MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

Tagungsbericht 36/1984

Topologie

12.8. bis 18.8.1984

Die Tagung fand unter der Leitung der Herren D. Puppe (Heidelberg), A. Ranicki (Edinburgh) und L. Siebenmann (Orsay) statt. Behandelt wurden verschiedene klassische Gegenstände der algebraischen Topologie, u.a. stabile Homotopietheorie, Poincarékomplexe, Transformationsgruppen, Raumformen und geometrische Darstellungen von Gruppen, Klassifikation von Singularitäten, Gestalttheorie, