Application for Grant of Funds

1.	Name of the Institution with Full Address	National Institute of Technology Tiruchirapplli, Tanjore main road, Tamil Nadu, PIN-620015
2.	Title of the Research Proposal	Deep learning for low resolution hyper spectral satellite image classification
3.	Name of the Principal Investigator (Address/Phone/E-mail)	Dr. E.S.Gopi Associate professor Department of Electronics and communication Engineering esgopi@nitt.edu Phone:914312503314 Mobile:9500423313
4.	Name(s) of other investigator(s) with the name(s) of their Institution	-Nil-
5.	Proposed duration of Research Project	3 years
6.	Amount of grant requested (in Rs.) 1st Year, 2nd Year, 3rd Year Total	First year=11,04,000 Second year=4,38,000 Third year=4,81,200 Total=20,23,200
	Manpower	9,36,000
	Equipment	5,00,000
	Satellite Data/Data	50,000
	Consumables & Supplies	35,000
	Internal Travel	1,50,000
	Contingency	15,000
	Others	0
	Overheads	3,37,200
	Total	20,23,200
7.	a) Bio-data of all the Investigators (Format-A). -Refer enclosed format-A- b) Brief description of the Research Proposal with details of budget (Format-B). -Refer enclosed format-B- c) Declaration (Format-C). -Refer enclosed format-C-	
8.	I/We have carefully read the terms and conditions for ISRO Research Grants and agree to abide by them. It is certified that if the research proposal is approved for financial is approved for financial support by ISRO, all basic facilities including administrative support available at our Institution and needed to execute the project will be extended to the Principal Investigator and other Investigators.	

Name	Institution	Designation
Principal Investigator		
Dr.E.S.Gopi	National Institute of Technology Tiruchirappalli	Associate professor, Department of Electronics

		and Communication Engineering
Co-Investigator(s)		
Niil	Nil	
Head of the Department/Area		
Prof. Dr. G. Lakshmi Narayanan	National Institute of Technology Tiruchirappalli	Professor and Head of Electronics and communication Engineering
Head of the Institution		
Prof. Dr. Mini Shaji Thomas	National Institute of Technology Tiruchirappalli	Director, National Institute of Technology

Form A

Bio-data of the Investigator(s)

(Bio-data for **all the investigators** should be given, each on a separate sheet)

1.	Name	Dr. E.S.Gopi
2.	Date of Birth (dd/mm/yyyy)	20/12/1977
3.	Designation	Associate professor
4.	Degrees conferred (begin with Bachelor's degree)	

Degree	Institution conferring the degree	Field(s)	Year
Ph.D.	National Institute of Technology Trichy	Investigations on Linear discriminant analysis	2015
M.E. (with Distinction)	Sri Venkateswara college of Engineering(Affiliated to Anna university)	Communication Systems	2005
B.E. (with Distinction)	Mohammad Sathak Engineering college (Affiliated to Madurai Kamaraj University)	Electronics and Communication Engineering	1998

5. Research/training experience (in chronological order)

Duration	Institution	Name of work done
2018-till date	National Institute of Technology Trichy	Associate professor (Teaching and Research)
2006-2018	National Institute of Technology Trichy	Assistant professor (Teaching and Research)
2003-2006	Sri Venkateswara college of Engineering, Chennai	Senior lecturer (Teaching and Research)
2001-2003	Sri Venkateswara college of Engineering, Chennai	Lecturer (Teaching and Research)
1999-2001	Sri Muthukumuran Institute of Technology,Chennai	Lecturer (Teaching and Research)

1998-1999	Raja Rajeswari Engineering college	Lecturer (Teaching and Research)

6.	Major scientific fields of Interest	Pattern recognition, Computational Intelligence, Digital signal processing

7. List of publications

Sole authored the following books :

[1] Multi-Disciplinary Digital Signal Processing: A functional approach using Matlab (2017), ISBN 978-3-319-57429-5, **Springer** publications
[2] Digital signal processing for wirelesss communication using Matlab (2015) ,ISBN 978-3-319-20651-6, **Springer** publications
[3] Digital Speech processing using Matlab (2014), ISBN 978-81-322-1676-6, **Springer** publications
[4] Digital signal processing for medical imaging using Matlab (2012), ISBN 978-1-4614-3139-8, **Springer** publications
[5] Mathematical summary for digital signal processing applications with Matlab (2010),ISBN:978-90-481-3746-6, **Springer** publications
[6] Algorithm Collections for Digital Signal Processing Applications Using Matlab (2007), ISBN: 978-1-4020-6409-, **Springer** publications
[7] Digital Image processing using Matlab (2007) : ISBN:9788183715867, Scitech publications

