MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

Tagungsbericht 37/1979

Topologie (Spezialtagung)

2.9. - 8.9.1979

Die Tagung fand unter der Leitung der Herrn E.Looijenga (Nijmegen), Th.Bröcker (Regensburg) und D.Eisenbud (Waltham) statt. Im Mittelpunkt des Interesses standen Fragen der Singularitätentheorie.

Vortragsauszüge

H. BRODERSEN:

∞ determinacy of smooth map germs

Let $\mathcal{E}$ denote the space of germs of C^∞ functions $f:(R^n,0) \to R$. We say that $f \in \mathcal{E}^p$ is ∞ determined if for each $g \in \mathcal{E}^p$ with $j^\infty(g) = j^\infty(f)$ we can find a germ of a C^∞ diffeomorphism $h:(R^n,0) \to (R^n,0)$ such that $f = g.h$. Considering germs of homeomorphisms and C^k diffeomorphisms define finitely (resp ∞) topologically and finitely C^k determined germs in an obvious way. Then all these notions are equivalent. Let $m_n \subset \mathcal{E}$ denote the maximal ideal, put $m_n^\infty = \bigcap_k m_n^k$, and consider the ideal $I(f) \subset \mathcal{E}$ generated by the $p \times p$ minors in $f'(x)$, and the $\mathcal{E}$ module $m_n\langle \frac{\partial f}{\partial x_1},\dots,\frac{\partial f}{\partial x_n}\rangle \subset \mathcal{E}^p$. Then $m_n^\infty \subset I(f) \Leftrightarrow m_n^\infty \mathcal{E}^p \subset m_n\langle \frac{\partial f}{\partial x_1},\dots,\frac{\partial f}{\partial x_n}\rangle \Leftrightarrow f$ is ∞ determined. This generalize a theorem of Nguỹen, et al. for functions and is in analogy with Mathers theorem of finitely determined map germs.

J.W. BRUCE:

<u>The duals of generic hypersurfaces</u>

By applying a transversality theorem due to Looijenga we first discuss the structure of the dual of a generic hypersurface M^n in $\mathbb{R}^{n+1}$. We then show that for generic projective algebraic hypersurfaces in $\mathbb{C}P^{n+1}$ (or $\mathbb{R}P^{n+1}$) similar results hold provided the degree $\overset{d}{\lambda}$ of the hypersurface is sufficiently large. The methods employed are novel insofar as they entail proving transversality theorems in the complex algebraic category. A sample result is: For $n \leq 6$ and $d \geq 2n+5$ the dual of a projective hypersurface is locally the intersection (transverse) of the discriminant varieties of simple singularities.
N.B.: The author remarks, that the results are in a preliminary form and may need correcting and rewriting.

J.N. DAMON:

<u>Finite determinacy and topological triviality</u>

In this talk, I will describe the role that finite A - determinacy plays in the topological triviality of unfoldings of weighted homogeneous polynomial germs

$$f:k^s,0 \to k^t,0 \quad (k = \mathbb{R} \text{ or } \mathbb{C}).$$

The original results for topological triviality concerned hypersurface germs and were obtained by Le-Ramanujam, Teissier, and Timourian. I will describe how these results have been extended to non-hypersurface germs including versal unfoldings by results of Looijenga, Wirthmüller, and myself.

G.-M. GREUEL:

Duality and isolated singularities

Let (X,x) be a pure n-dimensional germ of a complex space with isolated singularity and let Ω_X^p be the sheaf of holomorphic p-forms on X. A theorem of I.Naruki (Publ. RIMS 13, 1975) asserts the following strange duality between local cohomology groups:

$$(*) \qquad H^q_{\{x\}}(\Omega^p_X) \cong H^{n-q+1}_{\{x\}}(\Omega^{n-p}_X)^*, \quad 2 \le q \le n-1 .$$

This is proved by a combination of Serre duality and an approximation theorem of Andreotti and Grauert. We use this duality and local duality of Grothendieck to show the following theorem:

Let (X,x) be a complete intersection and $n \geq 1$. Let μ be the Milnor number of (X,x) and τ be the Tjurina number of (X,x) (i.e. the dimension of the base space of the semiuniversal deformation of (X,x)).

