

# Severo Ochoa Research Seminar : The Journey of Supercomputing in Pakistan

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**Barcelona  
Supercomputing  
Center**

*Centro Nacional de Supercomputación*

# Contents

- **Speaker's Introduction**
- **Supercomputing Trend**
- **Proposals and Marketing Strategy**
- **Research Projects**
- **Achievements**

# Intro: Tassadaq Hussain

## Research Areas:

- High Performance Computing
- Digital System Design
- Machine Learning
- Heterogeneous Computing, based on
  - FPGAs, GPUs and Microprocessors
- Real-time Embedded Vision

## Professional Affiliations

- HiPEAC: European Network on High Performance and Embedded Architecture and Compilation
- Barcelona Supercomputing Center Spain
- Université de Valenciennes France
- Centre of Chiropractic Research New Zealand

PhD – UPC BarcelonaTech Spain  
MS (Digital System Design) – ISEP  
Paris France

## Projects

- 1) Design, Development And Production Of Hardware Based Gel Documentation System For Dna, Rna And Proteins Analysis
- 2) Development of Scalable Heterogeneous Super-computing System
- 3) Low Power Low Cost Supercomputer Architecture for Undeveloped Countries. 2016 UCERD and BlueSurge Pvt Ltd 2.5 Million
- 4) FPGA Powered Supercomputer System Riphah and UCERD
- 5) Iris based Disease Diagnosis System (NRPU-18) 2.52 Million Rs.
- 6) Design Ultra Low Cost Display Camera Interface for Mobile Baseband XGold Chip at Infineon Technologies France.
- 7) Implementation of Reverse Time Migration on FPGAs at PLDA Italia

- Research Grants: (0.6 Million US \$)
  - HEC NRPU 1
  - Technology Development Fund (2)

- Publications: (I.F. 20.2)
  - Referred Top Conferences: 35
  - Book Chapter: 2
  - Journal 15

- Patent: 10

Industrial Experience: (Above 14 Years)



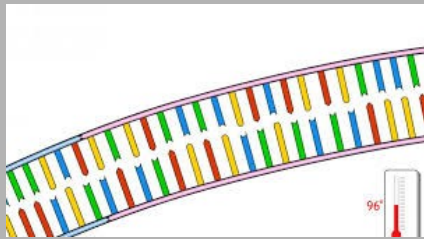
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- **Supercomputing Trend**
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- Research Projects
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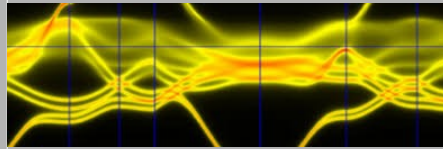
# Why Supercomputer?

- **Representative application domains requiring more than a Desktop PC Performance**

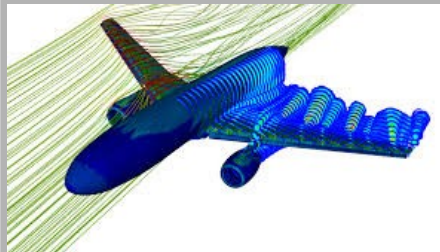
Biomedical  
[ Alpha Genomic ]



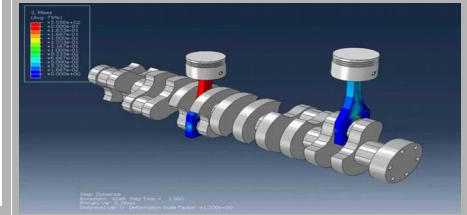
Control and  
Simulation  
[ CUST ]



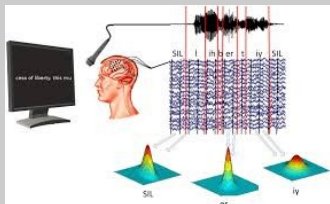
Aerodynamics  
[Risalpur College]



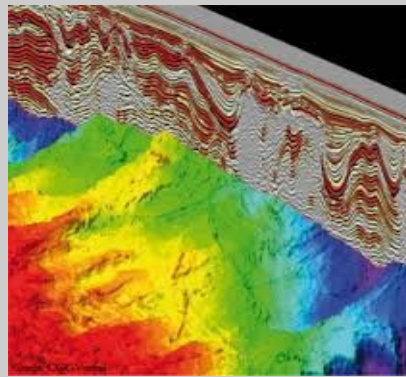
Mechanical Systems  
Modeling and  
Simulation  
[HITech]



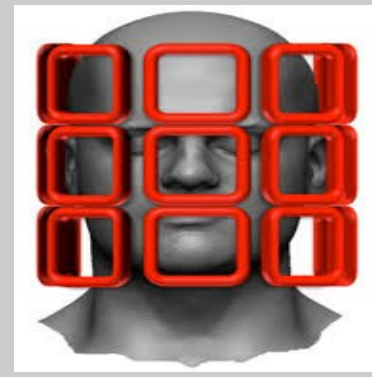
Brain Computer  
Interface  
[Riphah NewZeland  
College of  
Chiropractic]



Earth Sciences  
(QAU)



Parallel MRI  
[NCP]

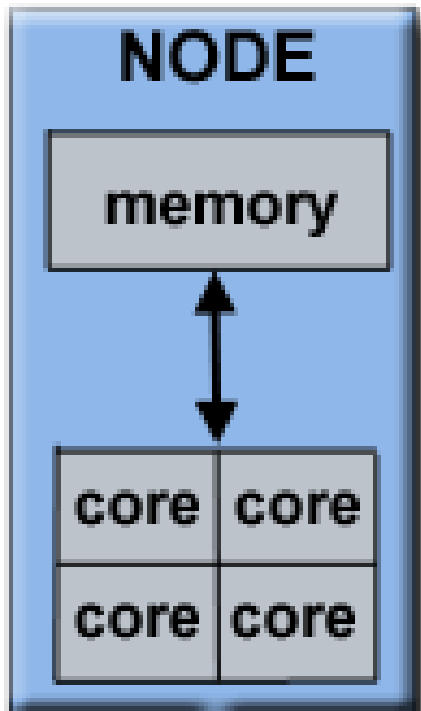


Artificial Intelligence



# Existing Solutions

- **Supercomputer**
- **Server based computing**
  - Shared Memory
  - Distributed Shared Memory
  - Centralized
  - Simulation Software Programs



