan. *Botanica Marina*, 39: 223-230 (1996).
31. De Clerck, O. & E. Coppejans. Note on *Stoechospermum* Kütz. (Dictyotales-Phaeopyta). *Cryptogamie: Algologie*, 18: 337-347 (1997).
32. Shameel, M. Change of divisional nomenclature in the Shameelian classification of algae. *International Journal of Phycology & Phycochemistry*, 4: 225 – 232 **(**2008).
33. Wynne, M. J. A study of *Padina antillarum* (Kützing) Piccone and a comparison with *P. tetrastromatica* Hauck (Dictyotales, Phaeophyta), *Cryptogamie: Algologie*, 1998: 271-298 (1998).
34. Ni-Ni- Win, T. Hanyuda, S. Arai, M. Uchimura, I. A. Abbott & H. Kawai. Three new records of *Padina* in Japan based on morphological and

molecular markers. *Phycological Research*, 56: 288-300 (2008).

35. Ni-Ni- Win, T. Hanyuda, S. Arai, M. Uchimura, A. Prathep, S. G. A. Draisma, Soe-Htun & H. Kawai. Four new species of *Padina* (Dictyotales, Phaeophyceae) from the western Pacific Ocean and reinstatement of *Padina japonica*. *Phycologia*, 49: 136-153 (2010).
36. Papenfuss, G. E. Notes on South African marine algae-I. *Botaniska Notiser*, 1940: 200-201 (1940).
37. Papenfuss, G. E. The taxonomy, structure and reproduction of the brown alga *Stoechospermum* (Dictyotales). *Journal of Phycology*, 12(Supp.): 27 (1976).
38. Shaikh, W., M. Shameel, A. Hayee-Memon, K. Usmanghani, S. Bano & V. U. Ahmad. Isolation and characterization of chemical constituents of *Stoechospermum marginatum* (Dictyotales, Phaeophyta) and their microbial activity. *Pakistan Journal of Pharmaceutical Sciences*, 3: 1-9 (1990).
39. Atewberhan, M., J. H. Bruggeman & A. M. Breeman. Seasonal patterns of biomass, growth and reproduction in *Dictyota cervicornis* and *Stoechospermum polypodioides* (Dictyotales, Phaeophyta) on a shallow reef flat in the southern Red Sea (Eritrea). *Botanica Marina*, 48: 8-17 (2005).

Proceedings of the Pakistan Academy of Sciences, 48 (4): 233-238 (2011)

ISSN: 0377 - 2969

Pakistan Academy of Sciences

Original Article

Data Reductionality Technique for Face Recognition

Muhammad Sharif*, Muhammad Kamran Ayub, Mudassar Raza and Sajjad Mohsin

Department of Computer Sciences,
COMSATS Institute of Information Technology, Wah Cantt., Pakistan

Abstract: The techniques of data reduction to display graphics play a vital role in saving cost and computational complexities. Principal Components Analysis (PCA) is such a well known technique for data compression. In this paper, a comparison of PCA-based face recognition technique and the proposed hybrid technique has been given. In the proposed technique, data compression is achieved through the combination of both Discrete Cosine Transform (DCT) and PCA. It is, in fact, an effort to get the reduced dimensions of image without losing imperative information. The idea of proposed work is based on getting pure co-efficients from the features of a face image. The performance of proposed algorithm is tested and the results obtained show significant improvement over the traditional PCA technique.

Keywords: Data reduction, dimensionality, recognition, face, DCT

INTRODUCTION

In authentication systems biometric applications have a great contribution; especially the field of face recognition contributes a greater extent to secure networked societies. Face recognition though a difficult task, but a tremendous work has been done in this area. It is still an unsolved problem in many situations and has a wide research scope under the conditions like illumination variations and poses. Face recognition has a large scope in surveillance systems, authentication in networked society, highly secured environments and many others [1].

Various methods are available for face recognition including holistic as well as modular approaches. Face recognition systems detect the face first and then move towards the phase of recognizing it. Recognition is achieved through a number of techniques (i.e., template matching, extracting local features, Principal Components Analysis (PCA) [2, 3, 4], Discrete Cosine Transform (DCT) and many others). One such popular method to extract face features is named as PCA. But when experiments are being performed for extracting local features by using the technique of DCT [5, 6], it has been observed that the DCT co-efficients give better results as far as data reduction is concerned. The reason lies in its unique nature of data independency. In this paper, an extension to both the approaches of PCA and DCT has been proposed which is then compared with the ordinary PCA technique.

PCA is a technique used for recognizing patterns in the data and finding out similarities and differences in that particular data [2]. As it is difficult to identify these similarities and differences in data of high dimensions, (where the luxury of graphical representation is not available), therefore, the technique of PCA is used for the purpose of analysis and recognition. PCA gets data of image, calculates its mean, subtracts mean from data and finally calculates covariance. Then it determines Eigen vectors and Eigen values [7]. Next, it gives feature vector as

Feature vector = [eig1, eig2, eig3… eign] (1)

Received February 2011, Accepted December 2011
*Corresponding Author: Muhammad Sharif, E-mail: muhammadsharifmalik@yahoo.com

The new data set is then derived as:

Final data = Row feature vector * Row data adjust (2)

The proposed algorithm applies DCT transform on each individual image after getting the detected face image. The use of DCT [8] helps to attain the high energy pixels. The obtained DCT co-efficients are then passed through all steps of PCA technique, as a result of which data dimensions get reduced as well as high energy data components are obtained.

The main idea behind the proposed work is to reduce the data dimensions which ultimately solve the bandwidth consumption problems. Although bandwidth is no more an issue now a days but still it needs to be consumed efficiently. Therefore, data compression is required to send more data on a limited bandwidth [9].

EXISTING TECHNIQUE

PCA [1, 2] is a well known technique for reduction of data dimensions and in recognition systems using the Eigen value approaches. It is based on statistical techniques and holds its place in the category of linear transformation [10]. PCA is also being used for image enhancement and analysis. DCT [8] is a powerful transform for getting the data of high energy. It is successfully used in data encoding, voice encoding and data compression. Besides, it also works well on image data.

Both the techniques mentioned above are being used for features' extraction from an image. But in this paper we have proposed an extension of DCT approach and a comparison of ordinary PCA technique. The proposed work is also made on the basis of data sets collected at the end.

The steps of ordinary PCA [2] are as under (see Fig. 1):

- Take an image data
- Take mean of data
- Subtract mean from data
- Find covariance of above matrix
- Calculate Eigen vectors & Eigen values
- Calculate Eigen face
- Extract features on the basis of Eigen vectors
- Check the data for reduction effects
- Plot the vectors
- Analyze the results

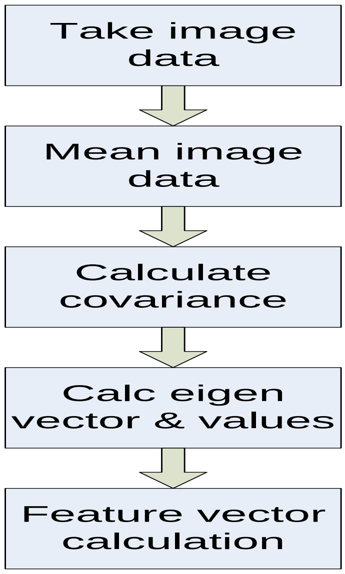


Fig. 1. Block diagram of PCA analysis.

MATERIALS AND METHODS

DCT is a well known signal compression tool along with its extra ability of data independence. It [8] is an orthogonal transform. Karhunen-Loeve transform (KLT) is the most optimal transform for information packing but its property of data dependence makes it unfeasible for many practical tasks [5]. When we try to implement PCA on DCT coefficients, it does not give the result because of some mathematical complexities. The procedure is as follows:

In the first step, face is detected through a normalized image. Now a DCT transform is applied to get the DCT co-efficients. In case of 1-D DCT transform:

$$y(k) = w(k)\sum_{n=1}^{N} x(n)\cos\frac{\pi(2n-1)(k-1)}{2N}, k = 1,\dots,N \quad (3)$$

where

$$w(k) = \begin{cases} \frac{1}{N}, k=1 \\ \sqrt{\frac{2}{N}}, 2 \le k \le N \end{cases} \quad (4)$$

To express as a vector:

$$a = \mathrm{cov}^T x \quad (5)$$

where

$$\mathrm{cov}_{n,k} = \begin{cases} \frac{1}{\sqrt{N}}, k=0, n=0,1,...,N-1 \\ \sqrt{\frac{2}{N}} \cos\left[\frac{\pi(2n+1)k}{2N}\right], k=1,2,...N-1, n=0,1,...,N-1 \end{cases} \quad (6)$$

So, for applying 2D DCT transform, we make 1D column and row vectors as:

$$E = \mathrm{cov}_M^T F \, \mathrm{cov}_N, F = \mathrm{cov}_M E \, \mathrm{cov}_N^T \quad (7)$$

Now for applying PCA on DCT coefficients, the DCT transform matrix is converted into vectors as:

$$\hat{E} = G^T \hat{F}, \hat{F} = H^T \hat{E} \quad (8)$$

Here $\hat{E}$ and $\hat{F}$ are vectors of dimensions [M x N] and G and H are transformation matrices. It must be ensured here that

$$G * H = I \quad (9)$$

$\hat{F}$ can be formed by concatenating the values

[f0, f1, f2 … fn]

Fig. 2 represents the sample image on which DCT is to be applied. Fig. 3 shows DCT transform applied on Fig. 2.

Fig. 2. Image used before applying DCT.

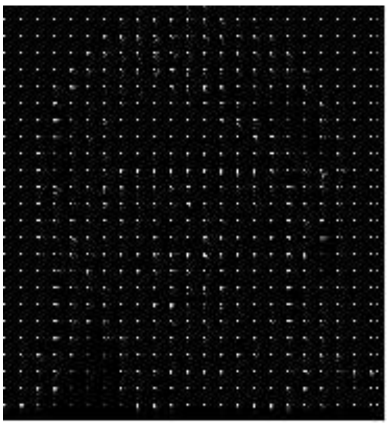


Fig. 3. Plot of DCT co-efficients.

For selection of suitable DCT co-efficients in order to compress an image, a zigzag scan is followed as shown in Fig. 4.

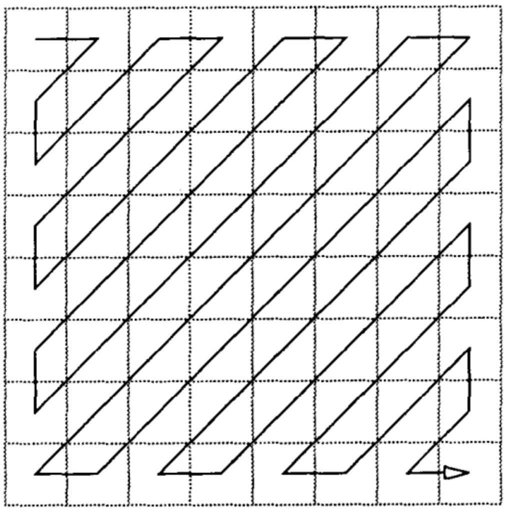


Fig. 4. Zigzag scan used for collecting coefficient values [10].

If G and H are orthogonal matrices then PCA can be implemented on the resulted DCT co-efficients. Both PCA and DCT give orthogonally transformed matrices. Applying PCA on each image co-efficient gives features' information through the following steps (also given in Fig. 5):

- Take the detected face image.
- Apply DCT on detected face image.
- Get DCT co-efficients.
- Arrange DCT coefficients in a vector form as E & F.
- Calculate mean of data.
- Find covariance matrix by subtracting mean from data and multiplying it with its transpose.
- Calculate Eigen vectors and Eigen values by using above calculated covariance matrix.
- Obtain Eigen faces from the above calculated Eigen vectors and Eigen values.
- Check the output of Eigen faces keeping in view its dimensionality reduction.

This will give the reduced data dimensions of a test image which significantly shows dominance over traditional PCA technique.

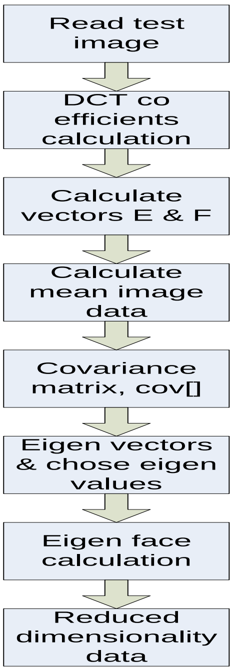


Fig. 5. Block diagram of proposed technique.

RESULTS AND DISCUSSION

In this section, experiments are listed to show the better performance of proposed idea. The image shown in Fig. 6 is taken as a test image for experiment.

Fig. 6.Test Image for experiment.

Fig. 7 shows the high intensity pixel values of test image.

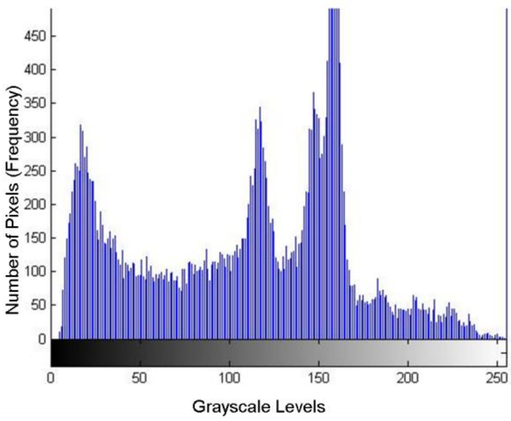


Fig. 7. Histogram of test image.

Fig. 8 shows the plot of DCT co-efficients of the selected test image.

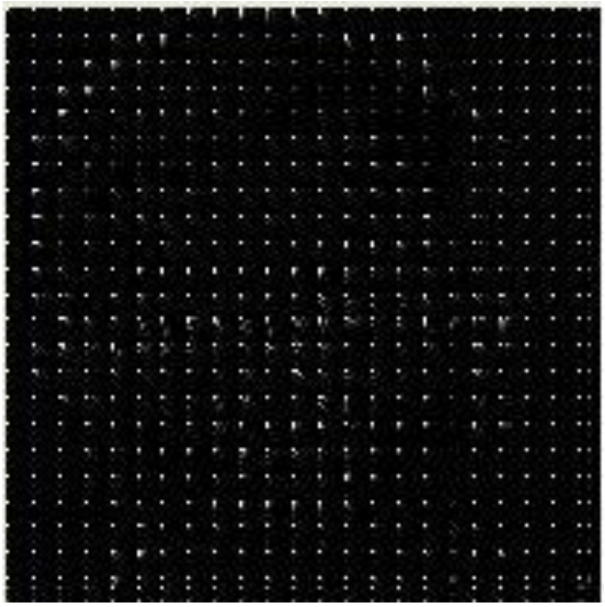


Fig. 8. Plot of DCT co-efficients.

Fig. 9 shows the reduction in pixel intensities after DCT transform is applied on the selected image.

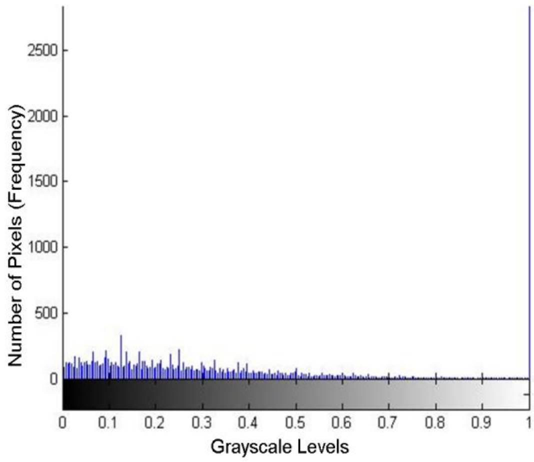
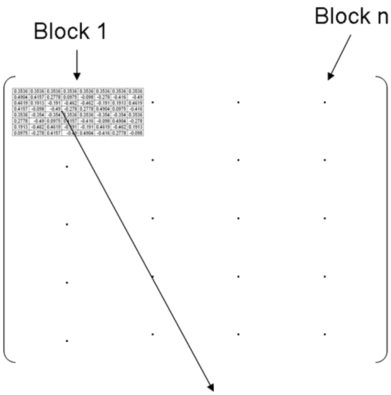


Fig. 9. Histogram of DCT co-efficients of selected image.

We get a matrix of DCT co-efficients blocks as a result of applying DCT transform. Every block represents 64 values of co-efficients. Fig. 10 shows 1st block of co-efficients followed by sequence of remaining blocks shown in dots.



1287.8	0.14414	-0.095671	0.12394	0	0.35769	-0.23097	-0.45926
-5.7757	-0.074932	-0.041347	-0.41503	0.11775	-0.017582	0.20787	0.064633
3.1402e-016	-7.2051	8.0141	0.023044	0.1353	0.25948	-0.19822	0.1059
0.24628	0.059059	0.048773	-0.020739	-0.057531	0.1809	-0.032589	-0.22369
-17.57	-.0061933	0.095671	-0.51679	1.2561e-015	0.23024	0.23097	-0.23426
-0.50974	0.046911	-0.2452	0.60768	0.086101	-0.15604	-0.36696	0.13228
-3.9252e-017	0.029237	0.55178	0.80727	-0.32664	0.60102	0.23591	-0.49374
0.44238	-.0085903	0.69826	0.44436	-0.59196	-0.23825	0.13889	0.25171

Fig. 10. 1st 64 DCT co-efficients.

Out of 64 co-efficients in a block, 20 are selected by using zigzag scanning. Normalized images are used for comparing the difference of compression results in the proposed and the existing techniques. By mathematical computations, it is concluded that for an image of 256 × 256, the data is reduced (in context of dimension) from 65,536 to 20,480. So, it concludes that applying PCA on DCT co-efficients is better than using direct PCA compression because it reduces the cost, computations and memory needs. Next, the steps of ordinary PCA are applied to calculate covariance matrix, Eigen vectors, Eigen values and Eigen face. As a result, the test image has been recovered successfully as shown in Fig. 11.

Fig. 11. Recovered image.

Histogram (Fig. 12) shows the pixels' intensity values for a recovered image. After the comparison of recovered and actual test images, it has been revealed that there is not much difference between the histograms of these two images. Therefore, recognition rate and compression results are improved by applying the proposed technique.

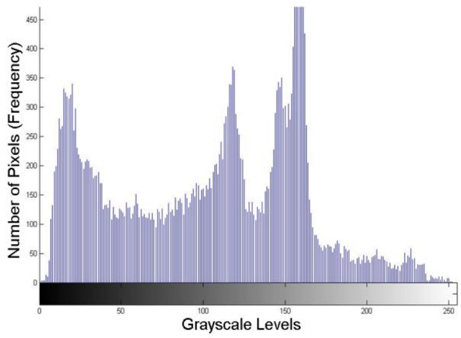


Fig. 12. Histogram of recovered image.

The difference between reduced image sizes after applying ordinary PCA technique and the proposed technique on an image are given in Table 1.

Table1. Comparison chart on different image sizes

Image Size	PCA on uncompressed Image (Pixels)	Proposed Technique (Pixels)
64 x 64	4096	1280
128 x 128	16,384	5120
256 x 256	65,536	20,480
512 x 512	262,144	81,920
640 x 640	409600	1,28,000

The comparison analysis given in Fig. 13 is being performed by using 20-DCT co-efficients. The performance can be enhanced by changing the number of co-efficients selected for further processing.

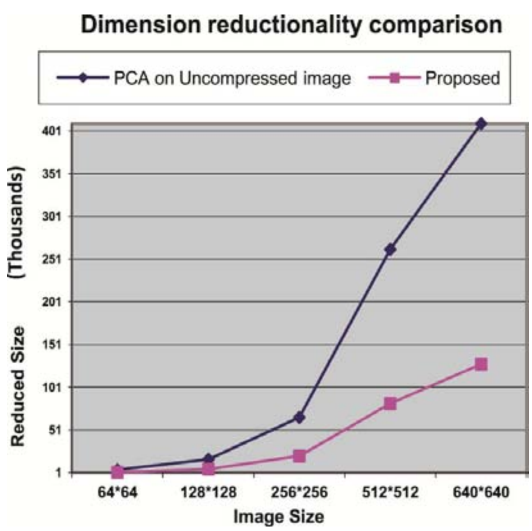


Fig. 13. Comparison analysis.

CONCLUSIONS

This paper presents a hybrid technique for reduction in data dimensions of an image. The method presented is simple and efficient, ultimately reducing the storage requirements. It represents an efficient way of using PCA directly on DCT coefficients. This idea can be used successfully for face recognition in real time applications because it solves the memory management problems which arise because of large databases in these applications.

REFERENCES

1. Ekenel, H.K. & R.Stiefelhagen, Face recognition for smart interactions, IEEE International Conference on Multimedia and Expo, ICME, p 1007 – 1010 (2007).
2. A tutorial on Principal Components Analysis. Lindsay I. Smith, February 26, 2002.
3. Draper, B.A. K. Baek, M. Bartlett, & J. Ross Beveridge. Recognizing faces with PCA and ICA. *Computer Vision and Image Understanding* 91(1-2): 115-137 (2003).
4. Delac, K. & M. Grgic. Statistics in Face Recognition: Analyzing Probability Distributions of PCA, ICA and LDA Performance Results, Proceedings 4th International Symposium on Image and Signal Processing and Analysis, ISPA 2005. p 289 – 294 (2005).
5. Ekenel, H.K. & R. Stiefelhagen. Local Appearance Based Face Recognition Using Discrete Cosine Transform. European Signal Processing Conference EUSIPCO (2005) Pages: 3-6.
6. Hafed, Z.M., & M.D. Levine. Face recognition using the discrete cosine transform. *Int. J. Comput.* Vis. 43 (3), 167–188 (2001).
7. Pan, Z., R. Adams, H. Bolouri. Image redundancy reduction for neural network classification using discrete cosine transforms. In: Proceedings of IEEE-INNSENNS International Joint Conf. on Neural Networks, Como, Italy 3, 2000, p. 149–154, (2000).
8. Penne-baker, W. J. Mitchell. *JPEG Still Image Data Compression Standard*, Van Nostrand Reinhold, New York (1993).
9. Turk, M.A. & A.P. Pentland, Eigenfaces for recognition. *J. Cognit. Neurosci*, 3: 71–86 (1991).
10. Belhumeur, P.N., J.P. Hespanha. & D.J. Kriegman. Eigenfaces versus fisherfaces: recognition using class specific linear projection. *IEEE Trans. Pattern Anal. Mach. Intell.*, 19 (7):711–720 (1997).

Proceedings of the Pakistan Academy of Sciences, 48 (4): 239-249 (2011)

ISSN: 0377 - 2969

Pakistan Academy of Sciences

Original Article

On Weakly $\ddot{g}$ -Closed Sets in Topological Spaces

O. Ravi[1*] and S. Ganesan[2]

[1]Department of Mathematics, P.M. Thevar College, Usilampatti,
Madurai District, Tamil Nadu, India
[2]Department of Mathematics, N.M.S.S.V.N. College
Nagamalai, Madurai, Tamil Nadu, India

Abstract: In this paper, the concepts of weakly $\ddot{g}$ -continuous functions, weakly $\ddot{g}$ -compact spaces and weakly $\ddot{g}$ -connected spaces are introduced and some of their properties are investigated.
2000 Mathematics Subject Classification: **54C10, 54C08, 54C05.**

Keywords and Phrases: Topological space, sg-closed set, $\ddot{g}$ -closed set, α g-closed set

INTRODUCTION

Ravi and Ganesan [16] have introduced the concept of $\ddot{g}$ -closed sets and studied their most fundamental properties in topological spaces. In this paper, we introduce a new class of generalized closed sets called weakly $\ddot{g}$ -closed sets which contains the above mentioned class. Also, we investigate the relationships among the related generalized closed sets.

PRELIMINARIES

Throughout this paper (X, τ), (Y, σ) and (Z, η) (or X, Y and Z) represent topological spaces on which no separation axioms are assumed unless otherwise mentioned. For a subset A of a space (X, τ), cl(A), int(A) and A^c or X$|$A or X – A denote the closure of A, the interior of A and the complement of A, respectively.

We recall the following definitions which are useful in the sequel.

Definition 2.1

A subset A of a space (X, τ) is called

(i) semi-open set [11] if A ⊆ cl(int(A));
(ii) α -open set [14] if A ⊆ int(cl(int(A)));
(iii) regular open set [22] if A = int(cl(A));
(iv) π-open set [25] if A is the finite union of regular open sets.

The complements of the above mentioned open sets are called their respective closed sets.

The semi-closure [5] (resp. α -closure [14]) of a subset A of X, scl(A) (resp. α cl(A)), is defined to be the intersection of all semi-closed (resp. α -closed) sets of (X, τ) containing A. It is known that scl(A) (resp. α cl(A)) is a semi-closed (resp. an α -closed) set.

Definition 2.2

A subset A of a space (X, τ) is called

(i) a generalized closed (briefly g-closed) set [10] if cl(A) ⊆ U whenever A ⊆ U and U is open in (X, τ). The complement of g-closed set is called g-open;
(ii) a semi-generalized closed (briefly sg-closed) set [2] if scl(A) ⊆ U whenever A ⊆ U and U is semi-open in (X, τ). The complement of sg-closed set is called sg-open;
(iii) a α -generalized closed (briefly α g-closed)

Received August 2011, Accepted December 2011
*Corresponding author: O. Ravi; E-mail: siingam@yahoo.com

set [12] if α cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is open in (X, τ). The complement of α g-closed set is called α g-open;

(iv) a $\ddot{g}$-closed set [16] if cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is sg-open in (X, τ). The complement of $\ddot{g}$-closed set is called $\ddot{g}$-open.

(v) a πg-closed set [7] if cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is π-open in (X, τ). The complement of πg-closed set is called πg-open set.

The family of all $\ddot{g}$-open (resp. $\ddot{g}$-closed) sets in X is denoted by $\ddot{G}$O(X) (resp. $\ddot{G}$C(X)).

Definition 2.3 [17]

For every set A $\subseteq$ X, we define the $\ddot{g}$-closure of A to be the intersection of all $\ddot{g}$-closed sets containing A.

i.e., $\ddot{g}$-cl(A) = $\cap$ {F : A $\subseteq$ F $\in$ $\ddot{G}$C(X)}.

Definition 2.4

Let X and Y be two topological spaces. A function f : X $\rightarrow$ Y is called

(i) completely continuous [1] (resp. R-map [4]) if $f^{-1}(V)$ is regular open in X for each open (resp. regular open) set V of Y.

(ii) perfectly continuous [15] if $f^{-1}(V)$ is both open and closed in X for each open set V of Y.

(iii) $\ddot{g}$-continuous [18] if $f^{-1}(V)$ is $\ddot{g}$-closed in X for every closed set V of Y.

(iv) $\ddot{g}$-irresolute [18] if $f^{-1}(V)$ is $\ddot{g}$-closed in X for every $\ddot{g}$-closed set V of Y.

(v) sg-irresolute [3, 24] if $f^{-1}(V)$ is sg-open in X for every sg-open set V of Y.

Definition 2.5

A subset A of a topological space (X, τ) is called

(i) a weakly g-closed (briefly wg-closed) set [23] if cl(int(A)) $\subseteq$ U whenever A $\subseteq$ U and U is open in (X, τ).

(ii) a weakly πg-closed (briefly wπg-closed) set [21] if cl(int(A)) $\subseteq$ U whenever A $\subseteq$ U and U is πg-open in (X, τ).

(iii) a regular weakly generalized closed (briefly rwg-closed) set [13] if cl(int(A)) $\subseteq$ U whenever A $\subseteq$ U and U is regular open in (X, τ).

Definition 2.6 [20]

A function f : X $\rightarrow$ Y is called contra $\ddot{g}$-continuous if $f^{-1}(V)$ is $\ddot{g}$-closed in X for every open set V of Y.

Definition 2.7 [20]

A function f : X $\rightarrow$ Y is called ($\ddot{g}$, s)-continuous if the inverse image of each regular open set of Y is $\ddot{g}$-closed in X.

Theorem 2.8 [20]

Let Y be a regular space and f : X $\rightarrow$ Y be a function. Suppose that the collection of all $\ddot{g}$-closed sets in X is closed under arbitrary intersections. Then if f is ($\ddot{g}$, s)-continuous, f is $\ddot{g}$-continuous.

Definition 2.9 [20]

A space X is called $\ddot{g}$-connected if X is not the union of two disjoint nonempty $\ddot{g}$-open sets.

Definition 2.10 [19]

A function f : (X, τ) $\rightarrow$ (Y, σ) is said to be an $\ddot{g}$-open map if the image f(A) is $\ddot{g}$-open in (Y, σ) for each open set A of (X, τ).

Definition 2.11 [9]

A space X is said to be almost connected if X cannot be written as a disjoint union of two non-empty regular open sets.

Remark 2.12 [2]

Every open set is sg-open but not conversely.

Remark 2.13 [7]

For a subset of a space, we have following

implications:
regular open $\rightarrow$ π-open $\rightarrow$ open

Corollary 2.14 [2]

Let A be a sg-closed set which is also open. Then A $\cap$ F is sg-closed whenever F is semi-closed.

Weakly $\ddot{g}$ -closed sets

We introduce the definition of weakly $\ddot{g}$-closed sets in topological spaces and study the relationships of such sets.

Definition 3.1

A subset A of a topological space (X, τ) is called a weakly $\ddot{g}$-closed (briefly w$\ddot{g}$-closed) set if cl(int(A)) $\subseteq$ U whenever A $\subseteq$ U and U is sg-open in (X, τ).

Theorem 3.2

Every $\ddot{g}$-closed set is w$\ddot{g}$-closed but not conversely.

Example 3.3

Let X = {a, b, c} and τ = {ϕ, {a, b}, X}. Then the set {a} is w$\ddot{g}$-closed set but it is not a $\ddot{g}$-closed in (X, τ).

Theorem 3.4

Every w$\ddot{g}$-closed set is wg-closed but not conversely.

Proof

Let A be any w$\ddot{g}$-closed set and U be any open set containing A. Then U is a sg-open set containing A. We have cl(int(A)) $\subseteq$ U. Thus, A is wg-closed.

Example 3.5

Let X = {a, b, c} and τ = {ϕ, {a}, X}. Then the set {a, b} is wg-closed but it is not a w$\ddot{g}$-closed.

Theorem 3.6

Every w$\ddot{g}$-closed set is wπg-closed but not conversely.

Proof

Let A be any w$\ddot{g}$-closed set and U be any π-open set containing A. Then U is a sg-open set containing A. We have cl(int(A)) $\subseteq$ U. Thus, A is wπg-closed.

Example 3.7

In Example 3.5, the set {a, c} is wπg-closed but it is not a w$\ddot{g}$-closed.

Theorem 3.8

Every w$\ddot{g}$-closed set is rwg-closed but not conversely.

Proof

Let A be any w$\ddot{g}$-closed set and U be any regular open set containing A. Then U is a sg-open set containing A. We have cl(int(A)) $\subseteq$ U. Thus, A is rwg-closed.

Example 3.9

In Example 3.5, the set {a} is rwg-closed but it is not a w$\ddot{g}$-closed.

Theorem 3.10

If a subset A of a topological space (X, τ) is both closed and αg-closed, then it is w$\ddot{g}$-closed in (X, τ).

Proof

Let A be a αg-closed set in (X, τ) and U be any open set containing A. Then U $\supseteq$ αcl(A) = A $\cup$ cl(int(cl(A))). Since A is closed, U $\supseteq$ cl(int(A)) and hence w$\ddot{g}$-closed in (X, τ).

Theorem 3.11

If a subset A of a topological space (X, τ) is both open and w$\ddot{g}$-closed, then it is closed.

Proof

Since A is both open and w$\ddot{g}$-closed, A $\supseteq$ cl(int(A)) = cl(A) and hence A is closed in (X, τ).

Corollary 3.12

If a subset A of a topological space (X, τ) is both open and w$\ddot{g}$-closed, then it is both regular open and regular closed in (X, τ).

Theorem 3.13

Let (X, τ) be a topological space and $A \subseteq X$ be open. Then, A is w$\ddot{g}$-closed if and only if A is $\ddot{g}$-closed.

Proof

Let A be $\ddot{g}$-closed. By Proposition 3.2, it is w$\ddot{g}$-closed.

Conversely, let A be w$\ddot{g}$-closed. Since A is open, by Theorem 3.11, A is closed. Hence A is $\ddot{g}$-closed.

Theorem 3.14

A set A is w$\ddot{g}$-closed if and only if cl(int(A)) – A contains no non-empty sg-closed set.

Proof

Necessity. Let F be a sg-closed set such that F $\subseteq$ cl(int(A)) – A. Since F^c is sg-open and $A \subseteq F^c$, from the definition of w$\ddot{g}$-closedness it follows that cl(int(A)) $\subseteq F^c$. i.e., F $\subseteq$ (cl(int(A)))^c. This implies that F $\subseteq$ (cl(int(A))) $\cap$ (cl(int(A)))^c = ϕ.
Sufficiency. Let $A \subseteq G$, where G is closed and sg-open set in X. If cl(int(A)) is not contained in G, then cl(int(A)) $\cap$ G^c is a non-empty sg-closed subset of cl(int(A)) – A, we obtain a contradiction. This proves the sufficiency and hence the theorem.

Theorem 3.15

Let (X, τ) be a topological space and $A \subseteq Y \subseteq X$ and Y be open. If A is w$\ddot{g}$-closed in X, then A is w$\ddot{g}$-closed relative to Y.

Proof

Let A $\subseteq$ Y $\cap$ G where G is sg-open in (X, τ). Since A is w$\ddot{g}$-closed in (X, τ), A $\subseteq$ G implies cl(int(A)) $\subseteq$ G. That is Y $\cap$ (cl(int(A))) $\subseteq$ Y $\cap$ G where Y $\cap$ cl(int(A)) is closure of interior of A in Y. Thus, A is w$\ddot{g}$-closed relative to Y.

Theorem 3.16

If a subset A of a topological space (X, τ) is nowhere dense, then it is w$\ddot{g}$-closed.

Proof

Since int(A) $\subseteq$ int(cl(A)) and A is nowhere dense, int(A) = ϕ. Therefore cl(int(A)) = ϕ and hence A is w$\ddot{g}$-closed in (X, τ).

The converse of Theorem 3.16 need not be true as seen in the following example.

Example 3.17

Let X = {a, b, c} and τ = {ϕ, {a}, {b, c}, X}. Then the set {a} is w$\ddot{g}$-closed set but not nowhere dense in (X, τ).

Remark 3.18

The following examples show that w$\ddot{g}$-closedness and semi-closedness are independent.

Example 3.19

In Example 3.3, we have the set {a, c} is w$\ddot{g}$-closed set but not semi-closed in (X, τ).

Example 3.20

Let X = {a, b, c} and τ = {ϕ, {a}, {b}, {a, b}, X}. Then the set {a} is semi-closed set but not w$\ddot{g}$-closed in (X, τ).

Remark 3.21

From the above discussions and known results in [21]. We obtain the following diagram, where A $\to$ B represents A implies B but not conversely.

Diagram

closed $\to$ w$\ddot{g}$-closed $\to$ wg-closed $\to$ wπg-closed $\to$ rwg-closed

None of the above implications is reversible as shown in the above examples and in the related paper [21].

Definition 3.22

A subset A of a topological space X is called w$\ddot{g}$-open set if A^c is w$\ddot{g}$-closed in X.

Proposition 3.23

(i) Every $\ddot{g}$-open set is w$\ddot{g}$-open but not conversely.
(ii) Every g-open set is w$\ddot{g}$-open but not conversely.

Theorem 3.24

A subset A of a topological space X is w$\ddot{g}$-open if G $\subseteq$ int(cl(A)) whenever G $\subseteq$ A and G is sg-closed.

Proof

Let A be any w$\ddot{g}$-open. Then A^c is w$\ddot{g}$-closed. Let G be a sg-closed set contained in A. Then G^c is a sg-open set containing A^c. Since A^c is w$\ddot{g}$-closed, we have cl(int(A^c)) $\subseteq$ G^c. Therefore G $\subseteq$ int(cl(A)).

Conversely, we suppose that G $\subseteq$ int(cl(A)) whenever G $\subseteq$ A and G is sg-closed. Then G^c is a sg-open set containing A^c and G^c $\supseteq$ (int(cl(A)))^c. It follows that G^c $\supseteq$ cl(int(A^c)). Hence A^c is w$\ddot{g}$-closed and so A is w$\ddot{g}$-open.

Lemma 3.25 [8]
The following properties hold for subsets U, V of a space X:

(i) x $\in$ ker(U) if and only if U $\cap$ F $\neq \phi$ for any closed set F containing x,
(ii) U $\subseteq$ ker(U) and U = ker(U) if U is open in X,
(iii) U $\subseteq$ V, then ker(U) $\subseteq$ ker(V).

Theorem 3.26

The following are equivalent for a function f : X $\to$ Y
(i) f is contra $\ddot{g}$-continuous,
(ii) the inverse image of every closed set of Y is $\ddot{g}$-open.

Proof

Let U be any closed set of Y. Since Y \ U is open, then by (i), it follows that f^{-1}(Y \ U) = X \ f^{-1}(U) is $\ddot{g}$-closed. This shows that f^{-1}(U) is $\ddot{g}$-open in X.

Converse is similar.

Theorem 3.27

Suppose that $\ddot{G}$C(X) is closed under arbitrary intersections. Then the following are equivalent for a function f : X $\to$ Y

(i) f is contra $\ddot{g}$-continuous,
(ii) the inverse image of every closed set of Y is $\ddot{g}$-open,
(iii) for each x $\in$ X and each closed set B in Y with f(x) $\in$ B, there exists a $\ddot{g}$-open set A in X such that x $\in$ A and f(A) $\subseteq$ B,
(iv) f($\ddot{g}$-cl(A)) $\subseteq$ ker(f(A)) for every subset A of X,
(v) $\ddot{g}$-cl(f^{-1}(B)) $\subseteq$ f^{-1}(ker(B)) for every subset B of Y.

Proof

(i) $\Rightarrow$ (iii). Let x $\in$ X and B be a closed set in Y with f(x) $\in$ B. By (i), it follows that f^{-1}(Y \ B) = X \ f^{-1}(B) is $\ddot{g}$-closed and so f^{-1}(B) is $\ddot{g}$-open. Take A = f^{-1}(B). We obtain that x $\in$ A and f(A) $\subseteq$ B. (iii)$\Rightarrow$ (ii). Let B be closed set in Y with x $\in$ f^{-1}(B). Since f(x) $\in$ B, by (iii) there exists a $\ddot{g}$-open set A in X containing x such that $f(A) \subseteq B$. It follows that $x \in A \subseteq f^{-1}(B)$. Hence $f^{-1}(B)$ is $\ddot{g}$-open.

(ii) $\Rightarrow$ (i). Follows from the previous Theorem.

(ii) $\Rightarrow$ (iv). Let A be any subset of X. Let $y \notin ker(f(A))$. Then there exists a closed set F containing y such that $f(A) \cap F = \phi$. Hence, we have $A \cap f^{-1}(F) = \phi$ and $\ddot{g}\text{-cl}(A) \cap f^{-1}(F) = \phi$. Hence, we obtain $f(\ddot{g}\text{-cl}(A)) \cap F = \phi$ and $y \notin f(\ddot{g}\text{-cl}(A))$. Thus, $f(\ddot{g}\text{-cl}(A)) \subseteq ker(f(A))$.

(iv) $\Rightarrow$ (v). Let B be any subset of Y. By (iv), $f(\ddot{g}\text{-cl}(f^{-1}(B))) \subseteq ker(B)$ and $\ddot{g}\text{-cl}(f^{-1}(B)) \subseteq f^{-1}(ker(B))$.

(v) $\Rightarrow$ (i). Let B be any open set of Y. By (v), $\ddot{g}\text{-cl}(f^{-1}(B)) \subseteq f^{-1}(ker(B)) = f^{-1}(B)$ and $\ddot{g}\text{-cl}(f^{-1}(B)) = f^{-1}(B)$. We obtain that $f^{-1}(B)$ is $\ddot{g}$-closed in X.

Weakly $\ddot{g}$-continuous functions

Definition 4.1

Let X and Y be two topological spaces. A function $f : X \to Y$ is called weakly $\ddot{g}$-continuous (briefly w$\ddot{g}$-continuous) if $f^{-1}(U)$ is a w$\ddot{g}$-open set in X for each open set U of Y.

Example 4.2

Let X = Y = {a, b, c}, $\tau = \{\phi, \{a\}, \{b, c\}, X\}$ and $\sigma = \{\phi, \{a\}, Y\}$. The function $f : (X, \tau) \to (Y, \sigma)$ defined by f(a) = b, f(b) = c and f(c) = a is w$\ddot{g}$-continuous, because every subset of Y is w$\ddot{g}$-closed in X.

Theorem 4.3

Every $\ddot{g}$-continuous function is w$\ddot{g}$-continuous.

Proof

It follows from Proposition 3.23 (i).

The converse of Theorem 4.3 need not be true as seen in the following example.

Example 4.4

Let X = Y = {a, b, c}, $\tau = \{\phi, \{a\}, \{b, c\}, X\}$ and $\sigma = \{\phi, \{b\}, Y\}$. Let $f : (X, \tau) \to (Y, \sigma)$ be the identity function. Then f is w$\ddot{g}$-continuous but not $\ddot{g}$-continuous.

Theorem 4.5

A function $f : X \to Y$ is w$\ddot{g}$-continuous if and only if $f^{-1}(U)$ is a w$\ddot{g}$-closed set in X for each closed set U of Y.

Proof

Let U be any closed set of Y. According to the assumption $f^{-1}(U^c) = X \setminus f^{-1}(U)$ is w$\ddot{g}$-open in X, so $f^{-1}(U)$ is w$\ddot{g}$-closed in X.

The converse can be proved in a similar manner.

Theorem 4.6

Suppose that X and Y are spaces and $\ddot{G}O(X)$ is closed under arbitrary unions. If a function $f : X \to Y$ is contra $\ddot{g}$-continuous and Y is regular, then f is $\ddot{g}$-continuous.

Proof

Let x be an arbitrary point of X and V be an open set of Y containing f(x). Since Y is regular, there exists an open set G in Y containing f(x) such that $cl(G) \subseteq V$. Since f is contra $\ddot{g}$-continuous, there exists $U \in \ddot{G}O(X)$ containing x such that $f(U) \subseteq cl(G)$. Then $f(U) \subseteq cl(G) \subseteq V$. Hence, f is $\ddot{g}$-continuous.

Theorem 4.7

Suppose that X and Y are spaces and the family of $\ddot{g}$-open sets in X is closed under arbitrary unions. If a function $f : X \to Y$ is contra $\ddot{g}$-continuous and Y is regular, then f is w$\ddot{g}$-continuous.

Proof

Let f : X → Y be contra $\ddot{g}$ -continuous and Y be regular. By Theorem 4.6, f is $\ddot{g}$ -continuous. Hence, f is w $\ddot{g}$ -continuous.

Definition 4.8

A topological space (X, τ) is said to be locally $\ddot{g}$ -indiscrete if every $\ddot{g}$ -open set of X is closed in X.

Theorem 4.9

Let f : X → Y be a function. If f is $\ddot{g}$ -continuous and (X, τ) is locally $\ddot{g}$ -indiscrete, then f is continuous.

Proof

Let V be an open in Y. Since f is $\ddot{g}$ -continuous, $f^{-1}(V)$ is $\ddot{g}$ -open in X. Since X is locally $\ddot{g}$ -indiscrete, $f^{-1}(V)$ is closed in X. Hence f is continuous.

Theorem 4.10

Let f : X → Y be a function. If f is contra $\ddot{g}$ -continuous and (X, τ) is locally $\ddot{g}$ -indiscrete, then f is w $\ddot{g}$ -continuous.

Proof

Let f : X → Y be contra $\ddot{g}$ -continuous and (X, τ) is locally $\ddot{g}$ -indiscrete. By Theorem 4.9, f is continuous, then f is w $\ddot{g}$ -continuous.

Theorem 4.11

Let Y be a regular space and f : X → Y be a function. Suppose that the collection of $\ddot{g}$ -closed sets in X is closed under arbitrary intersections. Then if f is ($\ddot{g}$, s)-continuous, f is w $\ddot{g}$ -continuous.

Proof

Let f be ($\ddot{g}$, s)-continuous. By Theorem 2.8, f is $\ddot{g}$ -continuous. Thus, f is w $\ddot{g}$ -continuous.

Proposition 4.12

If f : X → Y is perfectly continuous and w $\ddot{g}$ -continuous, then it is R-map.

Proof

Let V be any regular open subset of Y. According to the assumption, $f^{-1}(V)$ is both open and closed in X. Since $f^{-1}(V)$ is closed, it is w $\ddot{g}$ -closed. We have $f^{-1}(V)$ is both open and w $\ddot{g}$ -closed. Hence, by Corollary 3.12, it is regular open in X, so f is R-map.

Definition 4.13

A topological space X is called $\ddot{g}$ -compact if every cover of X by $\ddot{g}$ -open sets has finite subcover.

Definition 4.14

A topological space X is weakly $\ddot{g}$ -compact (briefly w $\ddot{g}$ -compact) if every w $\ddot{g}$ -open cover of X has a finite subcover.

Remark 4.15

Every w $\ddot{g}$ -compact space is $\ddot{g}$ -compact.

Theorem 4.16

Let f : X → Y be surjective w $\ddot{g}$ -continuous function. If X is w $\ddot{g}$ -compact, then Y is compact.

Proof

Let $\{A_i : i \in I\}$ be an open cover of Y. Then $\{ f^{-1}(A_i) : i \in I\}$ is a w $\ddot{g}$ - open cover in X. Since X is w $\ddot{g}$ -compact, it has a finite subcover, say $\{ f^{-1}(A_1), f^{-1}(A_2),\ldots, f^{-1}(A_n)\}$. Since f is surjective $\{A_1, A_2, \ldots, A_n\}$ is a finite subcover of Y and hence Y is compact.

Definition 4.17

A topological space X is weakly $\ddot{g}$ -connected (briefly w$\ddot{g}$-connected) if X cannot be written as the disjoint union of two non-empty w$\ddot{g}$-open sets.

Theorem 4.18

If a topological space X is w$\ddot{g}$-connected, then X is almost connected (resp. $\ddot{g}$-connected).

Proof

It follows from the fact that each regular open set (resp. $\ddot{g}$-open set) is w$\ddot{g}$-open.

Theorem 4.19

For a topological space X the following statements are equivalent:

(i) X is w$\ddot{g}$-connected.

(ii) The empty set ϕ and X are only subsets which are both w$\ddot{g}$-open and w$\ddot{g}$-closed.

(iii) Each w$\ddot{g}$-continuous function from X into a discrete space Y which has at least two points is a constant function.

Proof

(i) $\Rightarrow$ (ii). Let $S \subset X$ be any proper subset, which is both w$\ddot{g}$-open and w$\ddot{g}$-closed. Its complement $X \setminus S$ is also w$\ddot{g}$-open and w$\ddot{g}$-closed. Then $X = S \cup (X \setminus S)$ is a disjoint union of two non-empty w$\ddot{g}$-open sets which is a contradiction with the fact that X is w$\ddot{g}$-connected. Hence, $S = \phi$ or X.

(ii) $\Rightarrow$ (i). Let $X = A \cup B$ where $A \cap B = \phi$, $A \neq \phi$, $B \neq \phi$ and A, B are w$\ddot{g}$-open. Since $A = X \setminus B$, A is w$\ddot{g}$-closed. According to the assumption $A = \phi$, which is a contradiction.

(ii) $\Rightarrow$ (iii). Let $f : X \to Y$ be a w$\ddot{g}$-continuous function where Y is a discrete space with at least two points. Then $f^{-1}(\{y\})$ is w$\ddot{g}$-closed and w$\ddot{g}$-open for each $y \in Y$ and $X = \cup \{ f^{-1}(\{y\}) \mid y \in Y\}$. According to the assumption, $f^{-1}(\{y\}) = \phi$ or $f^{-1}(\{y\}) = X$. If $f^{-1}(\{y\}) = \phi$ for all $y \in Y$, f will not be a function. Also there is no exist more than one $y \in Y$ such that $f^{-1}(\{y\}) = X$. Hence, there exists only one $y \in Y$ such that $f^{-1}(\{y\}) = X$ and $f^{-1}(\{y_1\}) = \phi$ where $y \neq y_1 \in Y$. This shows that f is a constant function.

(iii) $\Rightarrow$ (ii). Let $S \neq \phi$ be both w$\ddot{g}$-open and w$\ddot{g}$-closed in X. Let $f : X \to Y$ be a w$\ddot{g}$-continuous function defined by $f(S) = \{a\}$ and $f(X \setminus S) = \{b\}$ where $a \neq b$. Since f is constant function we get $S = X$.

Theorem 4.20

Let $f : X \to Y$ be a w$\ddot{g}$-continuous surjective function. If X is w$\ddot{g}$-connected, then Y is connected.

Proof

We suppose that Y is not connected. Then $Y = A \cup B$ where $A \cap B = \phi$, $A \neq \phi$, $B \neq \phi$ and A, B are open sets in Y. Since f is w$\ddot{g}$-continuous surjective function, $X = f^{-1}(A) \cup f^{-1}(B)$ are disjoint union of two non-empty w$\ddot{g}$-open subsets. This is contradiction with the fact that X is w$\ddot{g}$-connected.

Weakly $\ddot{g}$-open functions and weakly $\ddot{g}$-closed functions

Definition 5.1

Let X and Y be topological spaces. A function $f : X \to Y$ is called weakly $\ddot{g}$-open (briefly w$\ddot{g}$-open) if f(V) is a w$\ddot{g}$-open set in Y for each open set V of X.

Remark 5.2

Every $\ddot{g}$-open function is w $\ddot{g}$-open but not conversely.

Example 5.3

Let $X = Y = \{a, b, c, d\}$, $\tau = \{\phi, \{a\}, \{a, b, d\}, X\}$ and $\sigma = \{\phi, \{a\}, \{b, c\}, \{a, b, c\}, Y\}$. Let $f : (X, \tau) \to (Y, \sigma)$ be the identity function. Then f is w $\ddot{g}$-open but not $\ddot{g}$-open.

Definition 5.4

Let X and Y be topological spaces. A function $f : X \to Y$ is called weakly $\ddot{g}$-closed (briefly w$\ddot{g}$-closed) if f(V) is a w$\ddot{g}$-closed set in Y for each closed set V of X.

It is clear that an open function is w$\ddot{g}$-open and a closed function is w$\ddot{g}$-closed.

Theorem 5.5

Let X and Y be topological spaces. A function $f: X \to Y$ is w$\ddot{g}$-closed if and only if for each subset B of Y and for each open set G containing $f^{-1}(B)$ there exists a w$\ddot{g}$-open set F of Y such that $B \subseteq F$ and $f^{-1}(F) \subseteq G$.

Proof

Let B be any subset of Y and let G be an open subset of X such that $f^{-1}(B) \subseteq G$. Then $F = Y \setminus f(X \setminus G)$ is w$\ddot{g}$-open set containing B and $f^{-1}(F) \subseteq G$.

Conversely, let U be any closed subset of X. Then $f^{-1}(Y \setminus f(U)) \subseteq X \setminus U$ and $X \setminus U$ is open. According to the assumption, there exists a w$\ddot{g}$-open set F of Y such that $Y \setminus f(U) \subseteq F$ and $f^{-1}(F) \subseteq X \setminus U$. Then $U \subseteq X \setminus f^{-1}(F)$. From $Y \setminus F \subseteq f(U) \subseteq f(X \setminus f^{-1}(F)) \subseteq Y \setminus F$ follows that $f(U) = Y \setminus F$, so f(U) is w$\ddot{g}$-closed in Y. Therefore f is a w$\ddot{g}$-closed function.

Remark 5.6

The composition of two w$\ddot{g}$-closed functions need not be a w$\ddot{g}$-closed as we can see from the following example.

Example 5.7

Let $X = Y = Z = \{a, b, c\}$, $\tau = \{\phi, \{a\}, \{a, b\}, X\}$ and $\sigma = \{\phi, \{a\}, \{b, c\}, Y\}$ and $\eta = \{\phi, \{a, b\}, Z\}$. We define $f : (X, \tau) \to (Y, \sigma)$ by $f(a) = c$, $f(b) = b$ and $f(c) = a$ and let $g : (Y, \sigma) \to (Z, \eta)$ be the identity function. Hence both f and g are w$\ddot{g}$-closed functions. For a closed set $U = \{b, c\}$, $(gof)(U) = g(f(U)) = g(\{a, b\}) = \{a, b\}$ which is not w$\ddot{g}$-closed in Z. Hence the composition of two w$\ddot{g}$-closed functions need not be a w$\ddot{g}$-closed.

Theorem 5.8

Let X, Y and Z be topological spaces. If $f : X \to Y$ is a closed function and $g : Y \to Z$ is a w$\ddot{g}$-closed function, then $gof : X \to Z$ is a w$\ddot{g}$-closed function.

Definition 5.9

A function $f : X \to Y$ is called a weakly $\ddot{g}$-irresolute (briefly w$\ddot{g}$-irresolute) function if $f^{-1}(U)$ is a w$\ddot{g}$-open set in X for each w$\ddot{g}$-open set U of Y.

Example 5.10

Let $X = Y = \{a, b, c\}$, $\tau = \{\phi, \{b\}, \{a, c\}, X\}$ and $\sigma = \{\phi, \{b\}, Y\}$. Let $f : (X, \tau) \to (Y, \sigma)$ be the identity function. Then f is w$\ddot{g}$-irresolute.

Remark 5.11

The following examples show that sg-irresoluteness and w$\ddot{g}$-irresoluteness are independent of each other.

Example 5.12

Let $X = Y = \{a, b, c\}$, $\tau = \{\phi, \{a, b\}, X\}$ and $\sigma = \{\phi, \{a\}, Y\}$. Let $f : (X, \tau) \to (Y, \sigma)$ be the identity function. Then f is w$\ddot{g}$-irresolute but not sg-irresolute.

Example 5.13

Let $X = Y = \{a, b, c\}$, $\tau = \{\phi, \{a\}, \{b\}, \{a, b\}, X\}$ and $\sigma = \{\phi, \{a, b\}, Y\}$. Let $f : (X, \tau) \to (Y, \sigma)$ be the identity function. Then f is sg-irresolute but not w$\ddot{g}$-irresolute.

Remark 5.14

Every $\ddot{g}$-irresolute function is w$\ddot{g}$-continuous but not conversely. Also, the concepts of $\ddot{g}$-irresoluteness and w$\ddot{g}$-irresoluteness are independent of each other.

Example 5.15

Let X = Y = {a, b, c, d}, τ = {ϕ, {a}, {b, c}, {a, b, c}, X} and σ = {ϕ, {a}, {a, b, d}, Y}. Let f : (X, τ) $\to$ (Y, σ) be the identity function. Then f is w$\ddot{g}$-continuous but not $\ddot{g}$-irresolute.

Example 5.16

Let X = Y = {a, b, c}, τ = {ϕ, {a}, {b, c}, X} and σ = {ϕ, {a}, {a, b}, Y}. Let f : (X, τ) $\to$ (Y, σ) be the identity function. Then f is w$\ddot{g}$-irresolute but not $\ddot{g}$-irresolute.

Example 5.17

In Example 5.13, then f is $\ddot{g}$-irresolute but not w$\ddot{g}$-irresolute.

Theorem 5.18

The composition of two w$\ddot{g}$-irresolute functions is also w$\ddot{g}$-irresolute.

Theorem 5.19

Let f : X $\to$ Y and g : Y $\to$ Z be functions such that g o f : X $\to$ Z is w$\ddot{g}$-closed function. Then the following statements hold:

(i) if f is continuous and injective, then g is w$\ddot{g}$-closed.
(ii) if g is w$\ddot{g}$-irresolute and surjective, then f is w$\ddot{g}$-closed.

Proof

(i) Let F be a closed set of Y. Since $f^{-1}(F)$ is closed in X, we can conclude that (g o f)($f^{-1}(F)$) is w$\ddot{g}$-closed in Z. Hence g(F) is w$\ddot{g}$-closed in Z. Thus g is a w$\ddot{g}$-closed function.
(ii) It can be proved in a similar manner as (i).

Theorem 5.20

If f : X $\to$ Y is an w$\ddot{g}$-irresolute function, then it is w$\ddot{g}$-continuous.

Remark 5.21

The converse of the above need not be true in general. The function f : X $\to$ Y in the Example 5.13 is w$\ddot{g}$-continuous but not w$\ddot{g}$-irresolute.

Theorem 5.22

If f : X $\to$ Y is surjective w$\ddot{g}$-irresolute function and X is w$\ddot{g}$-compact, then Y is w$\ddot{g}$-compact.

Theorem 5.23

If f : X $\to$ Y is surjective w$\ddot{g}$-irresolute function and X is w$\ddot{g}$-connected, then Y is w$\ddot{g}$-connected.

REFERENCES

1. Arya, S. P. & Gupta, R. On strongly continuous mappings, Kyungpook Math. J., 14, 131-143 (1974).
2. Bhattacharya, P. & B.K. Lahiri. Semi-generalized closed sets in topology. *Indian J. Math.*, 29(3), 375-382 (1987).
3. Caldas, M. Semi-generalized continuous maps in topological spaces. *Portugaliae Mathematica.*, 52 Fasc. 4, 339-407 **(**1995).
4. Carnation, D. Some properties related to compactness in topological spaces. Ph.D. thesis, University of Arkansas, (1977).
5. Crossley, S.G. & S.K. Hildebrand. Semi-closure, Texas J. Sci., 22, 99-112 (1971).
6. Devi, R., H. Maki & K. Balachandran. Semi-generalized closed maps and generalized semi-closed maps. Mem. Fac. Sci. Koch. Univ., 14, 41-54 (1993).
7. Dontchev, J. & T. Noiri. Quasi-normal spaces and πg-closed sets. *Acta Math. Hungar*., 89: 211-219 (2000).
8. Ekici, E. On a weaker form of RC-continuity, Analele Univ. Vest Din Timisoara, Seria Mathematica-Informatica, XLII (fasc.1): 79-91 (2004).
9. Ekici, E**.** Generalization of perfectly continuous, regular set-connected and clopen functions, *Acta Mathematica Hungarica.,* 107 (3): 193-206 (2005).
10. Levine, N. Generalized closed sets in topology, Rend. Circ. Math. Palermo, 19(2), 89-96 (1970).
11. Levine, N. Semi-open sets and semi-continuity in topological spaces. *Amer. Math. Monthly,* 70: 36-41 (1963).

12. Maki, H., R. Devi & K. Balachandran. Associated topologies of generalized α -closed sets and α -generalized closed sets. *Mem. Fac. Sci. Kochi. Univ. Ser. A. Math.,* 15: 51-63 (1994).
13. Nagaveni, N. Studies on generalizations of homeomorphisms in topological spaces. Ph.D. thesis, Bharathiar University, Coimbatore (1999).
14. Njastad, O. On some classes of nearly open sets, Pacific J. Math., 15, 961-970 (1965).
15. Noiri, T. Super-continuity and some strong forms of continuity. Indian *J. Pure Appl. Math.,* 15(3), 241-250 (1984).
16. Ravi, O. & S. Ganesan. $\ddot{g}$ -closed sets in topology. *International Journal of Computer Science and Emerging Technologies,* 2 (3), 330-337 (2011).
17. Ravi, O. & S. Ganesan. $\ddot{g}$ -interior and $\ddot{g}$ -closure in topological spaces. *Bessel J. Math.,* (in press).
18. Ravi, O. & S. Ganesan. On $\ddot{g}$ -continuous functions in topological spaces. *International Journal of Advances in Pure and Applied Mathematics* (in press).
19. Ravi, O. & S. Ganesan. $\ddot{g}$ -closed and $\ddot{g}$ -open maps in topological spaces, *Archimedes Journal of Mathematics* (in press).
20. Ravi, O., S. Ganesan, & J. Sivasakthivel. ($\ddot{g}$, s)-continuous functions between topological spaces. (submitted).
21. Ravi, O., S. Ganesan, & S. Chandrasekar. On weakly πg-closed sets in topological spaces, *Italian Journal of Pure and Applied Mathematics* (in press).
22. Stone, M. Application of the theory of Boolean rings to general topology. *Trand Amer. Math. Soc.,* 41: 374-481 (1937).
23. Sundaram, P. & N**.** Nagaveni. On weakly generalized continuous maps, weakly generalized closed maps and weakly generalized irresolute maps in topological spaces. *Far East J. Math. Sci.,* 6(6): 903-912 (1998).
24. Sundaram, P., H. Maki, & K. Balachandran. Semi-generalized continuous maps and semi-$T_{1/2}$-spaces. *Bull. Fukuoka Univ. Ed. III,* 40: 33-40 (1991).
25. Zaitsav, V. On certain classes of topological spaces and their bicompactifications. *Dokl. Akad. Nauk SSSR,* 178: 778-779 (1968).

Proceedings of the Pakistan Academy of Sciences, 48 (4): 251-260 (2011)

ISSN: 0377 - 2969
Pakistan Academy of Sciences

Review Article

Historical Variations in the Specialized Subjects of the Elected Fellows of the Pakistan Academy of Sciences

Shafiq Ahmad Khan[1] and M.M. Qurashi[2]

[1] 4-A, PCSIR, ECHS, Phase-1, Canal Bank Road, Lahore
[2] Pakistan Association for History & Philosophy of Sciences, c/o Pakistan Academy of Sciences, Sector G-5/2, Constitution Avenue, Islamabad

Abstract: The Pakistan Academy of Sciences (PAS) was inaugurated on 16th February 1953 by the then Prime Minister of Pakistan, Khawaja Nazim-ud-Din. The Academy is a non-governmental and non-political supreme body of distinguished scientists, to which the Government has entrusted the consultative and advisory status. The affairs of the Academy are regulated by its Charter and the Bye-Laws approved by its Fellows who are elected through the prescribed procedure. Since its establishment, the Academy has elected 162 scientists belonging to all branches of science as its Fellows during a period of 58 years (i.e., 1953-2010) at an average of 2.8 Fellows per year. However, no Fellows were elected for 10 years (i.e., 1955, 1960, 1962, 1963, 1965, 1969, 1975, 1981, 1985 and 1987) and, therefore, the average induction-rate works out to be about 3.5 Fellows per year during a period of 48 years. A comparison of the number of Fellows elected per decade during 50 years (i.e.,1961-2010) in physical and bio-sciences is provided and depicted graphically, showing the variation trend regarding the specialized fields of the elected Fellows for the studied five decades.

Keywords: Pakistan Academy of Sciences, elected Fellows, non-governmental, non-political, charter, bye-laws, physical and bio-sciences

INTRODUCTION

Establishment of the Academy

Soon after the creation of Pakistan in August 1947, the idea of establishing Pakistan Academy of Sciences was mooted in November 1947, at the first National Educational Conference held at Karachi. Subsequently, the following nine senior and eminent scientists were elected as Foundation Fellows of the proposed Academy:

1. Prof. M. Afzal Hussain
2. Dr. Nazir Ahmad
3. Prof. Dr. Bashir Ahmad
4. Prof. Dr. M. Qudrat-e-Khuda
5. Prof. Dr. Salimuzzaman Siddiqui
6. Prof. Dr. Razi-ud-Din Siddiqui
7. Dr. M. Sharif
8. Prof. Dr. Hamid Khan Bhatti
9. Dr. M. Ishaque

The constitution of the Academy was drafted by Dr. M. Razi-ud-Din Siddiqui, one of the Foundation Fellows, and was approved during the fifth Pakistan Science Conference at Lahore. The Foundation Fellows elected Prof. M. Afzal Hussain as the President and Prof. Dr. Razi-ud-Din Siddiqui as the Secretary of the Academy on 19th February, 1953.

Status of the Academy

The Pakistan Academy of Sciences is a non-governmental and non-political supreme scientific body of distinguished scientists in the country. The Government of Pakistan has entrusted the consultative and advisory status to the Academy "on all problems relating to the development of scientific efforts in the country", and "generally on such matters of national and international importance in the field of science as may be referred to the Academy" [1].

Received December 2011, Accepted March 2012
*Corresponding author: Shafiq Ahmad Khan

The Council of the Academy

The affairs of the Academy are regulated by its Charter and the Bye-Laws approved by the Fellows. The Academy is governed by a 15-Member Council that is composed of 13 Fellows elected by the majority of the living Fellows and 2 Fellows nominated, one each by the Ministry of Education and the Ministry of Science & Technology, Government of Pakistan. The Academy is the largest national constellation of scientists belonging to almost all the scientific fields / subjects. Its Fellows, with brilliant careers spread over a considerable period, are elected through a long drawn process as laid down in the Bye-Laws of the Academy. They have the capability and capacity, individually and collectively, to develop the Academy as a pool of scientific expertise (gained through diverse experience in their careers) to render independent opinion in matters where science can be of any assistance to the policy makers. As an example, the Councils of the Academy for the period 2007-2010 are given in Table 1.

