

THE STRUCTURE OF KOSZUL ALGEBRAS DEFINED BY FOUR QUADRICS

PAOLO MANTERO AND MATTHEW MASTROENI

ABSTRACT. Avramov, Conca, and Iyengar ask whether $\beta_i^S(R) \leq \binom{g}{i}$ for all i when $R = S/I$ is a Koszul algebra minimally defined by g quadrics. In recent work, we give an affirmative answer to this question when $g \leq 4$ by completely classifying the possible Betti tables of Koszul algebras defined by height-two ideals of four quadrics. Continuing this work, the current paper proves a structure theorem for Koszul algebras defined by four quadrics. We show that all these Koszul algebras are LG-quadratic, proving that an example of Conca of a Koszul algebra that is not LG-quadratic is minimal in terms of number of defining equations. We then characterize precisely when these rings are absolutely Koszul, and establish the equivalence of the absolutely Koszul and Backelin–Roos properties up to field extensions for such rings (in characteristic zero). The combination of the above paper with the current one provides a fairly complete picture of all Koszul algebras defined by $g \leq 4$ quadrics.

1. INTRODUCTION

A graded ideal I in a standard graded polynomial ring S over a field k defines a *Koszul algebra* $R = S/I$ if $k \cong R/R_+$ has a linear free resolution over R . This extraordinary homological condition leads to numerous other restrictions on the Hilbert series and Betti numbers of R over S ; see [Fro99] and [Con14]. In particular, a question of Avramov, Conca, and Iyengar asks:

Question 1.1 ([AC10, 6.5]). If R is Koszul and I is minimally generated by g quadrics, does the following inequality hold for all i ?

$$\beta_i^S(R) \leq \binom{g}{i}$$

In particular, is $\text{pd}_S R \leq g$?

This question is known to have an affirmative answer when R is LG-quadratic. We say that R or I is *G-quadratic* if, after a suitable linear change of coordinates $\varphi : S \rightarrow S$, the ideal $\varphi(I)$ has a Gröbner basis consisting of quadrics. We also say that R or I is *LG-quadratic* if R is a quotient of a G-quadratic algebra A by an A -sequence of linear forms. Every G-quadratic algebra is Koszul by upper semicontinuity of the Betti numbers; see [BC03, 3.13]. Since deforming by a regular sequence of linear forms preserves Koszulness (see Proposition 2.1), every LG-quadratic algebra is also Koszul.

Dualities On Generalized Koszul Algebras

Benoît Mselati



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Dualities on Generalized Koszul Algebras Edward L. Green, Idun Reiten, Øyvind Solberg, 2002 Koszul rings are graded rings which have played an important role in algebraic topology noncommutative algebraic geometry and in the theory of quantum groups One aspect of the theory is to compare the module theory for a Koszul ring and its Koszul dual There are dualities between subcategories of graded modules the Koszul modules Classification and Probabilistic Representation of the Positive Solutions of a Semilinear Elliptic Equation Benoît Mselati, 2004 Concerned with the nonnegative solutions of $\Delta u = u^2$ in a bounded and smooth domain in \mathbb{R}^d this title intends to prove that they are uniquely determined by their fine trace on the boundary as defined in DK98a answering a major open question of Dy02 **Connectivity Properties of Group Actions on Non-Positively Curved Spaces** Robert Bieri, Ross Geoghegan, 2003 Generalizing the Bieri Neumann Strebel Renz Invariants this Memoir presents the foundations of a theory of not necessarily discrete actions ρ of a suitable group G by isometries on a proper CAT 0 space M The passage from groups G to group actions ρ implies the introduction of Sigma invariants $\Sigma_k \rho$ to replace the previous $\Sigma_k G$ introduced by those authors Their theory is now seen as a special case of what is studied here so that readers seeking a detailed treatment of their theory will find it included here as a special case We define and study controlled k connectedness CC_k of ρ both over M and over end points e in the boundary at infinity ∂M $\Sigma_k \rho$ is by definition the set of all e over which the action is $k+1$ connected A central theorem the Boundary Criterion says that $\Sigma_k \rho = \partial M$ if and only if ρ is CC_{k+1} over M An Openness Theorem says that CC_k over M is an open condition on the space of isometric actions ρ of G on M Another Openness Theorem says that $\Sigma_k \rho$ is an open subset of ∂M with respect to the Tits metric topology When ρ of G is a discrete group of isometries the property CC_{k+1} is equivalent to $\ker \rho$ having the topological finiteness property type F_k More generally if the orbits of the action are discrete CC_{k+1} is equivalent to the point stabilizers having type F_k In particular for $k=2$ we are characterizing finite presentability of kernels and stabilizers Examples discussed include locally rigid actions translation actions on vector spaces especially those by metabelian groups **Descriptive Set Theory and Definable Forcing** Jindřich Zapletal, 2004 Focuses on the relationship between definable forcing and descriptive set theory the forcing serves as a tool for proving independence of inequalities between cardinal invariants of the continuum **Algebras and Modules II** Idun Reiten, Sverre O. Smalø, Øyvind Solberg, Canadian Mathematical Society, 1998 The 43 research papers demonstrate the application of recent developments in the representation theory of artin algebras and related topics Among the algebras considered are tame biserial cellular factorial hereditary Hopf Koszul non polynomial growth pre projective Termperley Lieb tilted and quasi tilted Other topics include tilting and co tilting modules and generalizations as modules exceptional sequences of modules and vector bundles homological conjectures and vector space categories The treatment assumes knowledge of non commutative algebra including rings modules and homological algebra at a graduate or professional level No index Member prices are 79