HP ProLiant Server

# Available Supercomputers in Pakistan

Organization	Architecture	Performance
National University of Sciences and Technology	CPU-GPU	132 TFLOPS
KUST, Kohat	CPU	0.416 TFLOPS
COMSATS	CPU	0.158 TFLOPS
CIIT, Islamabad	CPU	0.05 TFLOPS
GIK Institute	CPU-GPU	N/A

# So Whats Wrong with the existing solutions

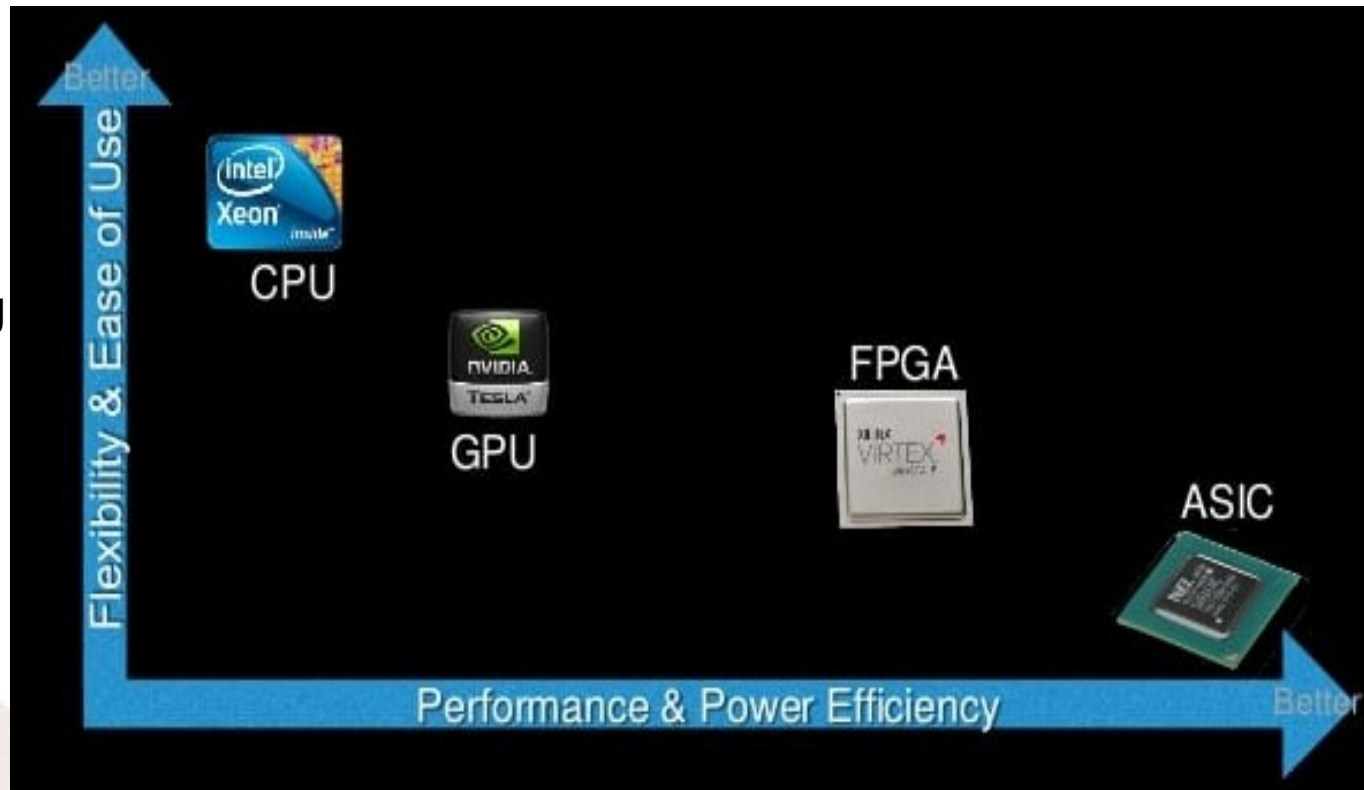
- **Based on conventional micro-processor architecture (Homogeneous)**
- **Sequential Model => not enough for High Performance Application**
- **Performance depends upon Simulation Software Tools not scalable.**



# How to Promote HPC

- **Heterogeneous Computing**
  - Scalable Hardware Architecture.
  - Different program segments run on heterogeneous platforms.
- **Parallel Programming Models**
- **Education and Training Programs**

Parallel  
Programming  
Model



# Contents

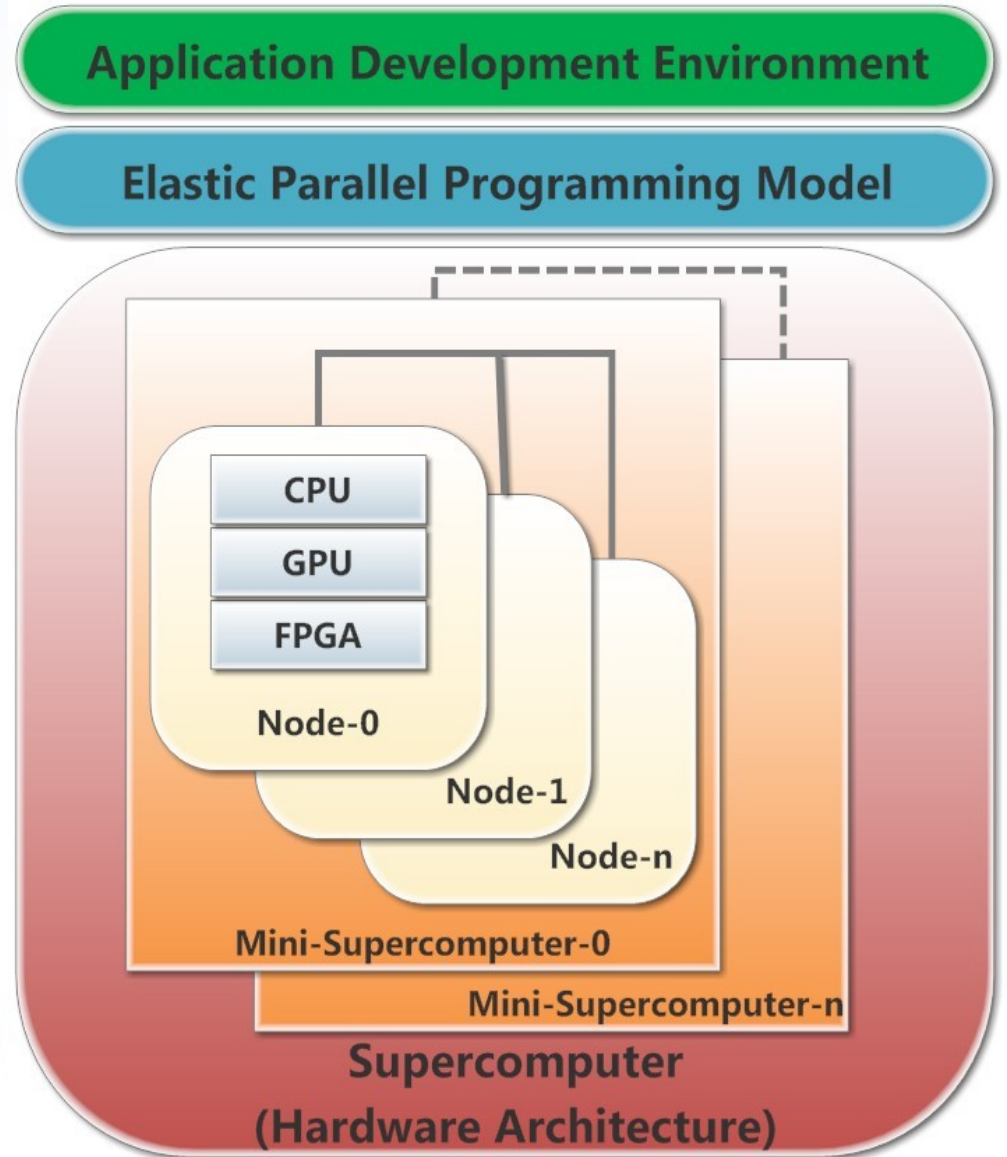
- Speaker's Introduction
- Supercomputing Trend
- **Proposals and Marketing strategy**
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# Our Proposed Solutions

- **CPU-GPU based Supercomputer (2015)**
- **FPGA Powered Supercomputer (2017)**
  - **Scientist**
  - **Hardware**
  - **Programming Models**
  - **Parallel Programmer**
- **Scalable Heterogeneous Supercomputer ( 2019**  
Proposal submitted to HEC TDF .3 Million\$)
  - **Hardware/Software Solutions**
  - **Marketing Strategy**

# Scalable Heterogeneous Supercomputer

- **Heterogeneous**
  - (CPU/GPU/FPGA)
  - Scalable Architecture
  - Cost Effective
- **Elastic Parallel Programming Models**
- **User Friendly HPC Development Environment**



## Applications Services

Computer Vision

Cognitive Radios  
(SDR)

Medical  
Healthcare

Real-time  
Processing

High Performance  
Computing

Mechanical Modeling  
and Simulation

Web  
(IoT, WBAN)

## Programming Frameworks

Interactive

GCC

Python

OpenMP

MPI

CUDA

OpenACC

OpenCL

TensorFlow

OpenCV

CAFFE

## Hardware Architectures

Multi-core  
X86

GPUs

Sensor  
Interfaces

FPGAs

Multi-Core  
Embedded

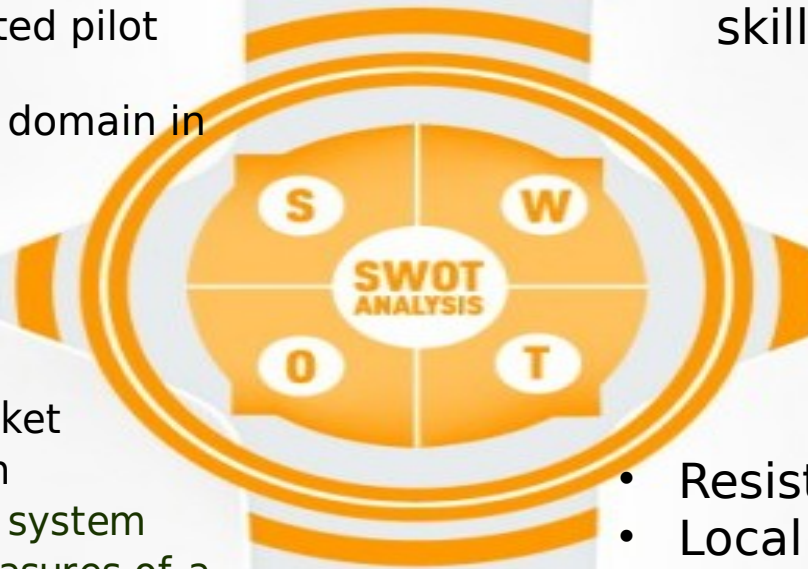
# SWOT Analysis

- Expertise in both hardware and software HPC
- Already completed pilot projects
- Pioneers in HPC domain in Pakistan