Table 1. Councils of Pakistan Academy of Sciences for the Biennia 2007-2010.

Office	2007-2008	2009-2010
President	Dr. Ishfaq Ahmad	Dr. Ishfaq Ahmad
Vice President	Dr. Manzoor-ul-Haq Hashmi	Prof. Dr. Khalid Mahmood Khan
	Prof. Dr. Syed Irtifaq Ali	Prof. Dr. Rafiq Ahmad
Secretary General	Maj. Gen. (R) Iftikhar A. Malik	Prof. Dr. M. Qasim Jan
Treasurer	Prof. Dr. M.D. Shami	Prof. Dr. G.A. Miana
Associate Secretary General	Prof. Dr. M. Qasim Jan	Prof. Dr. M.D. Shami
Members	Prof. Dr. Nasir-ud-Din	Prof. Dr. Nasir-ud-Din
	Dr. Hameed Ahmad Khan	Prof. Dr. Imtiaz Ahmad
	Prof. Dr. M. Ashraf	Prof. Dr. M. Ashraf
	Prof. Dr. Viqar-ud-Din Ahmad	Prof. Dr. M. Ajmal Khan
Member nominated by M/O Science & Technology	Prof. Dr. Khalid M. Khan	Prof. Dr. Sheikh Riazuddin
Member nominated by M/O Education	Dr. Samar Mubarakmand	Dr. Amir Muhammed
Secretary for Karachi Chapter	Prof. Dr. M. Ajmal Khan	Prof. Dr. M. Iqbal Choudhry
Secretary for Lahore Chapter	Prof. Dr. M. Salim Akhtar	Prof. Dr. M. Salim Akhtar
Secretary for Peshawar Chapter	Prof. Dr. G.A. Miana	Prof. Dr. G.A. Miana

The Charter of the Pakistan Academy of Sciences enlists the following 10 aims and objectives of the Academy:

- To promote higher studies and research on pure and applied sciences in Pakistan and to disseminate scientific knowledge.
- To formulate standards of scientific effort and achievement in Pakistan and to recognize outstanding contributions to the advancement of science.
- To publish and assist in the publication of Scientific Proceedings, Journals, Transactions, Monographs, Books and other scientific literature.
- To establish and maintain association and relations between Pakistani scientists and the international groups, meetings and unions of scientists and between Pakistani scientific activities and the activities of scientists in other countries.
- To award grants, scholarships, fellowships, prizes and medals for scientific research.
- To undertake such scientific work of national or international importance as the Academy may be called upon to perform by the Government.
- To have the advisory and consultative status with the Ministries and Divisions of Government dealing with scientific and technical matters, and to represent internationally the scientific work of Pakistan.
- To secure and administer funds, endowments and other grants for the promotion and development of scientific research or projects of a scientific nature, and for the attainment of the aims and objectives of the Academy.
- To co-relate and assist in co-relating the efforts of other scientific bodies.
- To do all other lawful things that the Academy may consider conducive to or necessary for the attainment of its aims and objectives.

Purpose of the Present Study

The present study / report is an attempt to analyze, both qualitatively and quantitatively, the variations in the scientific fields of the elected scientists as there appears to be an increased induction of the scientists from the bio-sciences compared to those from the physical sciences. This was desirable as their achievements, studied earlier were considered and analyzed in detail [2, 3].

DATA REGARDING FELLOWS OF THE PAS

As mentioned in the preceding paragraph, the procedure for the election of Fellows, Members and Foreign Fellows is well laid down in the Bye-Laws of the Academy. Accordingly, the list of the elected Fellows, since the establishment of the Academy (in 1953) till 2010 is provided in Table 2. The Table also contains the year of birth / death (for the deceased Fellows), ages at election and death, the year of election of the Fellow, subject of specialization and the number of Fellows elected in any year (year-wise). The missing years in the Table indicate that no Fellows were elected in those years (i.e. 1955, 1960, 1962, 1963, 1965, 1969, 1975, 1981, 1985 and 1987). The division of the elected Fellows into physical and biosciences per decade is provided in Table 3 and the same data is depicted graphically in Fig. 1 for better understanding of the situation.

Table 2. Elected and deceased Fellows of the Pakistan Academy of Sciences.

Sr. No.	Name of Fellow	Year of Birth / Death	Year of Election	Age at Election	Age at Death	Subject of Specialization
1	Prof. M. Afzal Hussain	1889-1970	1953	64	81	Zoology
2	Dr. Nazir Ahmad	1898-1973	1953	55	75	Physics
3	Prof. Dr. Bashir Ahmad	1902-1957	1953	51	55	Bio-chemistry
4	Prof. Dr. Salimuzzaman Siddiqui	1897-1994	1953	56	97	Chemistry
5	Prof. Dr. Raziuddin Siddiqui	1905-1998	1953	45	93	Physics
6	Prof. Dr. M. Sharif	1899-1965	1953	54	66	Education
7	Dr. M. Qudrat-e-Khuda	1900-1977	1953	53	77	Chemistry
8	Prof. Dr. Hamid Khan Bhatti	1895-1980	1953	58	85	Zoology
9	Dr. M. Ishaque	1902-1960	1953	51	58	Physics
10	Ch. Muhammad Afzal	1902-1991	1954	52	89	Agriculture
11	Prof. Dr. Abdus Salam	1926-1996	1954	28	70	Physics / Mathematics
12	Prof. Dr. M. O. Ghani	--- ---	1954	---	---	Chemistry
13	Dr. Taskhir Ahmad	1905-1991	1954	49	86	Botany
14	Dr. M. Abdussalam	1913 ---	1954	41	---	Vet. Sciences
15	Prof. Dr. Karimullah	1903-1998	1956	53	95	Chemistry
16	Col. M. K. Afridi	1900-1968	1956	56	68	Medical Sciences
17	Dr. S. Hedayatullah	1905- ---	1956	51	---	
18	Prof. Dr. M. Afzal Hussain Qadri	1912-1974	1956	44	62	Zoology
19	Prof. Dr. M.Q. Hussain	--- ---	1957	---	---	
20	Dr. Qazi M. Aslam	1900-1981	1957	57	81	Philosophy
21	Prof. Dr. Rafat Hussain Siddiqui	--- ---	1957	---	---	Chemistry
22	Dr. Nazir Ahmad	1910-1985	1958	48	75	Zoology/ Fisheries
23	Prof. Dr. Mukarram Hussain	1922-1972	1959	37	50	Chemistry
24	Prof. Dr. M. Ziauddin	--- ---	1959	---	---	Statistics
25	Dr. Atiqur Rehman Ansari	1911-1979	1959	48	68	
26	Prof. Dr. M. Annas Ali	--- ---	1959	---	---	Physics
27	Prof. Dr. Qazi Saeed-ud-Din Ahmad	1904-1970	1961	57	66	Geography
28	Prof. Dr. Kamal-ud-Din Ahmad	--- ---	1961	---	---	Chemistry
29	Dr. A. G. Asghar	1902-1979	1964	62	77	Chemistry
30	Prof. Dr. S. D. Chowdri	1922 ---	1964	42		
31	Prof. Dr. M.M. Qurashi	1925-2011	1964	39	86	Physics
32	Prof. Dr. M. A. Azim	1910-1987	1966	56	73	Chemistry
33	Dr. Amir-ul-Islam	--- ---	1967	---	---	
34	Prof. Dr. M. I. D. Chughtai	1919-2006	1967	48	87	Bio-chemistry
35	Dr. M.A. Ghani	1915 ---	1967	52		Agriculture
36	Dr. Ghulamullah Chaudhry	1913-1990	1967	54	77	
37	Prof. Majeed Ahmad	1916-1981	1968	52	65	Botany
38	Prof. Dr. Rafi Muhammad Chaudhry	1903-1988	1968	65	85	Physics
39	Prof. Dr. Badruddin	1911-1983	1968	57	72	Chemistry
40	Dr. Nazir Ahmad)	1910-2000	1968	58	70	Engineering
41	Prof. Dr. Mufizuddin Ahmad	1918 ---	1968	50		Physics

Table 2. (contd.)

Sr. No.	Name of Fellow	Year of Birth / Death	Year of Election	Age at Election	Age at Death	Subject of Specialization
42	Prof. Dr. Muzaffar Ahmad	1920 ---	1970	50		Zoology
43	Dr. S. A. Warsi	1916-1983	1970	54	67	Chemistry
44	Dr. S. M. A. Haque	--- ---	1970	---	---	Chemistry
45	Dr. Nurul Islam	--- ---	1970	---	---	Chemistry
46	Prof. Dr. Shafqat Hussain Siddiqui	1922-1985	1971	49	63	Chemistry
47	Dr. Ahmad Kamal	1914-1975	1971	57	61	Chemistry
48	Dr. M. A. Kazi	1928-1999	1972	44	71	Chemistry
49	Prof. Dr. Z. A. Hashmi	1914-1990	1972	58	76	Biology
50	Prof. Dr. Kh. Salahuddin	1912-1974	1972	60	62	Chemical Engineering
51	Dr. M. Aslam Khan	1926-1998	1972	46	72	Physics
52	Dr. M. K. Bhatty	1929-1990	1972	43	61	Chemistry
53	Dr. M. H. Hashmi	1928 ---	1973	45		Chemistry
54	Lt. Col. Dr. M. H. Shah	1902-1979	1973	71	77	Medical Sciences
55	Mr. M. Aslam	1924 ---	1974	50		Chemical Engineering
56	Prof. Dr. Sultan Ahmad	1911-1984	1974	63	73	Botany
57	Prof. Dr. Q. K. Ghori	1932-2009	1974	42	77	Mathematics
58	Prof. Dr. Ahmad Mohiuddin	1923-1998	1974	51	75	Zoology
59	Dr. Riaz Ali Shah	1924 ---	1974	50		Chemistry
60	Dr. Yousaf Ahmad	1928-2008	1976	48	80	Chemistry
61	Dr. Riaz-ud-Din	1937 ---	1976	39		Mathematics
62	Dr. S. Marghoob Ali	1927-1980	1976	49	53	Chemistry
63	Mr. A. S. Chotani	1923-2004	1976	53	81	Chemical Engineering
64	Prof. Dr. Fayyazuddin	1931 ---	1977	46		Physics
65	Prof. Dr. A. G. Kausar	1923-1980	1977	54	57	Agriculture
66	Dr. T. H. Hashmi	1923 ---	1977	54		Engineering
67	Dr. M. Saleh Quraishy	1909-1981	1977	68	72	
68	Dr. G. M. Khattak	1924 ---	1977	53		Botany
69	Dr. F. A. Farooqui	1927-2010	1978	51	83	Chemistry
70	Dr. Heshamul Haque	1928-1994	1978	50	66	Agriculture
71	Prof. Dr. K. M. Ibne Rasa	1926 ---	1979	53		Chemistry
72	Dr. Amir Muhammed	1930 ---	1979	49		Bio-chemistry
73	Dr. S. Mahdi Hassan	1892-1992	1980	88	100	Biology
74	Dr. M. Atta-ur-Rahman	1929 ---	1980	51		Bio-chemistry
75	Prof. Dr. Mrs. Nasima Tirmazi	1933-2005	1980	47	72	Zoology
76	Prof. Dr. M. D. Shami	1930 ---	1982	52		Chemical Engineering
77	Prof. Dr. Atta-ur-Rahman	1942 ---	1982	40		Chemistry
78	Prof. Dr. Irtifiq Ali	1930 ---	1982	52		Botany
79	Dr. Ishfaq Ahmad	1930 ---	1983	53		Physics
80	Maj. Gen. M. D. I. Burney	1922-2008	1983	61	86	Medical Sciences
81	Prof. Dr. R. A. K. Tahir Kheli	1928 ---	1983	55		Earth Sciences
82	Dr. F. H. Shah	1931-1994	1984	53	63	Bio-chemistry
83	Dr. Naeem Ahmad Khan	1928 ---	1986	58		Physics
84	Dr. Mahboob Ali	1923 ---	1988	65		Agriculture

Table 2. (contd.)