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Banach Embedding Properties of Non-Commutative L^p -Spaces U. Haagerup, Haskell P. Rosenthal, F. A. Sukochev, 2003 Let \mathcal{N} and \mathcal{M} be von Neumann algebras It is proved that $L^p(\mathcal{N})$ does not linearly topologically embed in $L^p(\mathcal{M})$ for \mathcal{N} infinite and \mathcal{M} finite

The Maximal Subgroups of Positive Dimension in Exceptional Algebraic Groups Martin W. Liebeck, Gary M. Seitz, 2004 Intends to complete the determination of the maximal subgroups of positive dimension in simple algebraic groups of exceptional type over algebraically closed fields This title follows work of Dynkin who solved the problem in characteristic zero and Seitz who did likewise over fields whose characteristic is not too small

Equivariant, Almost-Arborescent Representations of Open Simply-Connected 3-Manifolds; A Finiteness Result Valentin Poenaru, C. Tanasi, 2004 Shows that at the cost of replacing V DEGREES3 by V_h DEGREES3 V DEGREES3 with very many holes we can always find representations X DEGREES2 $\rightarrow V$ DEGREES3 with X DEGREES2 locally finite and almost arborescent with Ψ $\rightarrow \Phi$ and with the ope

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Advances in Lie Superalgebras Maria Gorelik, Paolo Papi, 2014-04-28 The volume is the outcome of the conference Lie superalgebras which was held at the Istituto Nazionale di Alta Matematica in 2012 The conference gathered many specialists in the subject and the talks held provided comprehensive insights into the newest trends in research on Lie superalgebras and related topics like vertex algebras representation theory and supergeometry The book contains contributions of many leading experts in the field and provides a complete account of the newest trends in research on Lie Superalgebras

Algebra, Geometry and Mathematical Physics Abdenacer Makhoul, Eugen Paal, Sergei D. Silvestrov, Alexander Stolin, 2014-06-17 This book collects the proceedings of the Algebra Geometry and Mathematical Physics Conference held at the University of Haute Alsace France October 2011 Organized in the four areas of algebra geometry dynamical symmetries and conservation laws and mathematical physics and applications the book covers deformation theory and quantization Hom algebras and n ary algebraic structures Hopf algebra integrable systems and related math structures jet theory and Weil bundles Lie theory and applications non commutative and Lie algebra and more The papers explore the interplay between research in contemporary mathematics and physics concerned with generalizations of the main structures of Lie theory aimed at quantization and discrete and non commutative extensions of differential calculus and geometry non associative structures actions of groups and semi groups non commutative

dynamics non commutative geometry and applications in physics and beyond The book benefits a broad audience of researchers and advanced students