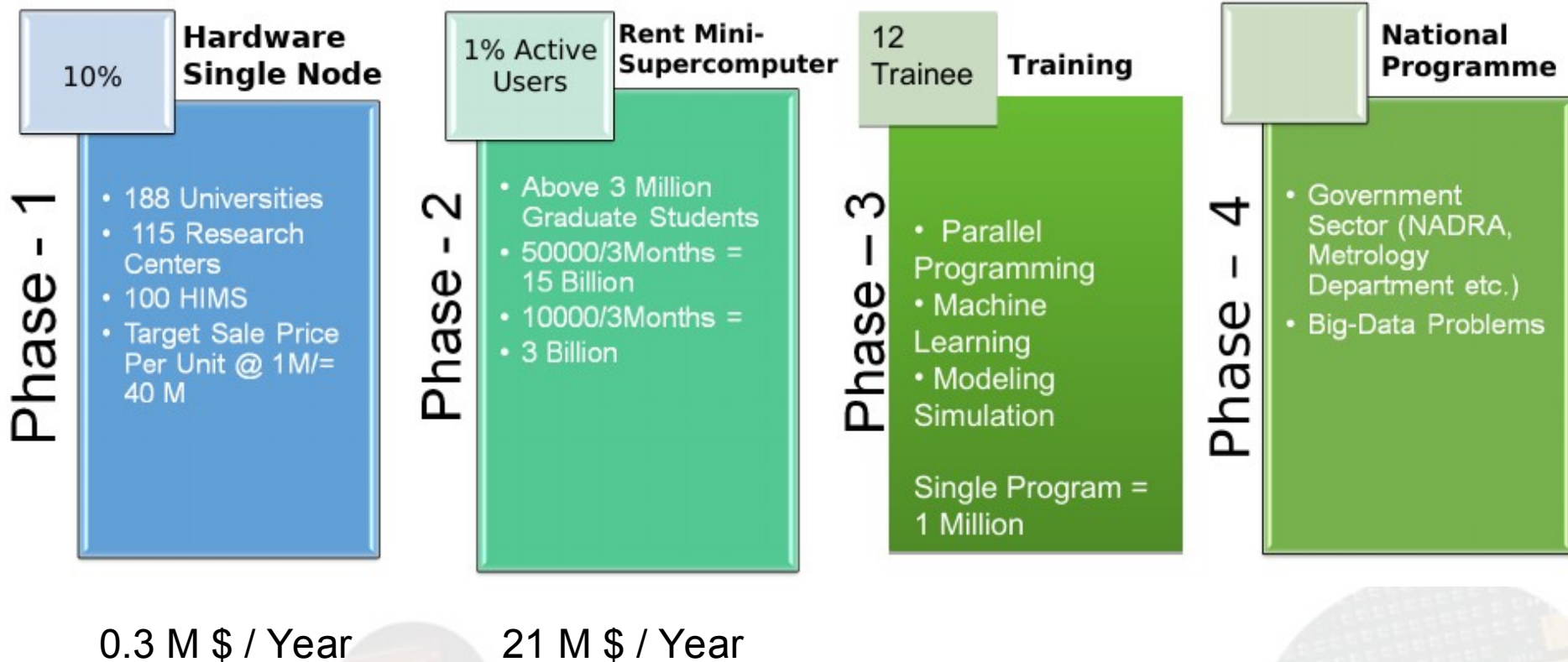
- New to Local Market
- Target only highly skilled community.

- Big research market
- Country Strength
- National security system
- An important measures of a country's overall prowess and economic strength.

- Resistance to adopt
- Local Economy Fluctuation
- Power Issues



# HPC Marketing Strategy (Pakistan)



# Financial Estimates and Revenue Forecast (Phase 1)

- Net units to be sold in three years: 80 (10+30+50 per year)
- Cost of all units:  $80 * 600,000 = 48,000,000$
- Sale value of all units:  $80 * 1,000,000 = 80,000,000$
- Net profit in five years:  $80,000,000 - 48,000,000 = 32,000,000$
- Average profit per year:  $32,000,000 / 3 = 10,666,665$
- Three years CAGR is given as under= 66.75%
- **ROI = 166% in 3 year time**
- **May 2019 HEC accepted project proposal (Approx 0.3 Million \$) for TDF.**



# Contents

- Speaker's Introduction
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# Research Project

- **Supercomputing and Artificial Intelligence**
  - **Iris based Disease Diagnosis System**
- **Processor based System**

# Iris based Disease Diagnosis System

- We are developing a Real-time Iris based Pre-diagnostic Tool detect dysfunctional organs.
- The system takes iris images as input and perform general pre-diagnosis for human organs disorders on the basis of iridology chart and artificial intelligent algorithm.

- **Problem/Need**

- Non-Invasive
- User Friendly
- Early Stage Pre-diagnostic tool

- **Affiliations**

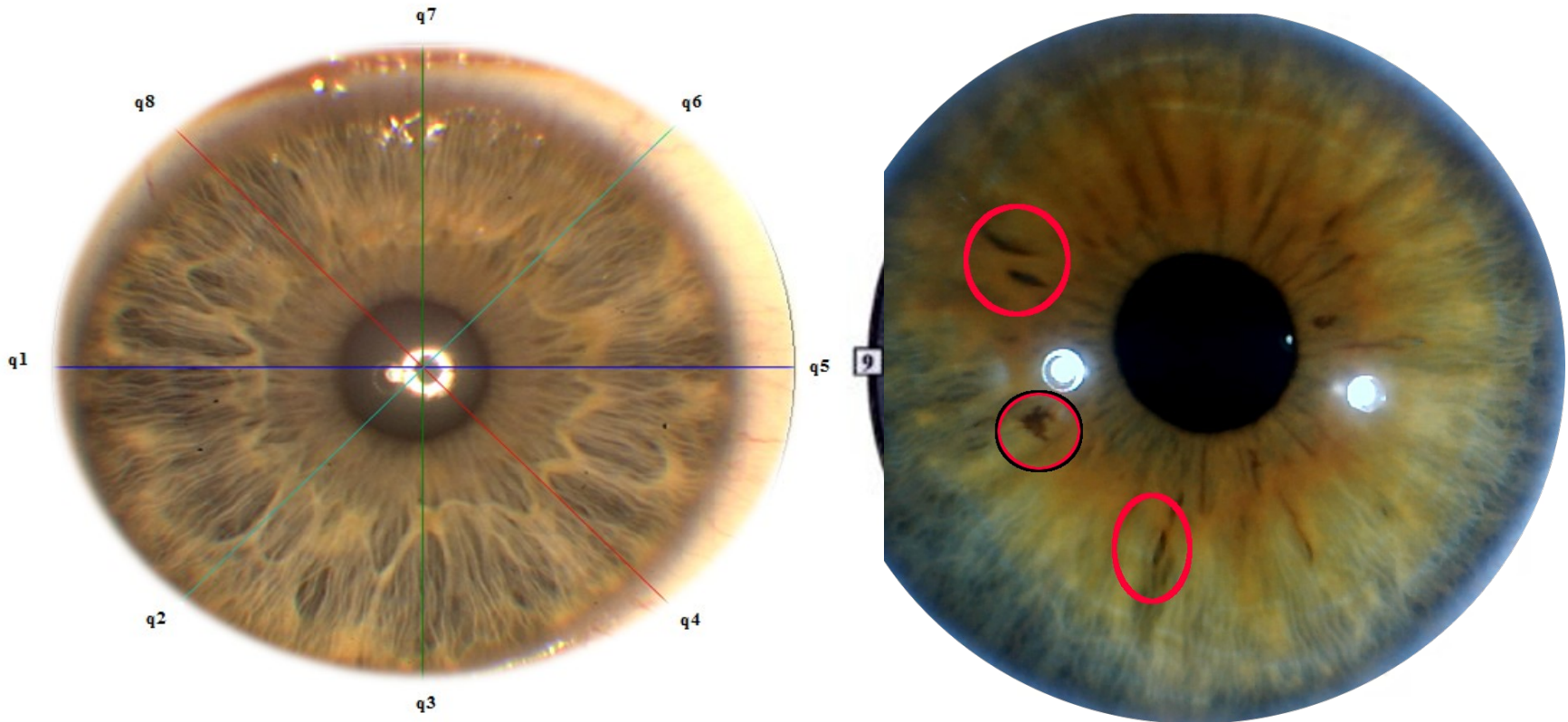
- Hospitals
- Diagnostic Labs
- Iridologist



Photograph of Early Prototype

# Iridology

- The practice examining the iris of the eye for disease diagnoses [1].
- Signs in the iris: **spot**, **pattern** and **change in color**.

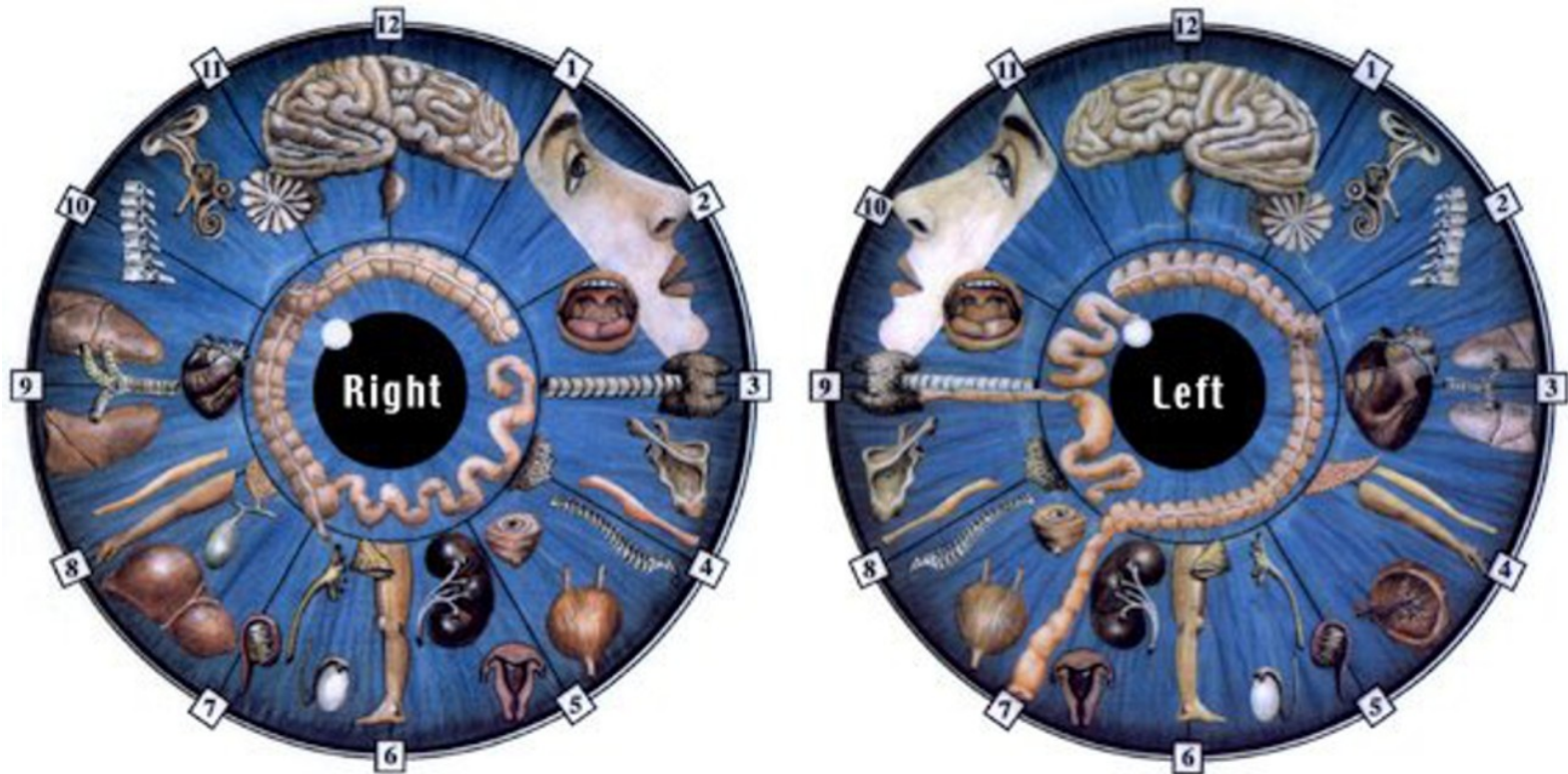


[1] Simon, Allie, David M. Worthen, and John A. Mitas. "An evaluation of iridology." *Jama* 242.13 (1979): 1385-1389.

[2] Iridology Chart developed by Dr. Bernard Jenson, D.C [2]. [ONLINE] Available at <http://www.betterhealththruresearch.com/Iridologist.html>.

# Iridology

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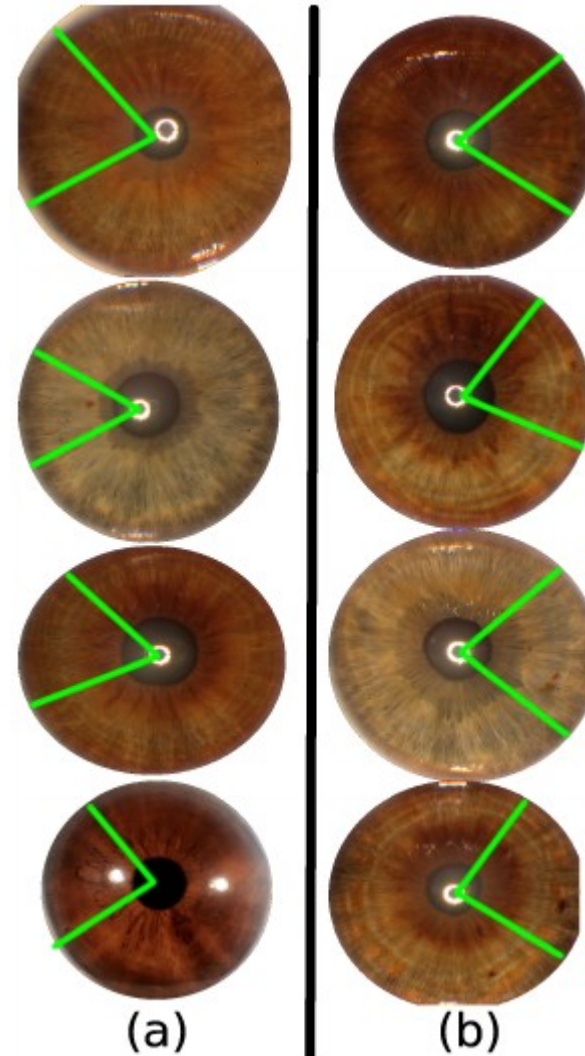
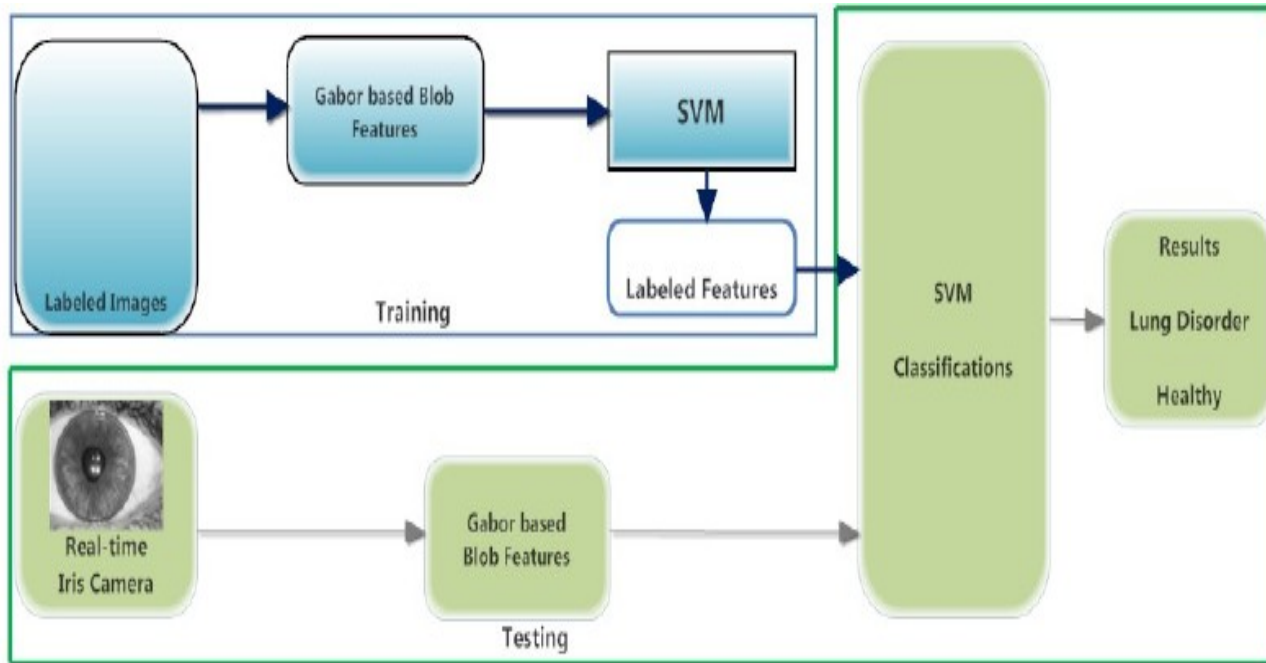
[2] Iridology Chart developed by Dr. Bernard Jenson, D.C [2]. [ONLINE] Available at <http://www.betterhealththruresearch.com/Iridologist.html>.

