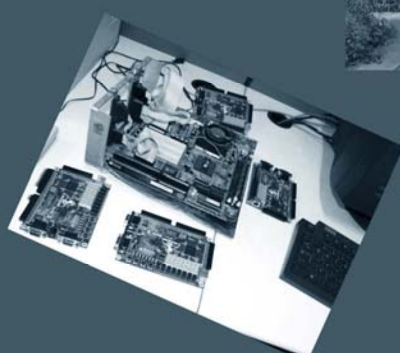
RIF

Research I Foundation

Annual Report 2007-08



Department of Computer Science & Engg.
IIT Kanpur

RIF: Aims and Objectives

One of our alumni, Mr. N. R. Narayana Murthy, Chairman, Infosys, has created the Research I Foundation for the department with an endowment of Rupees 10 crores. The Research I Foundation board has the following members.

- Mr. N R Narayana Murthy, Chairman and Chief Mentor, Infosys
- Professor Sanjay G. Dhande, Director, IIT Kanpur
- Professor V Rajaraman, Honorary Professor, SERC, IISc
- Professor Keshav Pingali, Cornell University
- Professor Rajeev Motwani, Stanford University
- Professor Jitendra Malik, Berkeley University
- Head, Computer Science and Engineering, IIT Kanpur

The aim of Research I Foundation is to foster research in the department. To increase the research profile of the department, the foundation funds several types of research activities:

1. Visits of the department faculty members to the best research groups in the world for a period of 1-6 months.
2. Visits of internationally renowned researchers to the department for a period of up to six months.
3. Full travel support to present papers in any of the top conferences in the broad computer science and engineering area.
4. Research grants for a period of 2-3 years against proposals submitted by the faculty members of the department. This also includes an additional salary of Rs 1 Lakh per year.
5. Support for the young faculty in the form of "Research I Fellowships" for a duration of three years that includes a research grant of Rs 3 lakhs and a salary component of Rs 1.2 lakhs per annum.
6. Full support for up to 2 workshops every year in cutting edge areas.
7. *Hari Sahasrabhddhe lecture series* that has leaders in the area giving talks at IITK and a city in southern part of India.
8. Fellowship to PhD students up to Rs 20,000 per month.
9. Visits by PhD students for a semester to leading research groups around the world.
10. Employment of IIT students as research associates for up to 2 years.
11. Support to students from other colleges for summer internship in the department with a focused research agenda.
12. Support for the students in the department to present their papers in good conferences.

Ratan Kumar Ghosh
Professor

Research Interests: Distributed computing, mobile computing, sensor and wireless networks, parallel algorithms, parallel Processing, genetic Algorithms.

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After receiving the grant, we have initiated research in deployment, localization, security and opportunistic communication in wireless network. One paper entitled "Cooperative Black and Gray Hole Attacks in Mobile Ad Hoc Network" http://doi.acm.org/10.1145/1352793.1352859) has been published in Proceedings of ICUIMC 2008 which was held in Suwon, Korea. In this paper, we proposed a complete protocol to detect a chain of cooperating malicious nodes in an ad hoc/sensor network that disrupts transmission of data by feeding wrong routing information. Currently, a student is working on coding the protocol over a collection of MicaZ class of sensors procured recently. We used only a small part of Research I equipment grant to procure these sensors, the major part of the cost is charged to another grant we received for an earlier project. We expect some results soon, and should be able to complete a journal draft of an extended version of the work incorporating another recent work on sensor localization. The ICUIMC paper was selected in invited paper category. So as an invited speaker, I also participated in expert panel for presentations of sensor network research by Korean scholars. The international travel and hospitality at Seoul was provided by the conference organizer. So only domestic travel and limited incidental expenditures were drawn from Research I grant for attending the conference. We are parallely working on a book chapter on deployment, connectivity and localization of wireless sensor network. One M. Tech student is working on energy aware routing in wireless sensor network. The work is centered on asymmetric links between sensor nodes. The protocol is in place and the student is now working on test cases for comparison of our protocol with other existing energy aware protocols like LEACH. The results so far have been quite encouraging. The student is currently working on more results to substantiate initial findings. We have also initiated work on experimental setups concerning sensor reprogramming, deployment, routing and localization. We hope to evolve opportunistic wireless communication architecture leveraging 802.11g, 802.11a/b, GSM and other communication technologies. One exchange visit is planned for Dr. Sajal K. Das during July-August. We will consolidate plans for ongoing work and draw up a schedule of activities for the next year as well during Dr. Das's visit. In order to spend more time on the Research I project, I have decided to take a sabbatical starting next semester. The first part of leave (Sept-Dec) will be spent at UTA where Dr. Das will be hosting me. We want to complete some work related to Research I project during the time of my stay at UTA. Only travel part of both the visits needs to be funded by Research I grant. The living expenses for both visits will be met from local resources.

T.V. Prabhakar
Professor

Research Interests: Software Architecture, Knowledge Modeling, Web 2.0 and Indian Language Content

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We are interested in the problem of Architecture design. The final objective is to build a 'tool' which will help 'design'. We are envisaging it to be knowledge based tool, with architectural knowledge encoded as a component. One needs to characterize and formalize architectural knowledge to build such a component. We have been working on this problem. Our results so far are summarized in the paragraph below:

Design Decision Topology Model for Pattern Relationship Analysis

Software patterns are solutions to recurring design problems, helping designers in repeating their successes. Existing large and continuously increasing number of patterns introduce new problems to designer who use them, one such problem is management of pattern knowledge base. For this, pattern relationship analysis, a sub-problem of pattern ontology, is an important and hard problem to solve. Non-uniform and incomplete pattern

descriptions further complicate the problem. Existing literature defines different pattern relationship types and many relationships among patterns. These relationships are analyzed based on designer's experience and formal methods are unclear. We propose graph based model to capture the semantics of a pattern using design decisions and their side-effects. Different relationships are analyzed using various graph properties which enables automation of relationship analysis. The complete paper is enclosed separately.

Papers Published in this year:

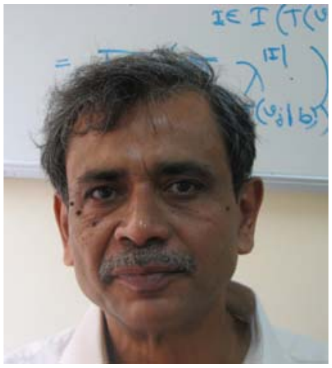
1. Design Decision Topology Model for Pattern Relationship Analysis by Kiran Kumar, TV Prabhakar, Submitted to IEEE Conference on Automated Software Engineering, awaiting response.
2. Some perspectives in teaching Software Architecture by Prabhakar TV, Kiran Kumar, Accepted at the SATURN Workshop, SEI-CMU, Pittsburg, April 29- May 1 2008.
3. Semantic LS – towards a Group Information Management System by Ajay Krishnan, Prabhakar TV, MS Ram, Vinay Jasti presented at PIM2008@SIGCHI 2008, Florence, Italy, April 2008

Talks:

Kiran Kumar gave a talk titled "Towards Building Application-Generic Architecture Knowledge" in the Workshop on Knowledge based Techniques in Software Architecture held in Conjunction with India Software Engineering Conference, Hyderabad, Feb 2008 Prabhakar TV gave a talk on An Ontlology for Software Architecture, at Vrije University, Brussels, September 2007. Kiran Kumar participated in the Doctoral Symposim at the Workshop on Research Directions in Software Engineering held at IIT Madras in December 2007

Visits

1. Vrije University, Amsterdam, September 2007.
2. SEI- CMU in April 28-May 1, 2008 for Saturn Workshop at SEI-CMU, Pittsburg
3. ISEC 2008, Hyderabad, February 2008
4. IIT Madras, December 2007
5. SIGCHI, Florence Italy, April 2008



Somenath Biswas
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Research Interests: Complexity Theory, randomized algorithms, bioinformatics, and logic.

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Structural Characterization of Good Instances for Randomized Search Strategies

The collaborative work with the group in MPI headed by Professor Benjamin Doerr is expected to begin with the scheduled visit of Professor Doerr and two of his colleagues in May to IITK.

In the meanwhile, through an MTech thesis work, we have made some progress on the case of Metropolis algorithm for its use in finding the minimum value in a large search space. In particular, we have considered the use of the algorithm for protein folding in the
lattice model. Sali, Shakhnovich, and Karplus, in a series of papers, had considered the performance of the Metropolis algorithm for this problem, using a bilologically acceptable modeling of free energy for configurations. Their motivation was primarily
to reason about characteristics of the energy landscape that would lead an amino acid chain to fold uniquely and rapidly. Their conclusion was that there should be a large gap between the minimum and the second minimum in the landscape for an amino acid chain to so fold. Peter Clote subsequently had attempted to justify theoretically this experimental conclusion, he had shown that a larger gap between the minimum and the second minimum would reduce a certain {\em upper bound} on the conductance of the underlying Markov chain. What we have found is that a necessary condition for rapid mixing of the underlying chain is that if a pair of states is adjacent in the neighbourhood graph, then the difference in their stationary probabilities cannot exceed an inverse polynomial. Another necessary condition is on the neighbourhood graph the Metropolis algorithm uses: exponentially many subsets of the set of vertices of the graph must have at least inverse polynomial edge expansion.

We now also have a sufficient condition for rapid mixing: the neighbourhood graph should be an expander graph, and the difference in stationary probabilities of adjacent vertices is upperbounded by a quantity that depends on the degree of the neighbourhood graph (always assumed to be a regular graph). We need now to examine how good is this sufficient condition-- can it shed some, at least qualitative, light on the protein configurations energy landscape?

Amitabha Mukherjee
Professor

Research Interests: Developmental Intelligence, Robotics in Education.

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Developmentally Motivated Models for Learning Ontology from Perception

During this period, work was done on three related areas of developmentally motivated learning for space and perception, which are outlined below. Also an international conference is being planned for December 2009 on "Cognitive Issues in Language and Perception". Several speakers have been invited, and it is hoped to attract a number of internationally known figures working in these areas. (co-organized with H. Karnick and A. Raina).

RESEARCH REVIEW:

I. Spatial ontology discovery
Here an unsupervised model was used to learn action schemas from observing a video of simple blocks moving around in a scene. The image schemas learned were used for language production on a novel 3D scene, thus validating that the models were general beyond the 2D scene. This work is premised on three assumptions: that the semantics of actions can be learned independently of language, that objects in attentive focus indicate the arguments participating in that action, and that knowing the arguments helps align linguistic attention on the relevant predicate (*verb*). Using a computational model of dynamic attention, we cluster ongoing events into action classes in an unsupervised manner using the Merge Neural Gas algorithm. With few clusters, the model correlates to coarse concepts such as *come-closer*, but with a finer granularity, it reveals hierarchical substructure such as *come-closer-one-object-static* and *come-closer-both-moving*. That the argument ordering is non-commutative is discovered for actions such as *chase* or *come-closer-one-object-static*. Knowing the arguments, and given the noun-referent mappings that are easily learned, we can constrain the language learning by considering only linguistic expressions and actions that refer to the objects in perceptual focus. We learn action schemas for linguistic units like ``moving towards" or ``chase", and validate our results by producing
output commentaries for 3D video.
Students involved:
Ph.D.: P. Guha
M.Tech. G. Satish, S. Daftardar

II. Learning appearance and action models from 3D video
Here the emphasis was on being able to analyze and find patterns in 3D video, resulting in the emergence of visual appearance models for 3D objects such as different classes of vehicles and humans. The abstracted agent models were tracked over time and their motion histories were clustered to obtain activity models.

Students:
Ph.D.: P. Guha
M.Tech. : Dipen Rughvani
B.Tech.: Makrand Sinha

III. Spatial modeling in design

Here the focus is on learning the spatial abstractions informing our interactions with 3D objects, especially as it obtains for tasks related to design. While interacting with sub-parts in a design task, humans quickly form functional constraints based on the behaviour. For instance, for a peg-in-hole task, the constraint that the hole has to be larger than the peg becomes obvious immediately. In this work, we attempt to discover such constraints from the mechanical interaction of parts for a limited families of designs, called Functional Part Families. Parts in such families share an embodiment and also a characteristic function; also some intermediate computations, such as constructing a Configuration space model, may be available. Given these, our proposed approach evaluates the functional performance for different designs, and discovers functional constraints as feasible regions in the design space. Considering mechanical assemblies from several lock families, we show how the system can learn obvious constraints like the peg-in-hole above, but also far less obvious functional constraints which may actually help novice designers.

Students involved:
Ph.D.: Madan Dabeeru
M.Tech. G. Satish

SELECTED PUBLICATIONS:

1. M. M. Dabbeeru, Mukerjee. A, Negotiating Design Specifications: Evolving Functional Constraints in Mechanical Assembly Design, Proceedings of the 2008 ACM Symposium on Solid and Physical Modeling, New York, USA, June 2-4, 2008.
2. M. M. Dabbeeru, Mukerjee. A, Discovering Implicit Constraints in Design, Proceedings of the Third International Conference on Design Computing and Cognition, June 23-25, 2008, Atlanta, USA.
3. Prithwijit Guha, Amitabha Mukerjee, Language Label Learning for Visual Concepts Discovered from Video Sequences In "Attention in Cognitive Systems: Theories and Systems from an Interdisciplinary Viewpoint", ed. Lucas Paletta, Springer LNCS v. 4840/2007, p. 91-105, December 2007.
4. Prithwijit Guha, Amitabha Mukerjee, and K.S. Venkatesh Occlusion Sequence Mining for Activity Discovery from Surveillance Videos In Pattern Recognition Technologies and Applications: Recent Advances, ed. Brijesh Verma and Michael Blumenstein, Information Science Reference Publishers, Australia (ISBN: 978-1-59904-807-9).

Piyush P. Kurur
Assistant Professor

Research Interests: Algorithms and Computational Complexity, Computational Algebra, Quantum Computing, Error correcting codes.

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The complexity of Matrix Multiplication

1 *Progress on Group theoretic approach*

The group theoretic approach of Cohn and Umans is based on embedding matrix multiplication exactly into a group algebra. However many of the fast matrix multiplication algorithms obtained previously use a weaker notion of *approximate embedding*. This is based on the concept of *border rank* (see [1, Definition 15.19]). We can have a weaker version of Cohn Umans criteria which may lead to interesting matrix multiplication algorithm even when the under lying group is abelian which we describe now.

Let G be a group and let A_i, $1 \leq i \leq 3$ be subsets of G of cardinalities n_i respectively. Recall that we say that the sets A_i satisfies the triple product property if for all $q_i \in Q_i = A_i^{-1} A_i$ we have $q_1 q_2 q_3 = 1$ implies $q_1 = q_2 = q_3 = 1$. The heart of the Group theoretic method of Cohn and Umans is that if A_i's satisfies the triple product property then the matrix multiplication bilinear map $\langle n_1, n_2, n_3 \rangle$ can be embedded in the group algebra multiplication of $\mathbb{C}[G]$. This leads to the bound $(n_1 n_2 n_3)^{\omega/3} \leq \sum d_i^{\omega}$ where d_i's are the character degrees of G. We weaken this condition as follows: Suppose that A_i's do not satisfy the triple product property but only the double product property i.e. for distinct
i and j for all q_i and q_j in Q_i and Q_j respectively, $q_i q_j = 1$ if and only if $q_i = q_j = 1$. Suppose that there are functions $a_{i,j} : Ai \times Aj \rightarrow Z$ with the property that for all $q_i = x_i^{-1} y_i$, x_i and y_i elements of A_i we have $a_{1,2}(x_1, y_2) + a_{2,3}(x_2, y_3) + a_{3,1}(x_3, y_1)$ is strictly positive if $q_1 q_2 q_3$ violates the triple product property and zero other wise. We can then embed "approximately" $\langle n_1, n_2, n_3 \rangle$ into the group algebra $\mathbb{C}[G]$ multiplication. In this case we say that G weakly realises $\langle m_1, m_2, m_3 \rangle$. Similar to Cohn and Umans, using border rank instead of rank, we can show that if G realises $\langle m,n,p \rangle$ and has character degrees $\{d_i\}_{1 \leq i \leq k}$ then using Schonhage's asymptotic sum inequality[1, Theorem 15.11] for border ranks we have

$$(mnp)^{\omega/3} \leq \sum_{i=1}^{k} d_i^{\omega}$$

This condition is weaker than that of Cohn and Umans as any sets with triple product property satisfies this weaker condition we have described above (where $a_{i,j}$ are the zero functions). It is possible that even abelian groups may yield nontrivial estimates under this weaker condition — we have a candidate family of such subsets of abelian groups satisfying the double product property for which we have not yet found the functions $a_{i,j}$'s.

2 Related research : Fast algorithms for integer multiplication

As part of the research done we were able to give a variant of the recent fast integer multiplication algorithm due to Furer [3]. We give an $N \cdot \log N \cdot {}^{O(\log^* N)}$ algorithm [2] for integer multiplication that uses modular arithmetic as opposed to arithmetic over complex numbers used by Furer in his algorithm. One advantage of this is that the analysis of the resulting algorithm is simplified. Also it gives a discrete solution for a discrete problem.

References

1. Peter Burgisser, Michael Clausen, and M. Amin Shokrollahi. Algebraic Complexity Theory. Springer Verlag, 1997.
2. Anindya De, Piyush P Kurur, Chandan Saha, and Ramprasad Saptharishi. Fast integer multiplication using modular arithmetic. In 40th ACM Symposium on Theory of Computing, To appear, 2008.
3. Martin Furer. Faster integer multiplication. Proceedings of the 39th ACM Symposium on Theory of Computing, pages 57–66, 2007.

Anil Seth Associate Professor

Research Interests: Logic in Computer Science.

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Temporal Logics for Interacting Process Classes

The project is being carried in collaboration with Prof. P. S. Thiagarajan from the department of computer science, School of Computing, National University of Singapore, Singapore. The objective of this project is to develop temporal logics for Interacting Process Classes (IPC). To simplify the matter, initially we consider only one process class. Objects in this class can interact with each other according to some interaction alphabet. An interaction among k distinct such objects is modeled by a pair of k-tuple of states $((q_1 \ldots q_k), (q'_1, \ldots ,q'_k))$, meaning that participating object i must be in state q_i just before the interaction and its state changes to q'_i as a result of this interaction. An crucial feature is that there is no bound on the number of objects in the class. This makes the system infinite state even if states of objects in the class range over a finite set Q. In line with the proposed schedule, we defined the execution sequences of IPC to interprete formulae of object temporal logic. The first semantics we considered allowed the ariables in existential quantifier to range over the entire universe of objects OBJ. A notion of model analogous to a transition system (or finite state Kripke structure) was also defined for interacting objects. Both satisfiability as well as model checking problem were shown to be undecidable. The undecidability argument is based on simulation of register machines. For a restricted fragment of this logic, where formulas are of the form $3x$.ø and ø does not have any object quantification, the satisfiabilty is shown equivalent to checking Buchi condition on vector addition systems. Next we restricted the semantics, to have variables occurring in existential quantifiers to refer only to those objects which participate in a action where the quantified formula is interpreted. This is somewhat like a local logic, but one may note here that only domain of the quantifier is restricted, the scope over temporal line is not restricted (the scope is determined by syntactic structure of the formula ø, which may have temporal operators containing x). The logic was seen to express many useful scenarios through examples. We are currently examining decidability for this logic. Going away from logic and focusing on the model, we show that reachability property (that a certain marking or configuration can be reached from the initial configuration) is decidable. Currently, we are examining liveness property of the object transition system (certain marking or configuration is visited infinitely often) from decidability point of view. On the logic side we also plan to examine branching time logic based on CTL. The IIT Kanpur faculty member of the project visited NUS Singapore for about a week in October 2007.

Surender Baswana

Assistant professor

Research Interests: Design and analysis of algorithms

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Efficient algorithms which solve problems approximately and/or in dynamic scenario.

The project involves doing research in two areas of algorithms. The first research area is that of dynamic graphs algorithms. The second research area deals with designing algorithms which achieve better running time at the expense of solving the problem approximately instead of exactly. In the last one year, we designed efficient dynamic and streaming algorithms for graph spanners. Spanner of an undirected graph G = (V,E) is a sub graph which is sparse and yet preserves all-pairs distances approximately. More precisely, a spanner with stretch $t \geq 1$ is a subgraph (V,E_S), with E_S a subset of E, such that the distance between any two vertices in the subgraph is at most t times their distance in G. Spanners have many applications in computing approximate distances in a graph, distributed computing, compact routing, and computational biology.