Sr. No.	Name of Fellow	Year of Birth / Death	Year of Election	Age at Election	Age at Death	Subject of Specialization
85	Dr. A. Q. Khan	1936 ---	1988	52		Engineering
86	Dr. N. M. Butt	1936 ---	1989	53		Physics
87	Prof. Dr. Rafiq Ahmad	1927 ---	1989	62		Botany
88	Dr. Abdul Hafiz	1915-2001	1989	74	86	Agriculture
89	Dr. M. S. Bokhari	1928-1990	1989	61	62	Physics
90	Dr. Shafiq Ahmad Khan	1935 ---	1989	54		Chemistry
91	Maj. Gen. Dr. Iftikhar Malik	1936-2008	1989	54	72	Medical Sciences
92	Prof. Dr. Imtiaz Ahmad	1941 ---	1990	49		Zoology
93	Dr. Hameed Ahmad Khan	1942 ---	1990	48		Physics
94	Prof. Dr. M. Zafar Iqbal	1942 ---	1990	48		Chemistry
95	Prof. Dr. M. Qasim Jan	1944 ---	1990	46		Earth Sciences
96	Prof. Dr. Viqaruddin Ahmad	1940 ---	1991	51		Chemistry
97	Dr. Mushtaq Ahmad	1910-1992	1991	80	82	Bio-chemistry
98	Prof. Dr. N. M. Awan	1942-1994	1991	49	53	Engineering
99	Prof. Dr. Ghulam Murtaza	1939 ---	1991	52		Physics
100	Hakim Muhammed Said	1920-1998	1991	71	78	Medical Sciences
101	Prof. Dr. Abdul Rauf Shakoori	1942 ---	1991	49		Zoology
102	Dr. Arshad M. Khan	1938 ---	1992	54		Physics
103	Dr. Agha Ikram Mohyuddin	1932-1998	1992	60	66	Agriculture
104	Prof. Dr. Asghar Qadir	1942 ---	1992	46		Mathematics
105	Prof. Dr. Abdul Ghaffar	1932 ---	1992	60		Botany
106	Prof. Dr. M. Arslan	1936 ---	1994	58		Zoology
107	Dr. Khushnood Ahmad Siddiqui	1937-2009	1994	57	72	Botany
108	Dr. Iqbal Hussain Qureshi	1936 ---	1994	58		Chemistry
109	Dr. Kauser Abdulla Malik	1945 ---	1995	50		Biology
110	Dr. Muhammad Anwar Waqar	1941-2010	1995	54	69	Bio-chemistry
111	Dr. Anwar-ul-Haq	1947 ---	1996	49		Engineering
112	Dr. M. Aslam Baig	1950 ---	1996	46		Physics
113	Dr. Nasir-ud-Din	1937 ---	1996	59		Bio-chemistry
114	Dr. Muhammad Zakaria Butt	1949 ---	1997	52		Physics
115	Dr. Ijaz Haider	1941 ---	1997	56		Medical Sciences
116	Dr. Riaz-ud-Din Sheikh	1944 ---	1997	53		Biology
117	Dr. Bina Shaheen Siddiqui	1948 ---	1997	49		Chemistry
118	Dr. M. Waheed Akhtar	1944 ---	1998	54		Bio-chemistry
119	Dr. Saleem Asghar	1947 ---	1998	51		Mathematics
120	Dr. M. Zafar Iqbal	1949 ---	1998	49		Physics
121	Dr. Ghulam Abbas Miana	1939 ---	1998	59		Chemistry
122	Dr. Syed Qasim Mehdi	1941 ---	1999	58		Bio-Technology
123	Dr. Muhammad Saleem	1937 ---	1999	62		Medical Sciences
124	Dr. M.A. Hafeez	1937-2010	1999	62	73	Biology
125	Dr. Nisar Ahmad	1942 ---	1999	57		Physics
126	Dr. S. Moosa Hasany	1942-2007	2000	58	65	Chemistry
127	Dr. Muhammad Ashraf	1953 ---	2000	47		Agriculture
128	Dr. Muhammad Salim Akhter	1936 ---	2001	65		Medical Sciences
129	Dr. Mashooda Hassan	1939 ---	2001	62		Chemistry

Table 2. (contd.)

Sr. No.	Name of Fellow	Year of Birth / Death	Year of Election	Age at Election	Age at Death	Subject of Specialization
130	Dr. Muhammad Ajmal Khan	1953 ---	2001	48		Botany
131	Dr. Kamal-ud-Din Ahmad	1939 ---	2002	63		Physics
132	Dr. Anwar-ul-Hassan Gilani	1955 ---	2002	47		Vet. Sciences
133	Dr. M. Perwaiz Iqhal	1942 ---	2002	60		Bio-chemistry
134	Dr. Khalid Mahmood Khan	1941 ---	2002	61		Bio-chemistry
135	Dr. Shaukat Hameed Khan	1941 ---	2002	61		Physics
136	Dr. M.Y.H. Bangash	1932 ---	2003	71		Engineering
137	Dr. Muhammad Iqbal Chaudhry	1959 ---	2003	44		Chemistry
138	Dr. Samar Mubarak Mand	1942 ---	2003	61		Physics
139	Dr. Shahzad A. Mufti	1942 ---	2003	61		Zoology
140	Dr. Riaz H. Qureshi	1943 ---	2003	60		Agriculture
141	Dr. Muhammad Nawaz Chaudhry	1942 ---	2004	62		Earth Sciences
142	Dr. Muhammad Qaisar	1946 ---	2004	58		Botany
143	Dr. Mustafa Shameel	1941 ---	2005	64		Biology
144	Dr. Azra Khanum	1949 ---	2005	56		Bio-chemistry
145	Dr. Ahmad Mukhtar Khalid	1942 ---	2005	63		Bio-Technology
146	Dr. Muhammad Ashfaq	1952 ---	2006	54		Agriculture
147	Dr. Ikram-ul-Haq	1952 ---	2006	54		Bio-Technology
148	Dr. Tasawar Hayat	1969 ---	2006	37		Mathematics
149	Dr. Rabia Hussain	1946 ---	2006	60		Biology
150	Dr. Fazal Ahmad Khalid	1957 ---	2007	50		Engineering
151	Dr. Muhammad Luqman	1950 ---	2007	57		Medical Sciences
152	Dr. Iqrar Ahmad Khan	1953 ---	2007	54		Agriculture
153	Dr. Ismat Beg	1951 ---	2008	57		Mathematics
154	Dr. Z.A. Bhutta	1955 ---	2008	53		Medical Sciences
155	Dr. Muhammad Aslam Khan	1945 ---	2008	63		Physics
156	Dr. Zabta Khan Shinwari	1959 ---	2008	49		Botany
157	Prof. Dr. M. Asif Khan	1954 ---	2009	55		Geology
158	Prof. Dr. Raheel Qamar	1962 ---	2009	47		Biology
159	Prof. Dr. Wasim Ahmad	1957 ---	2010	50		Biology
160	Prof. Dr. Khalid Mohammad Khan	1960 ---	2010	50		Chemistry
161	Prof. Dr. Asghari Maqsood	1947 ---	2010	63		Physics
162	Prof. Dr. Muhammad Sharif	1962 ---	2010	48		Mathematics

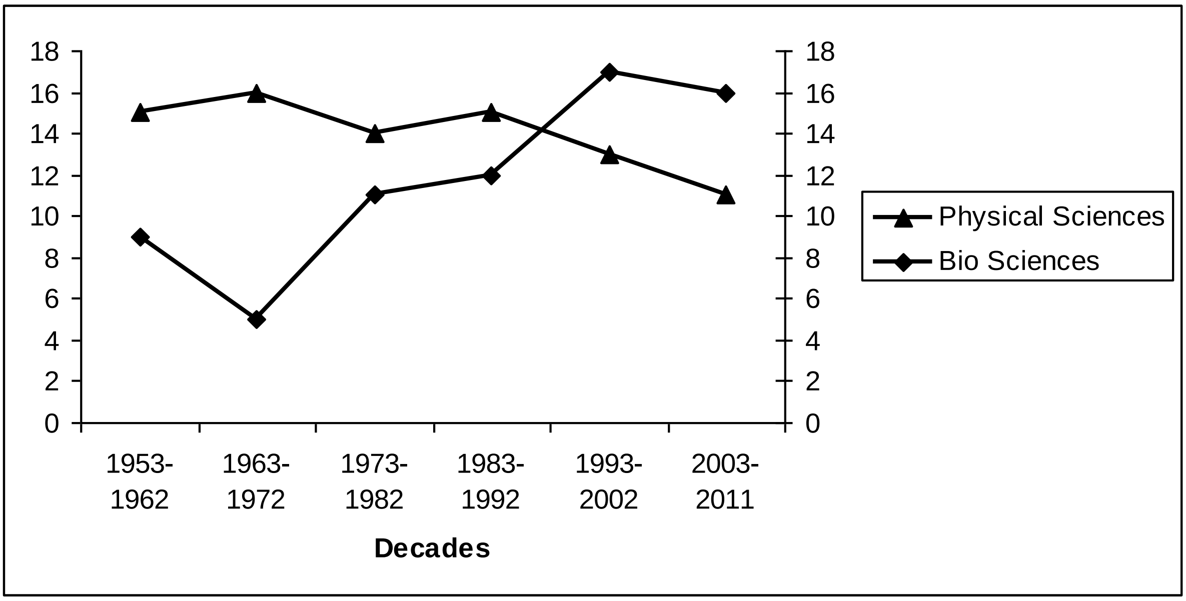


Fig. 1. Division of elected Fellows in physical and bio-sciences.

ANALYSIS OF THE DATA

Table 3. Division of elected Fellows in physical and bio-sciences during various decades.*

Decade	Physical Sciences	Bio-sciences
1953-1962	17	9
1963-1972	16	6
1973-1982	15	11
1983-1992	15	11
1993-2002	13	17
2003-2011	11	14
Total	**87**	**68**

***Notes:**
1. The Table provides the division of the elected Fellows per decade into physical and bio-sciences.
2. The Table includes 136 elected Fellows of the Pakistan Academy of Sciences over a period of 50 years, i.e., 1961-2010.
3. The Table does not contain comprehensive information concerning the 33 scientists elected as Fellows of the Academy.

Observations on the Data in Table 2

The Pakistan Academy of Sciences, since its establishment in 1953 till 2010, has elected 162 scientists as its Fellows during a period of 58 years, at an average of 2.80 scientists per year. However, in fact, there were no Fellows elected / inducted for the 10-year period, as stated already under section 1.4, and therefore the *average induction-rate* works out to be about 3.5 scientists per year, during a period of 48 years. A closer look at Table 1 further reveals that there were only 2 inductions in 1961, 3 in 1964, 1 in 1966, 2 in 1971, 2 in 1973, 2 in 1979, 1 in 1984, 1 in 1986, 2 in 1988, 2 in 1994, 2 in 1995, 2 in 2000, 2 in 2001 and 2 in 2009; while in all other years the number of elected fellows was three or more throughout. The reason for no elections in earlier years and low number of inductions could very well be attributed to the less availability of the recognizable scientists, as the country was in the process of establishing R&D and S&T institutions, along-with strengthening the scientific departments of the universities. A separate and detailed study could perhaps bring out the factual basis for this phenomenon, to throw better light on the various issues.

Observations on the Data in Table 3

Data regarding subject-wise division (into physical sciences and bio-sciences) of the elected Fellows of the Pakistan Academy of Sciences per decade from 1953 to 2010 (for a period of 58 years**)** is provided in Table-3. These data concern the 154 elected Fellows of the Academy over a period of 5 decades (i.e., 1953-2010). It can be seen from this Table that during the earlier three decades the number of elected

Fellows belonging to physical sciences was almost double the number of the elected Fellows belonging to biosciences (i.e., 2:1 ratio). In the later two decades, however, the situation changed, as the ratio works out to be about 1:1.3 in favor of biosciences. One reason for this change could be traced in the increasing number of scientist returning from abroad, after obtaining training in the emerging biosciences fields, and continuing their researches in the home country. Resultantly they formed new research groups and brought out large number of publications and thus earned recognition to be elected as Fellows of the Academy. This reason is well supported by the already published fact that, in the last two decades, the universities share for the elected Fellows of the Pakistan Academy of Sciences was more than that from the R&D organizations [3]. Another possible reason for this trend could be the enhanced financial allocations for the universities made by the Higher Education Commission (HEC) that helped the scientists to obtain grants from the HEC for their research projects and produce recognizable results in their publications.

These interesting conclusions deserve to be extended to other fields and locations, in Pakistan, in order to study the gradual change in emphases from the physical sciences towards the biological, environmental and ecological sciences. Training/education at graduate level may also be worth examining.

It is, however, hoped that more serious and coordinated efforts are made to strengthen the R&D and S&T base in the country, both in the public as well as the private sectors, so that science plays its due role in effectively raising the standard of living in the country.

Age of the Elected Fellows

The Pakistan Academy of Sciences elected 162 Fellows during the 58 year period (i.e. 1953-2010) and 60 (i.e., 37% of the total elected Fellows) have died. Their years of birth / death, election and ages at election and death are listed in Table 1, and the frequency of deaths between the ages of 51-60, 61-70, 71-80, 81-90 and 91-100 years works out to be 6, 19, 20, 12 and 3 numbers. Similarly, their age-groups at the time of election are represented in the first column of Table 4, during different decades, as under:

Table 4. Age distribution of Fellows of the Academy elected during 1953-94 and 1995-2010.*

Age groups (in years) at the time of election	Number of Fellows elected in periods	
	1953-1994 (42 years)	1995-2010 (16 years)
21-30	1	-
31-40	3	1
41-50	27	14
51-60	46	24
61-70	10	15
71-80	2	1
81-90	1	-
Total	**90**	**55**

***Note:** The total number of elected Fellows during the 58-year period (i.e., 1953-2010), excluding the nine Foundation Fellows, works out to be 138. Out of this total, the largest number of Fellows (i.e., 68) was in the age group of 51-60 years at the time of election, followed by 38 in the age group of 41-50 years, 25 in the age group of 61-70 years, 4 in the age group of 31-40 years, 3 in the age group of 71-80 years and one each in the age groups of 21-30 years and 81-90 years, respectively.