Then 1) $\mu \geq \tau$ if the neighbourhood boundary ∂X of (X,x) is a Betti sphere.

2) $\mu = \tau$ if (X,x) is quasihomogeneous.

We conjecture that $\mu \geq \tau$ always holds (which is true for curves and hypersurfaces).

Now assume that (X,x) is a quasihomogeneous complete intersection and n > 2. Then Naruki showed $H^r(\partial X, \mathbb{C}) \cong \bigoplus_{p+q=r} H^p(R^q i_*(i^*\Omega_X)_x)$ (where $i: X-\{x\} \to X$ denotes the inclusion) which provides a rich structure on $H^r(\partial X, \mathbb{C})$. Using the duality (*) and $\mu = \tau$ we can show: For an n-dimensional isolated singularity, n even, to be topological equivalent to a quasihomogeneous complete intersection it is necessary that $\dim_{\mathbb{C}} H^n(\partial X, \mathbb{C})$ is even. This was first proved by Steenbrink (for hypersurfaces) and later by Varchenko with quite different methods.

A. HAMM:

<u>Weighted homogeneous complete intersections</u>

The topological type of an affine weighted homogeneous complete intersection with isolated singularity depends only on the neighbourhood boundary K. There is a natural S^1-action on K, and K/S^1 is a subvariety of a weighted projective space. Since the χ_y-genus of K/S^1 has been computed [Funkcional.Anal.i Prilozen. 11, vyp.1, 87-88 (1977)], it is easy to derive a formula for the rational homology of K. To get the torsion part of the integral homology is harder; there is an inductive procedure to compute it. The special case of Brieskorn varieties has already been treated by R.Randell [Topology 14, 347-355 (1975)].

U.KARRAS:

A normal surface singularity is smoothable if their exists a flat family $\mathfrak{X} \to D$ of normal surfaces over a small disc such that the special fibre is isomorphic to V and such that the generic fibre is smooth. In 1973, Mumford gave first examples of surface singularities which are not smoothable. These examples are certain cones over smooth curves. For example, it turns out that cones over smooth rational curves are always smoothable but cones over smooth elliptic curves are smoothable if and only if their degrees are less than 10.

Let g(V,p) denote the genus of a normal surface singularity. For rational cones, the number is equal to zero, and for elliptic cones it equals one. More generally, one calls (V,p) rational (elliptic) if g(V,p) = 0 (g(V,p) = 1). Thus rational (elliptic) singularities are smoothable if they can be deformed into cones over rational curves (resp. elliptic curves of degree < 10). Using deformations of resolutions, Artin showed that rational singularities can be always deformed into rational cones. The only thing one has to do is to smooth the exceptional set. However, deformations of resolutions of non-rational singularities blow down to deformations of given singularities if and only if the genus does not jump. In case of elliptic singularities one has therefore to make sure that the minimally elliptic cycle E in the sense of Laufer lifts to the deformations. The aim of the talk is to outline a proof of following result.

<u>Theorem.</u> Elliptic singularities are smoothable if the selfintersections of their minimally elliptic cycles are not less than -9.

H.C. KING:

<u>The topology of real algebraic sets</u>

This talk will be on the problem of when a topological space is homeomorphic to an algebraic set (the set of solutions of polynomial equations). For instance in low dimensions it is possible to give necessary and sufficient conditions.

H. LAUFER:

Adjacencies via resolutions

Let (V,p) be a normal two-dimensional singularity of one of the following types: simple, unimodal, bimodal, rational triple point or quotient singularity. Let $\pi:M \to V$ be a resolution of V. Let $\varpi:\mathfrak{M} \to Q$ be the versal deformation of M. The simultaneous blow-down subspace T of Q can be easily described. Then one can calculate which singularities are above T. For the unimodal and bimodal singularities, this gives all adjacencies between singularities with the same $Z\cdot Z$ (degree). A computer is needed for some of the calculations.