Journal publications

[1] G.Jayabrindha, **E.S.Gopi,** "Ant Colony Technique for Optimizing the Order of Cascaded SVM Classifier for Sunflower Seed Classification" , **IEEE Transactions on Emerging Topics in Computational Intelligence,**pp.78 - 88, Vol.2, Issue 1, 2017.
[2] E.S.Gopi, "Digital image forgery detection using artificial neural network and independent component analysis", **Elsevier journal on Applied Mathematics and Computation (Impact factor:1.738)** ,Vol. 194-2, 2007, pp. 540-543. ISSN:0096-3003
[3] E.S.Gopi, P.Palanisamy "Neural network based class-conditional probability density function using kernel trick for supervised classifier", **Elsevier journal on neuro computing (Impact factor:3.317)**, Vol.154, pp. 225-229, 2014, ISSN:0925-2312
[4] E.S.Gopi,P.Palanisamy, "Maximizing Gaussianity using kurtosis measurement in the kernel space for kernel linear discriminant analysis", **Elsevier journal on neuro computing (Impact factor:3.317)**,Vol.144, pp.329-337, 2014, ISSN:0925-2312
[5] E.S.Gopi, P.Palanisamy "Formulating particle swarm optimization based membership linear discriminant analysis", **Elsevier journal on swarm intelligence and evolutionary computation (Impact factor:3.893)** , Vol.12, pp.65-73, 2013, ISSN:2210-6502
[6] E.S.Gopi, P.Palanisamy, "Fast computation of PCA bases of image subspace using its inner-product subspace", **Elsevier journal on Applied Mathematics and Computation (Impact factor:1.738)**, Vol.219-12, pp.6729-6732, 2013, ISSN:0096-3003

Chapter in the book

[1] E.S.Gopi, R.Lakshmi, N.Ramya, and S.M. Shereen Farzana, " Music indexing using Independent Component Analysis with pseudo-generated sources,Independent Component Analysis and Blind Signal Separation", **Springer** Berlin Heidelberg,pp.1237-1244, 2004

[2] E.S.Gopi, P.Palanisamy, "Scatter Matrix versus the Proposed Distance Matrix on Linear Discriminant Analysis for Image Pattern Recognition", **Springer**, pp.101-108, 2014

[3] Florintina.C, **E.S.Gopi**, "Music composition inspired by sea wave patterns observed from beaches", (accepted for publication in Advances in Intelligent systems and Computing series),**Springer,**2017.

[4] Kshitij Rachchh, **E.S.Gopi,** "Inclusion of Vertical bar in the OMR sheet for Image Based Robust and Fast OMR Evaluation Technique using Mobile Phone Camera ",(accepted for publication in Advances in Intelligent systems and Computing series), **Springer,** 2017

[5] Vineetha Yogesh, **E.S.Gopi,** Shaik Mahammad, "Particle Swarm Optimization based HMM parameter estimation for spectrum sensing in Cognitive radio system", Edited volume on Computational intelligence for Pattern Recognition, **Springer,** 2018.

Conference publications

[1] Hemant Sharma and **E.S. Gopi**. "Signal processing approach for music synthesis using bird's Sounds", **Elsevier journal** on Procedia Technology, Volume 10, 2013, Pages 287-294

[2] Vinoth S and **E S Gopi**. "Neural network modeling of color array filter for digital forgery detection using kernel LDA", **Elsevier journal** on Procedia Technology, Volume 10, 2013, Pages 287-294

[3] Jay.K.Patel and **E.S.Gopi**, "Musical Notes identification using Digital signal processing", **Elsevier journal** on procedia computer science, Volume 57, 2015, Pages 876–884,

[4] Hari Babu Padarthi and **E.S.Gopi**, " Medical data classifications using Genetic algorithm based Generalized Kernel Linear Discriminant analysis", **Elsevier journal** on procedia computer science, Volume 57, 2015, Pages 868–875

[5] E.S.Gopi, P.Palanisamy, "Formulating Particle Swarm Optimization based Generalized Kernel Function for Kernel-Linear Discriminant Analysis", **Elsevier journal** on Proceedia technology, Vol.6, pp.517-525, 2013,

[6] E.S.Gopi,"A Novel approach to transformed biometrics",second international conference on digital image processing during 26-28 Feb 2010,singapore.

[7] C. Florintina, **E.S.Gopi, "**Constructing a Linear Discrete System in Kernel Space as a Supervised Classifier",- Wispnet 2017, Chennai, 22-24 March 2017.

[8] E.S.Gopi, Sylvester Vijay R, Vasudha Rangarajan,Lakshmanan Nataraj,"Brain computer Interface Analysis using Wavelet Transformations and Auto Regressive Coefficients", - ICECE , Bangladesh, December 21,2006

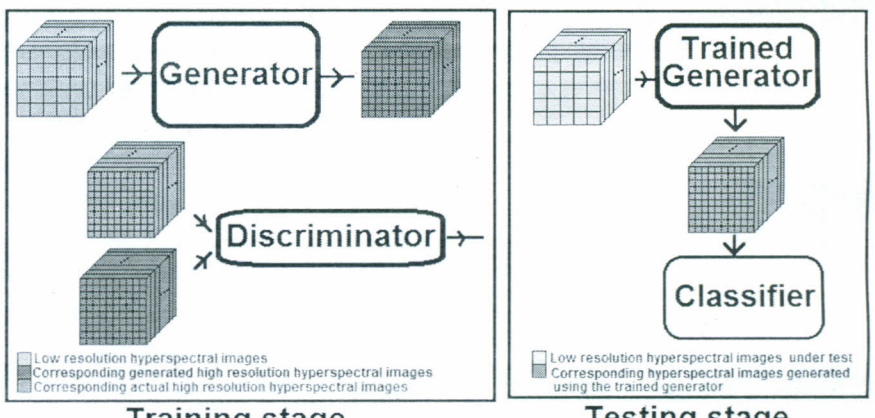
[9]E.S.Gopi, N.Lakshmanan, T.Gokul,S.KumarGanesh, Prerak.R.Shah,"Digital Image forgery detection using Artificial Neural Network and Autoregressive Coefficients", - IEEE Canada, Canadian Conference on Electrical and Computer Engineering.(CCECE-CCGEI) Ottawa 2006.

[10] E.S.Gopi, Poorani Vijayakumar, Shyamala Pandiyan,Preethi kannan,Revathy, "A Novel Approach to Transformed Biometrics using ANN", - Third International Conference on Intelligent Sensing and Information Processing ICISIP

	06,Bangalore, India. **[11] E.S.Gopi**, Vibha Viswanathan,Priya Sankaralingam,Sowmya ramakumar,"A New approach to create high level features from low level features of audio clips" International Conference on Communication, Circuits and Systems (ICCCAS2005), 27 to 30 May 2005,HongKong, China. PP 1022-1026. **[12] E.S.Gopi,** E.S.Sathya,"SVM Approach to number plate recognition and Classification System"-Second International Conference on Intelligent Sensing and Information Processing-(ICISIP 05) 4-7 January 2005 at Le Royal Meridian, Chennai, India. **[13] E.S.Gopi**, S.R.Nirmala,Shreyans Chopra,N.H.Kaliprasad,"Karhunen-Leove transform based hand identification system"- Second International Conference on Intelligent Sensing and Information Processing-(ICISIP 05) 4-7 January 2005 at Le Royal Meridian, Chennai, India.	
8.	Email id and Telephone number of PI with STD Code	esgopi@nitt.edu 914312503314 Mobile number:9500423313
9.	Email id of the Head of the academic institution	director@nitt.edu

Form B

1.	Title of the research proposal	**Deep learning for low resolution hyper spectral satellite image classification**
2.	**Summary of the proposed research** A Simple concise statement about the investigation, its conduct and the anticipated results in no more than 200 words	The hyper spectral images captured from the satellite ar subjected to classification, to classify each pixel into on among the finite number of classes. For instance: Indian pine database consists of hyper spectral images captured using 22 spectral reflectance bands. In this, every pixel (across the 22 spectral reflectance bands) is subjected to supervise classification, to classify it into one among the 16 classes. Th typical size of the captured image is of the size 144x144 pixels The corresponding pixel values collected from all the 22 bands form the vector (220x1). This vector is subjected t classification to one among the 16 classes (Corn, Oats, Whea etc.). By fixing the area under consideration number of pixel captured with various spectral bands describes the resolutio of the image. For instance, collecting 50x50 pixels instead c 144x144 form the low resolution image corresponding to th high resolution image of size 144x144. Collecting hig resolution images consume more time and is expensive. In our proposal, we are planning to convert lo resolution image of size 50x50 into 144x144 (say) and t classify every pixel of the generated high resolution images int the finite number of classes using **Generative Adversaria Network** (GAN). (It is understood that the class index assigne to every pixel need not be mutually exclusive)
3.	**Objectives** A brief definition of the objectives and their scientific, technical and techno-economic importance.	1. To demonstrate the developed algorithm to convert the low resolution hyper spectral images into high resolution hyper spectral images using GAN. 2. To construct the classifier to classify the pixels of the high resolution images (obtained from the trained GAN) into finite number of classes and to compare the performance of the classifier with the corresponding actual high resolution images. **Importance:** The Hyper spectral images captured with high resolution i expensive. In our proposal, we suggest to use the cost effectiv low resolution hyper spectral images for the pixel-wis supervised classification that performs at par with the one usin high resolution images using GAN (Generative Adversaria Network).
4.	**Major Scientific fields of Interest** A brief history and basis for the proposal and a demonstration of the need for such an investigation preferably with	GAN was introduced during 2014 (by Ian Good fellow) that wa actually developed to generate photographs. But in recer years, GAN is being used in many applications like convertin MRI to the corresponding CT image, Thermal image to th corresponding visible image, low resolution to high resolutio image conversion [1], etc.

	reference to the possible application of the results to ISRO's activities. A reference should also be made to the latest work being carried out in the field and the present state-of-art of the subject.	There are attempts made on GAN based Hyper spectral imag classification [2]. In this technique, GAN is used to obtain th class label of the individual pixel of the high resolution hype spectral images directly. In our proposal, we plan to use the low resolution hyperspectra images for classification. We use GAN network to convert the low resolution hyper spectral images into high resolution image hyper spectral images. We further use the obtained high resolution images for further classification. **References:** [1] Christian Ledig et.al. Photo-Realistic Single Image Super Resolution Using a Generative Adversarial Network, 2017 IEEE Conference on Computer Vision and Pattern recognition. [2] Lin Zhu, Yushi Chen Pedram Ghamisi and Jón At Benediktsson, Generative Adversarial Networks fo Hyperspectral Image Classification, IEEE Transactions on Ge science and Remote sensing.
5.	**Linkages to Space Programme** **/Deliverables to ISRO on successful completion of the project**	**Linkage to space programme:** [1] Demonstration of the performance of the developed algorithm on the hyper spectral satellite images (collected from ISRO) like the one collected from Mangrove forest. **Deliverables to ISRO** [2]High quality research publications (based on the research) and Books/ Book chapters. [3]Completion of the Ph.D. - 1 student
6.	**Approach** A clear description of the concepts to be used in the investigation should be given. Details of the method and procedures for carrying out the investigation with necessary instrumentation and expected time schedules should be included. All supporting studies necessary for the investigation should be identified. The necessary information of any collaborative arrangement, if existing with other investigators for such studies, should be furnished. The principal Investigator is expected to have worked out his collaborative arrangement himself. For the development of balloon, rocket and satellite-borne payloads it	 **Fig.1 Proposed Generative Adversial Network used for low resolution hyper spectral satellite image classification** In Generative Adversarial Network, we have two convolutio network structures. One acts as the generator block and th other as the discriminator block. Group of hyper spectral images are given as the input to th generator block. The generator block tries to convert the grou of low resolution images into group of corresponding hig