# Iridology: Mystery or Revolution

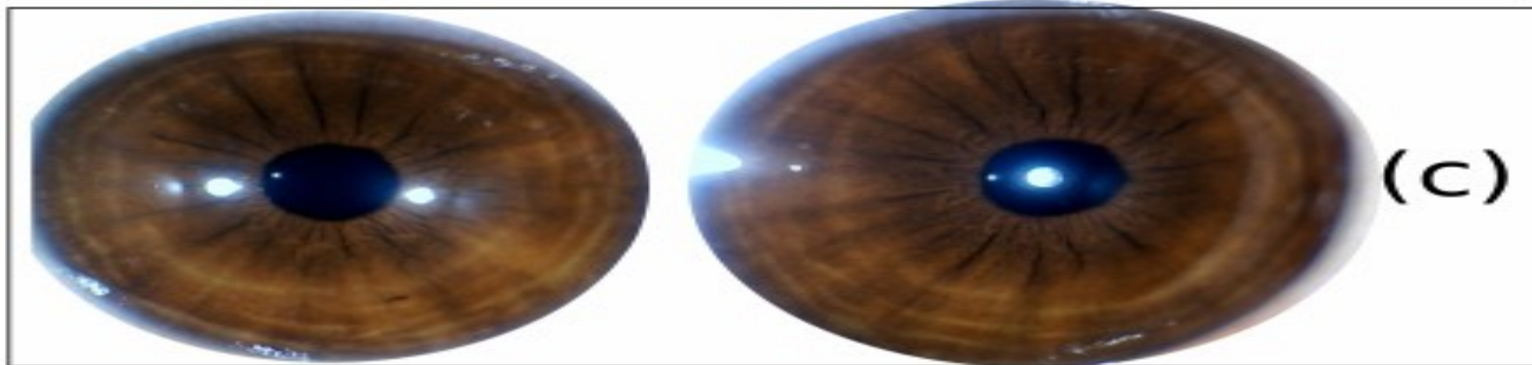
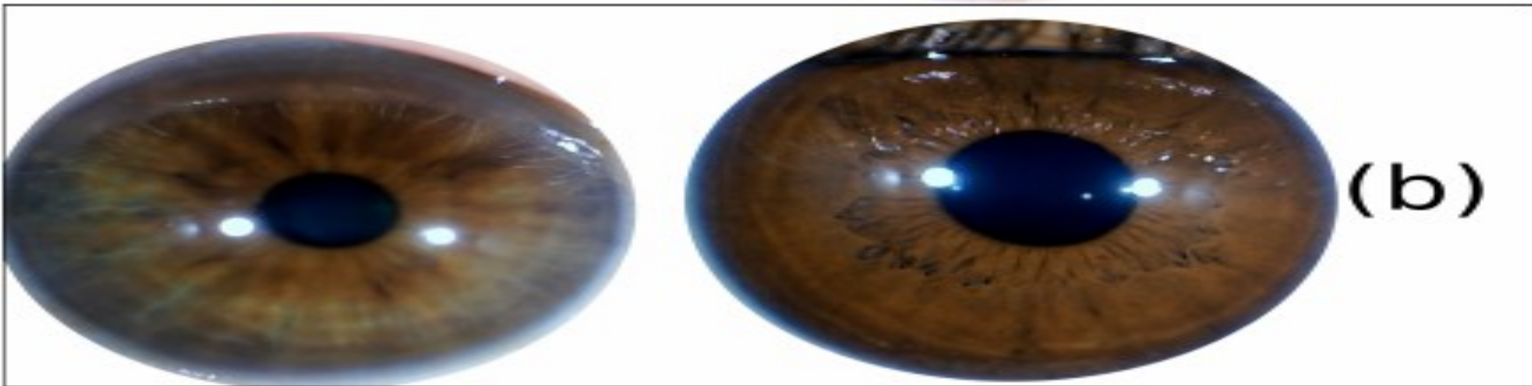
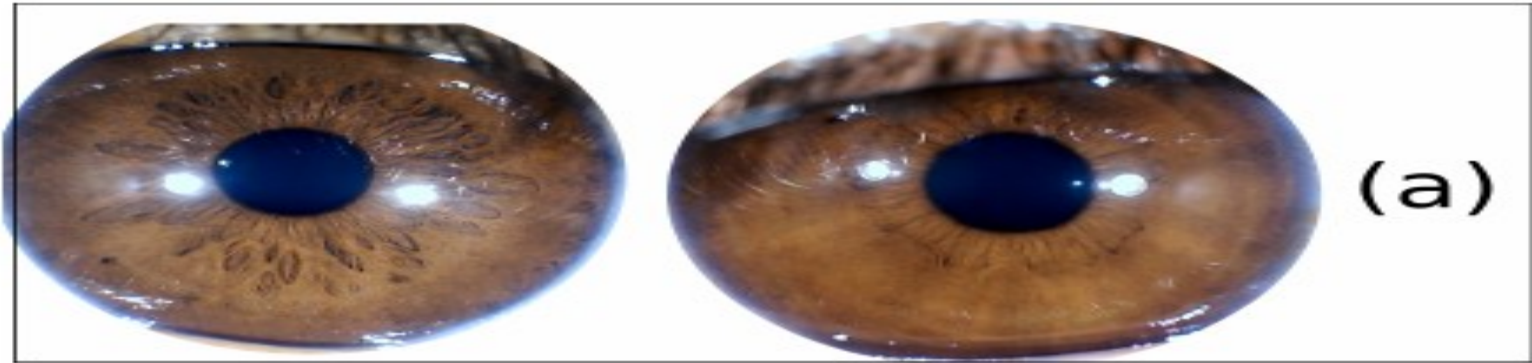
Dysfunctional Organs	Approximate Number of Publications in last few years	Citations
Heart	11 [6-16]	93
Liver	10 [17-26]	43
Kidney	15 [27-42]	137
Stomach	11 [43-53]	83
Lung	12 [54-65]	55
Books	11 [66-76]	

Papers Published in Last Few Years

# Lungs Dysfunction



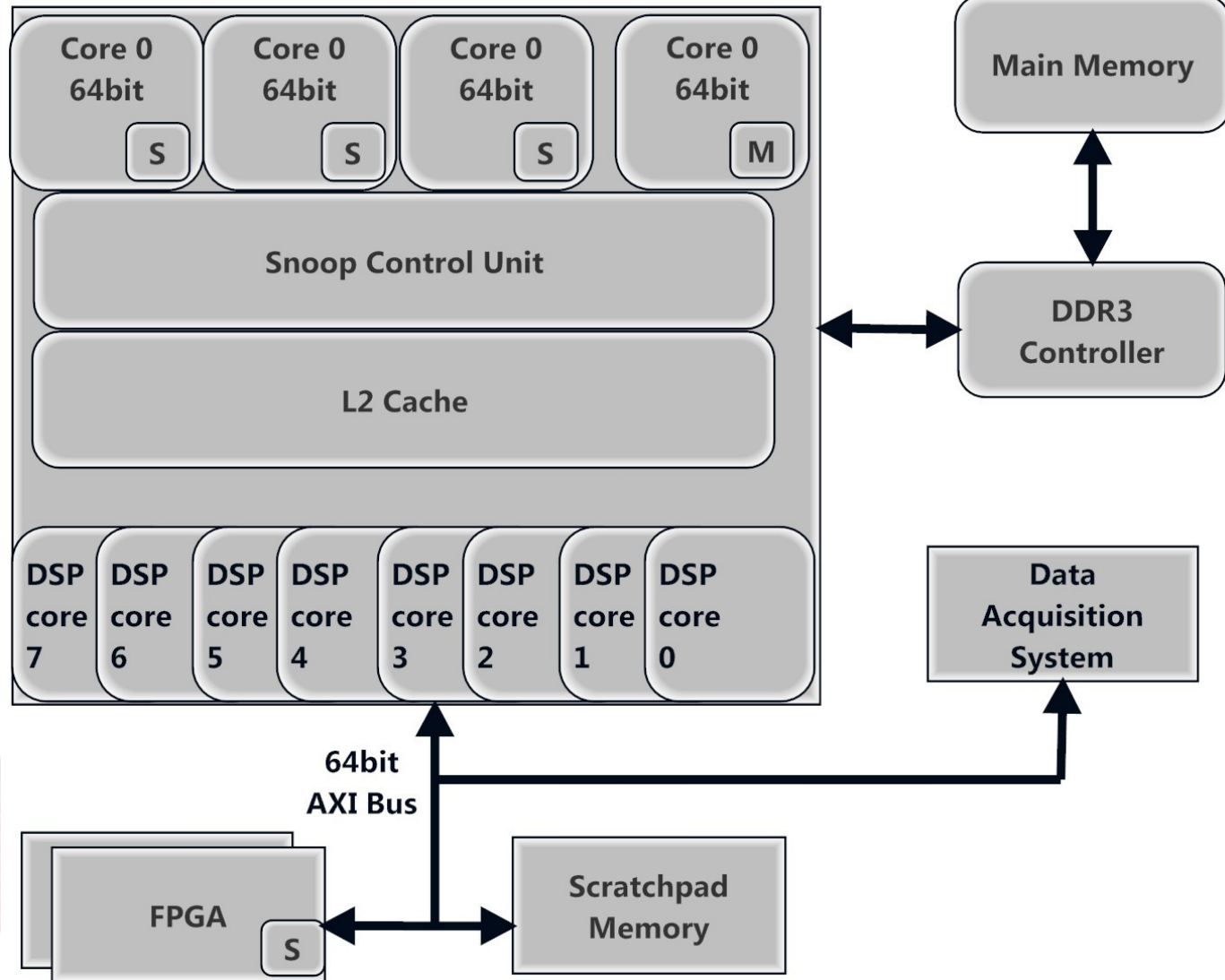
# Stress Identification





# Processor based System

- HPC Embedded System for Health-care
- ECG (Heart)
- EMG
- EEG (BCI)



- **Signal Conditioning**
  - Filtering
  - Amplification
- **Real-time Processing**
  - ECG
  - EEG



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# Achievements

- **Talks and Workshops (20)**
  - CUST, Risalpur, Heavy Industries Taxila, PEC, DICE Mega Event.
- **Patents (10)**
- **Publications (12)**
- **Collaboration**
  - International (3)
    - BSC Spain, Valenciennes France, College of Chiropractic
  - National (5)
    - NCP, BuleSurge, RadioPak, AlphaGenomics, Fusion Groups

# Achievements

## ● Developments

- Developed Low Power Low Cost GPU Powered Supercomputer (2015/16)

## ● Awards

- South Asia Triple Helix Award (SATHA) Innovation Award 2017
- DICE Mega Event of Innovation and Entrepreneurship 2017.

# The Nation

The Nation, Islamabad, Friday, January 22, 2016

## Riphah team develops supercomputer architecture

OUR STAFF REPORTER  
RAWALPINDI

A team of engineers at faculty of computing and applied science, Riphah International University, has successfully developed supercomputer architecture.

A supercomputer is composed of multiple processors, memory and I/O system while an interconnect mechanism has significantly complex architecture than the ordinary computers, informed the university spokesman yesterday.

The system supports CUDA, MPI/LAM, OpenMP, OpenCL and OpenACC as the programming models and allows to solve larger algorithms & numerical techniques, big data & data mining, bioinformatics & genomics, business intelligence & analytics, climate, and weather & ocean related problems, he said. He added that the benchmarking results show that the system can achieve up to 3.20 terra FLOPS, which can be extended up till 10 FLOPS.

Previously, only a few universities in Pakistan could

# THE NEWS

January 21, 2016

## Riphah University engineers develop super computer architecture

Islamabad & numerical techniques, big data & data mining, bioinformatics & genomics, business intelligence & analytics, climate, and weather & ocean related problems, he said. He added that the benchmarking results show that the system can achieve up to 3.20 Terra FLOPS, which can be extended up till 10 FLOPS.

Previously, only few universities in the country could have developed the super computer architecture. When performance of this super-computer is compared with the existing systems in Pakistan, the results show that the proposed Super-Computer architecture stands at the second position.



## FPGA-powered supercomputer

Dr Tassadaq Hussain, Assistant Professor,  
Riphah International University

Researchers from Barcelona Supercomputing Center, Riphah International University and UCERD Islamabad have joined forces to design a supercomputing system powered by field-programmable gate arrays (FPGAs).

Combining hardware accelerators, or co-processors, with multicore processors has become a popular way of achieving greater computing performance within a restricted power budget. These accelerators improve the performance of compute-intensive applications by executing a specific task.

FPGA architectures have established themselves as an attractive choice for high-performance computing systems architects, thanks to the considerable advancements in performance and power efficiency that they offer. By achieving higher performance per watt, FPGAs have proved themselves capable of competing with superscalar and graphics processing unit (GPU) accelerators, especially for high-performance computing applications.

This new FPGA-powered supercomputer system executes compute-intensive applications on FPGA. The design system uses message passing interface libraries for communication between compute nodes, while the communication between the Arm processors and FPGAs uses AXI4-Stream interfaces to execute a compute-intensive portion of an application. The Finite Impulse Response (FIR) filter has been implemented as a test application on the system to evaluate the computational capability of the Arm processors with and without hardware acceleration.

The results of this research were presented at the International Conference on Computing and Mathematical Sciences 2018 and have received patent number 311/2018 from the Government of Pakistan's Intellectual Property Organization.



# The Journey of Supercomputing in Pakistan

## Thanks

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Www.tassadaq.ucerd.com



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**30**