LE DUNG TRANG:

Démonstration du "théorème" de Zariski par Fulton et Deligne

Soit C une courbe projective complexe plane dont les singularités sont des points quadratiques ordinaires. Le groupe fondamental de son complémentaire dans P^2 est abélien.

La démonstration de Zariski repose sur un resultat de F.Severi dont la démonstration est inconnecte. On ignore en fait encore si ce resultat de F.Severi est vrai ou non.

Le résultat énoncé par Zariski a été démontré par P.Deligne en suivant une demonstration de Fulton du theorème "algébrique" correspondant au théorème de Zariski. Précisément (sur $\mathbb{C}$) Fulton obtient: Soit C une courbe projective plane dans P^2 dont les seules singularités sont quadratiques ordinaires. Alors tout revêlement galoisien de P^2 ramifié le long de C est abélien.

Ce théorème implique que le complété $\hat{\pi}_1(P^2-C,*)$ de $\pi_1(P^2-C,*)$ pour la topologie des sous-groupes d'indice fini est abélien. Ceci implique que $\pi_1(P^2-C,*)$ est abélien si l'intersection de ces sous-groupes d'indice fini est triviale.

La démonstration de Fulton repose sur le théorème suivant de Abhyankar:

Soit V une surface non singulière algébriquement simplement connexe (i.e. $\pi_1(V_\mu) = 0$), soit $C \subset V$ une courbe de V dont les singularités sont quadratiques ordinaires. Soit $f:V' \to V$ un revêtement Galoisien de V ramifié de long de C; si deux composantes irreductibles de $f^{-1}(C) = D$ s'intersectent, on a que le groupe de Galois des corps des fonctions $\mathbb{C}(V')$ de V' sur $\mathbb{C}(V)$ est abélien.

Dans le cas ou $V = P^2$, Fulton remarque que pour démontrer que tout revêtement Galoisien de P^2 ramifié le long de C est abélien, il suffit de demontrer que pour un cel revêtement ramifié $f:V' \to P^2$, l'image inverse $f^{-1}(C_i)$ d'une composante irreductible C_i de C est irréductible.

Pour obtenir ce resultat, Fulton fait l'ingénieuse construction suivante:

Soit $\bar{C}_i \xrightarrow{n} C_i$ la normalisation de C_i, Notons $\pi:\bar{C}_i \to P^2$ l'application composée de n et de l'inclusion $C_i \subset P^2$. On a alors $F = \pi \times f : \bar{C}_i \times V' \to P^2 \times P^2$. On appelle $p:\bar{C}_i \times V' \to V'$ la projection. On remarque alors que, si Δ est la diagonale de $P^2 \times P^2$, on a:

$$p(F^{-1}(\Delta)) = f^{-1}(C_i).$$

Fulton obtient son résultat en remarquant: i) l'image par p d'une composante connexe de $F^{-1}(\Delta)$ est une composante irréductible de

$f^{-1}(C_i)$. ii) $F^{-1}(\Delta)$ est connexe.

Le i) est facile à vérifier. Le ii) est conséquence d'un récent théorème de Hansen et Fulton:

Soit $f:Z \to (P^d)^n$ un morphisme algébrique d'une variété algébrique irréductible projective dans $(P^d)^n$. Si dim $f(Z) > d(n-1)$, l'image inverse $f^{-1}(\Delta)$ de la diagonale Δ de $(P^d)^n$ est connexe.

La démonstration de Deligne du "théorème" de Zariski utilise des résultats un peu plus généraux que ceux utilisés par Hansen et Fulton. En particulier il utilise le théorème suivant:

Soit Z une sous-variété non singulière connexe <u>localement fermée</u> de $(P^d)^n$ avec dim $Z > d(n-1)$. La diagonale Δ de $(P^d)^n$ a un système fondamental $V_\alpha(\Delta)$ de voisinages tels que $V_\alpha(\Delta) \cap Z$ est connexe et $\pi_1(Z \cap V_\alpha(\Delta)) \to \pi_1(Z)$ surjectif.

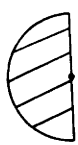
H. LEVINE:

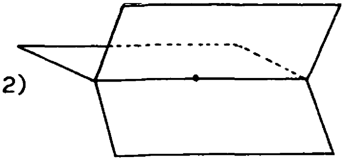
<u>Lifting 3 - manifolds out of the plane</u>

Let be M a compact 3-manifold and $f:M \to R^2$ be a C^∞-stable map. To study such maps generally and to find out when such maps can be lifted to immersions of M into R^4, introduce the following equivalence relation on M: x,y are equivalent if x and y are both in the same connected component of $f^{-1}(f(x))$. Let W_f be the quotient by this relation, and let $q:M \to W_f$ be the quotient map. If $\Sigma(f)$ is the set of points at which Tf has rank 1, W_f fails to be a 2-manifold exactly at $q(\Sigma(f))$. However since the singularities of f are very limited, the local description of W_f at the non-manifold points is very limited:

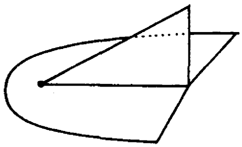
1) Halfplane

q-image of a neighbourhood of a point at which f has the form: $(u,x,y) \to (u,x^2+y^2)$



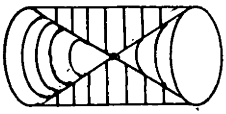
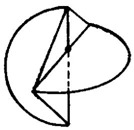
2) 

q-image of a neighbourhood of a point at which f has the form: (u,x^2-y^2) provided the point is not a double point of q/Σ (f).

3) 

q-image of a neighbourhood of a point at which f has the form:

$(u,x,y) \to (u,y^2+xu+u^3)$.

4)  

q-image of a neighbourhood of two distinct points into common q-image, at which f has the form:

$(u,x,y) \to (u,x^2-y^2)$

By first immersing W_f in R^3 over $f\circ g^{-1}$: $W_f \to R^2$ with only normal crossings in the regular points, I think one can show that for all orientable M, f can be lifted to a immension of M into R^4. For non-orientable M, one needs a further assumption on the orientability of the circle bundles over neighbouring regions of $W_f-g(\Sigma(f))$. This condition was not stated explicitly due to lack of time.

This work is an collaboration with Leon Kushner and Paulo Porto.

W. NEUMANN:

Topology of normal surface singularities

We show that the oriented homeomorphism type of the link (i.e. regular neighbourhood boundary) M^3 of a normal surface singularity (V,p) determines the topology of the resolution. Except for obvious exceptions (lens spaces and certain torus bundles) $\pi_1(M)$ already suffices. Analogous results are also obtained for degenerating families of curves. The method is Waldhausen's classification of graph manifolds, which also has some other corollaries for the topology of surface singularities and degenerating families of curves.

A. DU PLESSIS

Determinacy of smooth map-germs

A (smooth) map-germ f is said to be r-determined if every germ with the same r-jet is equivalent to f under (smooth) changes of co-ordinates in sources and target.

In 1969 Mather gave a characterization of finitely-determined germs (i.e. germs that are r-determined for some $r < \infty$); the method also gave an estimate for the actual order of determinacy, but this was extremely large. (Better estimates have since been obtained by Gaffney and Martinet).

Rather precise estimates are naturally essential in order to carry out any classification of map-germs; such precise estimates will be derived in the lecture. Indeed the ideas involved also lead to rather generally applicable classification methods.

F. RONGA

A geometric approach to the arithmetic genus of a projective manifold of dimension three.

(This is a joint work with R. Piene (Oslo)).

Let $V^3 \to P^N_C$ be a complex projective three-dimensional manifold (i.e. non-singular) and let $f: V^3 \to P^4$ be a generic projection. Let $\chi(O_V)$ denote the arithmetic genus of V, i.e. $\chi(O_V) = \Sigma(-1)^i \dim(H^i(V, O_V))$, where O_V denotes the structure sheaf of V. It is a consequence of

Hirzebruch's Riemann-Roch theorem that $\chi(O_V)$ equals $c_1(V)\cdot c_2(V)/24$ evaluated on the fundamental class of V, where $c_i(V)$ denotes the i-th Chern class. We prove this equality by examining the singularities of f.

JAYANT SHAH:

Insignificant Limit Singularities

The question is, "What kind of restriction one must impose on the singularities that varieties acquire as they vary in a family?". In this context, Mumford has introduced the notion of insignificant limit singularities. Briefly, if the fibers in a one-parameter family of varieties are restricted to such singularities, then any blow-up of the family produces exceptional divisions which can only be birationally ruled varieties. We present a (presumably complete) list of hypersurface singularities of dimension 2 which are insignificant limit singularities. We also interpret the role of these singularities in the context of the theory of mixed Hodge structure.

PETER SLODOWY:

Monodromy Representations of Weyl Groups

Let G be a semisimple group over an algebraically closed field k, x a nilpotent element of its Liealgebra and B_x the set of Borel-subgroups of G whose Liealgebra contains x. We put $B=B_o$. Let C(x) be the component group of the centraliser of x. Under some mild restrictions char(k) T.A. Springer defined representations of C(x)xW in the l-adic cohomology $H_c^*(B_x, Q_c)$ lX char(p), or in the singular cohomology in case k=C. We give a different construction for ((x) x W actions as $H^*(B_x)$ which is inspired by the construction of monodromy representations in the study of isolated singularities (Brieskorn, Milnor, Pham,...). We can show that Springer's representations and the monodromy action agree at least on the image of the canonical map $H^*(B) \to H^*(Bx)$. This map is surjective in case $G=SL_u$. As an application we give as interpretation of a Conjecture of Lusztig in terms of a generalised Picard-Lefschetz-formula.

JOHN SCHERK:

On the monodromy theorem for hypersurface singularities

Let $f=f(x_o,\dots,x_n)$ be an analytic function defined in a neighbourhood of 0 in $\mathbb{C}^{n+1}$. Assume that f(O)=O and that O is an isolated critical point of f. Let δ be the monodromy of f.

Monodromy Theorem: (a) The eigenvalues of δ are roots of unity.

(b) If δ^m is unipotent, then $(\delta^m-1)^{n+1}=0$.

The result discussed in this talk is the following:

Theorem: If $f^{n+1} \in (f_o,\dots,f_n) \subset \mathbb{C}\{x_o,\dots,x_n\}$ $(f_j=\partial d/\partial x_j)$, then $(\delta^m-1)^{r+1}=0$.

Conjecture: Let ann $f^j = \{g \in \mathbb{C}\{x_o,\dots,x_n\} | (f_o,\dots,f_n) \mid f^j g=0\}$

then dim ann $f^j \leq$ dim ker $(\delta^m-1)^j$ $j \geq 1$.

Equality definitely does not hold.

Idea of proof:

1. Embed the Milnor fibration in a family of projective hypersurfaces.
2. Using results of Brieskorn and Malgrange, obtain a condition on the Gauss-Manin connection of the Milnor fibration.
3. Use Griffiths' description of the primitive cohomology of a smooth hypersurface, translate this condition into a condition on the

Gauss-Manin connection of the projective family.

4. Take "limits" in the sense of Schmid to obtain a condition on a logarithm of the monodromy.
5. Use Schmid's theorem on the limit mixed Hodge structure and the invariant cycle theorem to prove the theorem.

J.H.M. STEENBRINK:

Newton polyhedron and vanishing cohomology (following V.I. Danilov)

We discuss a result of V.I. Danilov (Functional analysis and its appl. 13:2 (1979), 32-47) concerning the computation of the mixed Hodge structure on the vanishing cohomology for complex polynomials of a special type. One requires that f has an isolated singularity at the origin, that its Newton diagram Δ is a simple polyhedron, equal to $\mathbb{R}^n_+$ outside a compact set, and that f is nondegenerate with respect to Δ. In this case Danilov determines the numerical invariants of the mixed Hodge structure in a combinatorial way from Δ. Key ingredients are the us of toric varieties and the computation of the Hodge numbers of hypersurfaces in these by Danilov, A.G. Hovanski and A.N. Kirillov.