	will be necessary to provide relevant details of their design. ISRO should also be informed whether the Institution has adequate facilities for such payload development or will be dependent on ISRO or some other Institution for this purpose.	resolution images. The generated high resolution images along with the corresponding actual high resolution images ar given as the input to the discriminator. The discriminator network is trained such that the variabl associated with the output of the discriminator takes the valu 0.5 (for the ideal cases) for both original high resolution imag and the high resolution image obtained from the generato This is done to make sure that the discriminator is not able t discriminate the original high resolution image and the on generated by the generator. The output of the discriminato along with the output of the generator is also considered t adjust the weights involved in the generator and th discriminator during the training phase. The high resolution image (corresponding to the low resolutio image under test) is obtained using the trained generator an are subjected to the classification using the classifier lik Support Vector Machine. This approach has the advantage of making use of correlatio between different spectral bands during training phase. A batch processing is involved during the training phase, slo convergence is expected. **Alternative approach:** Instead of using single GAN, 220 different GANs (one for eac spectral band) is considered. Upon training, classification i done by combining the decision taken by the individual traine GAN. As the complexity of the individual GAN is limited, w expect fast convergence in this approach.
7.	**Data base and analysis** A brief description of the data base and analysis plan should be included. If any assistance is required from ISRO for data analysis purposes, it should be indicated clearly.	[1] Proof of the concept of the developed algorithm is demonstrated using widely used dataset like (1) Salinas with 204 bands [after removal of low signal to noise ratio bands]. Captured using Airborne Visible/Infrared imaging (AVIRAS), 512x217 pixels. Number of classes-16 (2) KSC dataset NASA (AVIRAS) with 176 bands (after removal of low signal to noise ratio bands), 512x 614 pixels, Number of classes-13 (3) Indian Pines test with 200 spectral bands (after removal of low signal to noise ratio bands), 145x145 pixels, Number of classes-16 [2] Upon completion of proof of concept, the developed algorithm is tested using Hyper spectral images collected from ISRO. Example: Hyper spectral images collected from the Mangrove Ecosystem. **This needs assistance from ISRO for the proper selection of the dataset.**

8.	**Available Institutional facilities** Facilities such as equipments, etc, available at the parent Institution for the proposed investigation should be listed.	1. Laboratory space with electricity facility and other basic facilities 2. High speed Internet 3. Matlab software. 4. Other free softwares will be downloaded and installed through high speed internet.

9. **Fund Requirement**

Detailed year wise break-up for the Project budget should be given as follows:

Fellowships*	**I^st Yr**	**2^nd Yr**	**3^rd Yr**
Research Scientist	-	-	-
Research Associate	-	-	-
Research Fellows (SRF)	**25000X12**	**25000X12**	**28000X12**
Total	**3,00,000**	**3,00,000**	**3,36,000**

*Note: please specify the designation, qualification and rate of salary per month for each category

	I^st Yr	**2^nd Yr**	**3^rd Yr**	**Total**
Equipment**	5,00,000 High end workstation (greater than 3.5 GHz)+24" LED Monitor+16GB Memory with UPS	-	-	**5,00,000**
Total	**5,00,000**	-	-	-

Please specify the various individual items of equipment and indicate foreign exchange requirement, if any

	I^st Yr	**2^nd Yr**	**3^rd Yr**	**Total**
Satellite data	50000	-	-	50,000
	I^st Yr	**2^nd Yr**	**3^rd Yr**	**Total**
Consumables &	15000	10000	10000	35000
	I^st Yr	**2^nd Yr**	**3^rd Yr**	**Total**
Internal Travel	50000	50000	50000	150000
	I^st Yr	**2^nd Yr**	**3^rd Yr**	**Total**
Contingencies	5000	5000	5000	15000
	I^st Yr	**2^nd Yr**	**3^rd Yr**	**Total**
Others	-	-	-	**0**
Total	**9,20,000**	**3,65,000**	**4,01,000**	
	I^st Yr	**2^nd Yr**	**3^rd Yr**	**Total**

Overheads(Overhead Expenses of 20% of Total Project Cost not exceeding 3.00 lakhs)	**1,84,000**	**73,000**	**80,200**	**3,37,200**
Total	**11,04,000**	**4,38,000**	**4,81,200**	**20,23,200**

10.	Whether the same or similar proposal has been submitted to other funding agencies of Government of India. If Yes please provide details of the institution & status of the proposal.	No

**Justify each equipment. If computer is proposed, only desktop has to be purchased not laptop

Form C

Declaration

I / We hereby agree to abide by the rules and regulations of ISRO research grants and accept to be governed by all the terms and conditions laid down for this purpose.

I / We certify that I / We have not received any grant-in-aid for the same purpose from any other Department of the Central Government / State Government / Public Sector Enterprise during the period to which the grant relates.

	Name	Signature	Designation
Principal Investigator	Dr.E.S.Gopi	15/6/2018	Associate professor
Head of the Department / Area	Prof.Dr.Lakshmi Narayanan	15/6/18	Professor and Head of Electronics and Communication Engineering
Head of the Institution	Prof.Mini Shaji Thomas	18/6/18	Director, National Institute of Technology Tiruchirappalli