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Representations of Algebras and Related Topics Ragnar-Olaf Buchweitz, Helmut Lenzing, 2005 Twelve year old Molly and her ten year old brother Michael have never liked their younger stepsister Heather Ever since their parents got married she s made Molly and Michael s life miserable Now their parents have moved them all to the country to live in a house that used to be a church with a cemetery in the backyard If that s not bad enough Heather starts talking to a ghost named Helen and warning Molly and Michael that Helen is coming for them Molly feels certain Heather is in some kind of danger but every time she tries to help Heather twists things around to get her into trouble It seems as if things can t get any worse But they do when Helen comes Genuinely scary complete with dark secrets from the past unsettled graves and a very real ghost The Bulletin of the Center for Children s Books An unusually scary well crafted ghost fantasy Kirkus Reviews

New Spaces in Mathematics Mathieu Anel, Gabriel Catren, 2021-04 In this graduate level book leading researchers explore various new notions of space in mathematics

Higher Structures and Operadic Calculus Bruno Vallette, 2025-05-19 This book presents the notes originating from five series of lectures given at the CRM Barcelona in 21-25 June 2021 during the Higher homotopical structures programme Since their introduction 60 years ago the notions of infinity algebras Stasheff Sugawara higher categories Boardman Vogt operads May and model categories Quillen have given rise to powerful new tools which made possible the resolution of open problems and prompted revolutions in many domains like algebraic topology rational homotopy theory faithful algebraic invariants of the homotopy type of spaces deformation theory formality theorems formal moduli problems and mathematical physics quantization of Poisson manifolds quantum field theories to name but a few This theory of higher structures using operadic calculus is currently under rapid development The aim of this book is to provide the community with an accessible state of the art while at the same time giving interested researchers and advanced students a brief overview on the subject

Numerical Control over Complex Analytic Singularities David B. Massey, 2003 Generalizes the Le cycles and numbers to the case of hyper surfaces inside arbitrary analytic spaces This book defines the Le Vogel cycles and numbers and prove that the Le Vogel numbers control Thom s a_1 condition It describes the relationship between the Euler characteristic of the Milnor fibre and the Le Vogel numbers

Representations of Semisimple Lie Algebras in the BGG Category \mathcal{O} James E. Humphreys, 2021-07-14 This is the first textbook treatment of work leading to the landmark 1979 Kazhdan Lusztig Conjecture on characters of simple highest weight modules for a

semisimple Lie algebra \mathfrak{g} over \mathbb{C} The setting is the module category \mathcal{O} introduced by Bernstein Gelfand Gelfand which includes all highest weight modules for \mathfrak{g} such as Verma modules and finite dimensional simple modules Analogues of this category have become influential in many areas of representation theory Part I can be used as a text for independent study or for a mid level one semester graduate course it includes exercises and examples The main prerequisite is familiarity with the structure theory of \mathfrak{g} Basic techniques in category \mathcal{O} such as BGG Reciprocity and Jantzen's translation functors are developed culminating in an overview of the proof of the Kazhdan Lusztig Conjecture due to Beilinson Bernstein and Brylinski Kashiwara The full proof however is beyond the scope of this book requiring deep geometric methods \mathcal{D} modules and perverse sheaves on the flag variety Part II introduces closely related topics important in current research parabolic category \mathcal{O} projective functors tilting modules twisting and completion functors and Koszul duality theorem of Beilinson Ginzburg Soergel

Homological Algebra of Semimodules and Semicontramodules Leonid Positselski, 2010-09-02 This book provides comprehensive coverage on semi infinite homology and cohomology of associative algebraic structures It features rich representation theoretic and algebraic geometric examples and applications

The Conjugacy Problem and Higman Embeddings Aleksandr Ilyukhin, Mark Sapir, 2004 For every finitely generated recursively presented group G we construct a finitely presented group H containing G such that G is Frattini embedded into H and the group H has solvable conjugacy problem if and only if G has solvable conjugacy problem

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