D.J.A. TROTMAN (Orsay):

Transversality and intersection type of transversals

Let X be a C^1 submanfold of $\mathbb{R}^n$ such that near O the frontier of X is a C^1 submanifold Y containing O. Tzee-Char Kuo has proved that if X is Whitney (a)-regular over Y at O, and if X and Y are C^∞, then any two transversals to Y at O have the germs of their intersection with X homeomorphic, i.e. (X,Y) is (h)-regular at O. We describe an improvement of Kuo's result: We suppose X and Y are just C^1, and use only (t)-regularity (weaker than (a)), which says that transversals to Y and O are transverse to X near O. We further show that (h)-regularity implies (t)-regularity, which is of interest in the analytic case since then (t) implies (a).

JONATHAN WAHL:

Smoothings of normal surface singularities

We study the Milnor fibre F of a smoothing of an n-dimensional local analytic space V, with isolated singularity. F has the homotopy type of a complex of dimension n. We conjecture b_1 (F) = 0 if V is normal, and prove it for smoothings of negative weight. F depends on the particular smoothing; but if dim V = 2 and the deformation globalizes, we derive formulas for the Euler characteristic and signature of F, plus the dimension of the irreducible component of the moduli space where the smoothing occurs. If V is Gorenstein, formulas for the first two were found by Laufer and Durfee, respectively. The globalization applies if V is either: a complete intersection; Cohen-Macaulay, of codimension 2; Gorenstein, of codimension 3; or a rational singularity with C^Δ-action (i.e., V= C^2/G, G a finite group).

C.T.C. WALL: (work of Bruce, Giblin, Wall).

Whitney regularity in versal unfoldings

Motivated by Mather's C^0-stability theorem, where C^0-stable maps are constructed as those multitransverse to a "canonical stratification" S of jet space, which in turn is constructed by stratifying versal unfoldings, several of us at Liverpool have studied the simplest cases: results so far are disappointing.

Each simple singularity gives a canonical stratum: as to unimodals, hyperbolic ones to two and the 14 exceptionals to 1 or 2 each. Bruce has shown that for K_{12} and K_{14} (and one guesses the same will happen for the rest) Whitney regularity breaks down at $\lambda=0$ (although topological triviality holds). Detailed calculations for $\tilde{E}_6$ (and $\tilde{E}_7$), though still incomplete, give breakdown at equiunharmonic curves (and harmonic); perhaps nowhere else.

A similar situation arises in stratifying spaces of functions: the canonical stratification of Looijanga is easy to work with only for simple singularities: for $\tilde{E}_6$, at least 17 curves (all with $J\in\mathbb{Q}$) are singled out as separate strata.

Y. YOMDIN:

The local topological structure of the central set
of a bounded domain in R^n.

Let G be a connected bounded open set in R^n. A closed ball contained in $\bar{G}$ which is not a proper subset of another ball in $\bar{G}$ is called a maximal ball. The set C(G) consisting of the centers of all maximal balls is called the central set of G. This notion was initially introduced in the theory of Pattern Recognition. It was recently shown, that if the boundary ∂G is C^2-smooth, then C(G) is a compact subset of G and is a deformation retract of $\bar{G}$.

We study the local topological structure of stable central sets (which do not change their topological type under small deformations of G. In considered cases stability turns out to be a generic property). A complete description is obtained for G - the polyhedron, and, on the other hand, for ∂G - C^∞ - smooth and n = 2,3. Partial results are obtained for ∂G - C^∞ - smooth, n $\geq$ 3. We prove also that generically the pair ($\bar{G}$, C(G)) can be triangulated and $\bar{G}$ collapses to C(G).

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