CONCLUSIONS

In conclusion, it is observed that the Pakistan Academy of Sciences has been electing Fellows according to its bye-laws, for the fulfillment of its declared aims and objectives. The elected Fellows are recognized / decorated scientists whose contributions to science have been acknowledged through their election to the highest, most prestigious and coveted scientific body of the country, i.e., the Pakistan Academy of Sciences (PAS). They represent almost all branches of science, including physical, biological and earth, etc., etc., and have remained working scientists in the S&T and R&D sectors and the scientific departments of the universities. Majority of them have also served in diverse capacities at various responsible positions, including scientific administration, during the pursuit of their scientific careers.

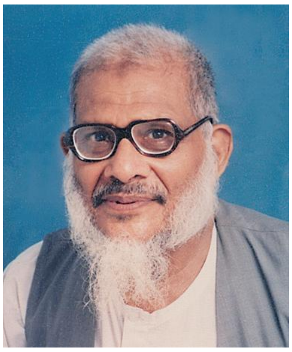
REFERENCES

1. Year Book, 2008-2009. Pakistan Academy of Sciences. Islamabad (2010).
2. Khan, Shafiq Ahmad, Shireen Taj and G.H.R. Baluch. Aspects of publications of some recognized Pakistani scientists. *Proceedings of Pakistan Academy of Sciences*, 33: 105-114 (1996).
3. Khan, Shafiq Ahmad, Aspects of publications of some Pakistani scientists, Part-II. *Proceedings of Pakistan Academy of Sciences*, 47(3): 171-180 (2010).

Proceedings of the Pakistan Academy of Sciences, 48 (4): 261-262 (2011)

ISSN: 0377 - 2969

Pakistan Academy of Sciences



OBITUARY

Prof. Dr. Mazhar Mahmood Qurashi
(1925-2011)

Man is Mortal. Every one of us, no matter how strong, intelligent or genius, has to depart to the next world when his divined moment approaches.

Dr. M.M. Qurashi, a genius scientist and super activist of *Tablighi Jamat*, was born in Gujrat in 1925. He earned his BA (Hons) in English and MSc in Physics (1944) from the University of Punjab and stood first in the University – a rare distinction for a Muslim student at that time. He possessed first class academic career, from Matriculation to MSc. Later, he obtained PhD (Experimental Solid-State Physics) (X-Ray Crystallography) from the University of Manchester, UK in 1949. He was also awarded DSc in 1962 by the University of Manchester on the basis of about 50 research papers published by him from 1949 to 1962. Probably, he was the first Pakistani to receive a DSc degree in Physics.

Dr. M.M. Qurashi was the first employee of the Pakistan Council of Scientific and Industrial Research (PCSIR) that came into being in 1953, where he held various positions from Research Officer to Chief Scientific Officer, from 1950 to 1985. During this period he also held positions of Member (Science) in PCSIR, Chief Scientist in Defense Science Organization and Director of PCSIR Laboratories at Peshawar and Karachi. He also served as Professor of Physics in Quaid-i-Azam University, Islamabad and Director General – Appropriate Technology and Director of Studies in National Science Council, Islamabad (1985-88).

Dr. M.M. Qurashi received various honors and awards during his service, which included: Fellowship of the Institute of Physics in 1961; Fellowship of Pakistan Academy of Sciences in 1964; General Presidentship of Scientific Society of Pakistan in 1968-69; Open Gold Medal of Pakistan Academy of Sciences in 1972; Fellowship of the Islamic World Academy of Sciences in 1988; *Sitara-e-Imtiaz* by the Government of Pakistan in 1992; Incharge of a Project on "Science & Technology in the Muslim Ummah" of the Pakistan Academy of Sciences during 1988-1992; and Secretary of Pakistan Association of History and Philosopy of Science (1988-92) and its Vice President (2010-11).

Dr. M.M. Qurashi was interested in many and variable aspects of scientific disciplines and made worthwhile contributions in these fields. His publications appeared in local as well as international journals (British, Canadian, etc.) and their number exceeds 300. Additionally, he also published over a dozen Monographs on the under mentioned topics:

1. Study of atomic and molecular arrangements in alloys and minerals.
2. Accurate measurement of flow activation energy for viscous flow of pure liquids and aquous solutions.
3. Studies in the free energy of mixing of phenolic compounds with straight-chain hydrocarbon.
4. Operation research and scientometric studies.

5. Studies on History of Science, Islamic Contributions and Motivation (Quran and Science).

Dr. Qurashi supervised more than 30 PhD and MSc students in a subject of this own creation. He served as Editor of "Proceedings of the Pakistan Academy of Sciences", published by Pakistan Academy of Sciences; "Science Technology and Development", published by Pakistan Council of Science & Technology; and "Science Vision", published by COMSATS. He also served on the Editorial Boards of the PCSIR's Journal ,"Pakistan Journal of Scientific and Industrial Research", and "Pakistan Journal of History and Philosophy of Science" of the Pakistan Association for History and Philosophy of Science.

In addition to being an eminent scientist, Dr. M.M. Qurashi was a devoted religious scholar, who practiced Islam in his daily life. He spent one to three months every year on *Tabligh* Missions inside the country and abroad. He was a thorough gentleman of simple habits and always looked after the welfare of others as his own. He led a disciplined life and advised others to do the same as it helped avoid the stresses and strains of the modern times. A pleasant aspect of his life was his passion for jokes, of all types, and it should not sound strange as he had only this 'entertainment' in his rather tight and busy schedule of thinking and practicing.

Dr. M.M. Qurashi, a man of courage, unimpeachable integrity and indomitable will, is no more amongst us. There is no hope either that anyone with even a fraction of his genius will ever come to help the national R&D structure and to play a role in strengthening the national development through technological innovations.

May Allah Almighty rest his soul in eternal peace *(Ameen).*

Shafiq Ahmad Khan, Syed Riaz Ali Shah, and Muhammad Aslam
Fellows of Pakistan Academy of Sciences

Proceedings of the Pakistan Academy of Sciences

Instructions for Authors

Purpose and Scope: Proceedings of the Pakistan Academy of Sciences (PPAS) is official journal of the Academy, published quarterly, in English. PPAS publishes original research papers in Engineering Sciences & Technology, Life Sciences, Medical Sciences**,** and Physical Sciences. State-of-the-art reviews (~ 20 pages, supported by recent references) summarizing R&D in a particular area of science, especially in the context of Pakistan, and suggesting further R&D are also considered for publication. All manuscripts under go double-blind review. Authors are not required to be Fellows or Members of the Pakistan Academy of Sciences or citizens of Pakistan.

Manuscript Format:
Manuscripts, typewritten in Times New Roman **Font Size 11**, double spaced; with one inch margins on all sides on A-4 size paper, should not exceed 20 pages including Tables, Figures and illustrations. Number manuscript pages throughout. *To conserve space, the Instructions are not double spaced and are in font size 10.*

*The manuscripts may contain **Abstract, INTRODUCTION, MATERIALS AND METHODS (or METHODOLOGY), RESULTS, DISCUSSION (or RESULTS AND DISCUSSION), CONCLUSIONS, ACKNOWLEDGEMENTS and REFERENCES** and any other information that the author(s) may consider necessary.*

Title Page: Should carry: (a) Concise **Title** of the article **(**in Initial Capital and then lower case letters for each main word; font size 16; **Bold**), ≤ 160 characters, depicting its contents. Do not use abbreviations or acronyms; (b) Author(s)' first name, middle initial and last name (font size 12, **Bold**), and professional affiliation(s) [i.e., each author's Department, Institution, Mailing address and Email address; but no position titles]; (e) Indicate the corresponding author with *; (d) **Short running title** of ≤ 50 characters.

Second Page should start with the **Title** of the Article, followed by entire manuscript comprising **Abstract, Keywords, INTRODUCTION, MATERIALS AND METHODS, RESULTS, DISCUSSION, ACKNOWLEDGEMENTS, and REFERENCES**.

Headings and Subheadings: All flush left

LEVEL-1: **ALL CAPITAL LETTERS; Bold**
Level-2: **Capital letter for each main word; Bold**
Level-3: Initial Capital and then lower case letters for all words; Bold, italic
Level-4: *Run-in head*; *Italics,* in the normal paragraph position with only an Initial Capital and ending in a colon (i.e., **:**)

Abstract: Must be self-explanatory**,** of 200–250 words (in font size 10), stating rationale, objective(s), methodology, main results and conclusions of the study. Abbreviations, if used, must be defined on first mention in the Abstract as well as in the main text. ABSTRACT of review articles may have variable format, but must be of 200–250 words.

Keywords: Suggest three to eight keywords**,** depicting the article.

INTRODUCTION: Provide a clear and concise statement of the problem, citing relevant literature, and objectives of the investigation.

MATERIALS AND METHODS: Provide an adequate account of the procedures or experimental details, including statistical tests (if any), in a concise manner but sufficient enough to replicate the investigation.

RESULTS: Be clear and concise with the help of appropriate Tables, Figures and other illustrations. Data should not be repeated in Tables and Figures.

DISCUSSION: Provide interpretation of the Results in the light of previous relevant studies, citing published references.

ACKNOWLEDGEMENTS: In a brief statement, acknowledge financial support and other assistance.

REFERENCES: Cite references in the text **by number only** in **square brackets**, e.g. "Brown et al [2] reported ..." or ".. as previously described [3, 6-8]", and list them in REFERENCES section, in the order of citation in the text, Tables and Figures (not alphabetically). Only published (and accepted for publication) journal articles, books, and book chapters qualify for REFERENCES. List of REFERENCES (in font size 10) may be prepared as under:

a. **Journal Articles** *(Name of the journal to be stated in full)*

1. Golding, I. Real time kinetics of gene activity in individual bacteria. *Cell,* 123**:** 1025–1036 (2005).
2. Bialek, W. & S. Setayeshgar. Cooperative sensitivity, and noise in biochemical signaling. *Physical Review Letters,* 100**:** 258–263 (2008).
3. Kay, R.R. & C.R.L. Thompson. Forming patterns in development without morphogen gradients: scattered differentiation and sorting out. *Cold Spring Harbor Perspectives in Biology,* 1: doi: 10.1101/cshperspect.a001503 (2009).

b. **Books**

4. Luellen, W.R. *Fine-Tuning Your Writing*. Wise Owl Publishing Company, Madison, WI, USA (2001).
5. Alon, U. & D.N. Wegner (Eds.). *An Introduction to Systems Biology: Design Principles of Biological Circuits*. Chapman & Hall/CRC, Boca Raton, FL, USA (2006).

c. **Book Chapters**

6. Sarnthein, M.S., & J.D. Stanford. Basal Sauropodomorpha: historical and recent phylogenetic developments. In: *The Northern North Atlantic: A Changing Environment.* Schafer, P.R. & W. Schluter (Eds.), Springer, Berlin, Germany, p. 365–410 (2000).
7. Smolen, J.E. & L.A. Boxer. Functions of Europhiles. In: *Hematology, 4th ed.* Williams, W.J., E. Butler, and M.A. Litchman (Eds.), McGraw Hill, New York, USA, p. 103–101 (1991).

Tables, with concise but comprehensive headings, on separate sheets, must be numbered according to the order of citation (like **Table 1.**, **Table 2.**). If applicable, round off data to the nearest three significant digits. Provide essential explanatory footnotes, with superscript letters or symbols keyed to the data. Do not use vertical or horizontal lines, except for separating column heads from the data and at end of the **Table**.

Figures may be printed in two sizes: (i) column width of 8.0 cm; or (ii) entire page width of 16.5 cm. **Captions to Figures** may be typed on a separate page; number them as **Fig. 1.**, **Fig. 2.**, … in the order of citation in the text. Computer generated, laser printed, **line drawings** or original line drawings made with black ink on white drawing or tracing paper are acceptable. Do not use lettering smaller than 9 points or unnecessarily large. **Photographs**, as glossy prints, must be of high quality. If to form multiple panels on the journal page, they should be mounted and be separated from adjacent photographs by uniform spaces. A scale bar should be provided on all photomicrographs.

Declaration: Provide a declaration that the results are original; approval of all authors has been obtained to submit the manuscript; the same material is neither 'in press' nor under consideration elsewhere, and, in case the article is accepted for publication, its copyright will be assigned to *Pakistan Academy of Sciences*. Authors are responsible for obtaining permission to reproduce copyrighted material from other sources.

Reviewers: Authors must suggest three prospective reviewers, two local and one from a scientifically advanced country, who are expert in the paper's scientific area.

MORE DETAILED INFORMATION can be seen at **website** of the Pakistan Academy of Sciences, i.e., www.paspk.org

Manuscript Submission: Soft copy of the manuscript in **Microsoft (MS) Word,** as e-mail attachment or on a CD, **may be submitted to:**

Editor-in-Chief
Pakistan Academy of Sciences
3-Constitution Avenue, G-5/2, Islamabad, Pakistan
E-mail: pas.editor@gmail.com
Tel: 92-51-9207140
Website: www.paspk.org

Proceedings
OF THE PAKISTAN ACADEMY OF SCIENCES

C O N T E N T S

PAKISTAN ACADEMY OF SCIENCES, ISLAMABAD, PAKISTAN
HEC Recognised, Category X