Dynamic Algorithms for spanners: Working with Soumojit Sarkar (M.Tech. student), we designed two fully dynamic algorithms [1] for maintaining a sparse t-spanner of an unweighted graph. The expected size of the t-spanner maintained at each stage by our algorithms matches the worst case optimal size of a t-spanner upto poly-logarithmic factor. Our first algorithm achieves expected $O(7^{t/4})$ time per update independent of the size of the graph. This algorithm is particularly of interest for maintaining small stretch spanners. Our second algorithm achieves expected O(polylog |V|) time per update irrespective of the stretch. This work appeared in the publication [1].

Streaming Algorithms for spanners: Spanners are used in various algorithms for computing approximate distances of undirected graphs. We also address the problem of computing spanners in streaming model. A streaming model has the following two characteristics: firstly the input data can be accessed only sequentially in the form of a stream; secondly the working memory is considerably smaller than the size of the entire input stream. An algorithm in this model is allowed to make one or more passes over the input stream to solve a given computational problem. The number of passes, the size of working memory, and the processing time per data item are the parameters which one aims to optimize in a streaming algorithm. We present a one pass streaming algorithm that spends just constant average time per edge and computes a $(2k-1)$-spanner of expected size $O(kn^{1+1/k})$. Note that the size of the spanner (and the working memory) is away from the conjectured optimal bound just by a factor of k, and so is essentially optimal for any constant k. Moreover, one pass and O(m) time to process the stream is the best one can hope for in the streaming model. This result has appeared in the publication [2].

1. S. Baswana and S. Sarkar. Fully Dynamic Polylogarithmic Algorithms for Graph Spanners. Proc. 19th Symposium on Discrete Algorithms (SODA), pp. 672-681. ACM and SIAM, 2008.
2. S. Baswana. Streaming algorithm for graph spanners - single pass and constant processing time per edge. Information Processing Letters 106(3), 110-114, 2008.

Shashank K. Mehta
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Research Interests: Graph theory, Algorithms, VLSI Circuit testing, Algebraic Geometry.

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Representation for Rings and Modules

The problem proposed to study in this project is the structure of the ring generated by 0/1-matrices using the structure of the graphs represented by these matrices, treated as adjacency matrix. Let $X=(V,A)$ be a graph and let $C_X = \{A_0,A_1,\ldots\}$ be the most coarse partition of $\mathbb{J}$ (all entries 1), respecting $I,A,\bar{A}$ such that $A_iA_j=\sum_k p_{ijk} A_k$ for some integers p_{ijk}. We want to study the properties of the ring generated by , $C_X=K(C_X)$, using the properties of the graphs defined by A_i. Specifically we want to find what graph properties imply that $K(C_X)$ is commutative in a division ring.

We focus on graphs X that belong to the graph classes *strongly regular*(SR), *distance regular*(DR), *generously regular*(GR), and *vertex transitive*(VR), where each class is the subclass of the next. In SR $C=\{I,A,\bar{A}\}$; I and A remain intact for DR; in GR all matrices in C are symmetric and I belongs to it; and in VT $I \in C$ and if $A_i \in C$ then A_i^t also belongs to C. One question we are trying to answer is, "**is the automorphism group of** X **a complete system of commuting operator of** $K(C_X)$ **?"**.

If G is an automorphism of X, then it also acts on $V(X)\times V(X)$. The orbits of this action are called the orbitals graphs. The second problem of inquiry is, "**is** C_X **same as the set of orbitals of** X,O_X **?".** In case of DR graphs $\{A^0,A^1,\ldots,A^d\}$ is a basis of $K(O_X)$, where d is the diameter of X. This algebra is isomorphic to $K[x]/p(x)$ where p is the minimal polynomial of A. Third query is **"is** $K(O_X)$ **isomorphic to** $K[x]/\langle p_0(x),p_1(x),\ldots\rangle$ **where** $p_i(x)$ **is the minimal polynomial of** A_i **for all** i**, in case of generously transitive graphs ?".** The algebra generated by the sum of the conjegacy classes in the automorphism group is called the class algebra. It is isomorphic to the centralized, $Z(KG)$. We conjecture that **"**$K(C_X)$ **is isomorphic to some sunalgebra of the class algebra of the automorphism groups of** X **?**". We have to study representation theory of permutation graphs, character theory, and Bose-Mesner algebra to get a full understanding of the problem.

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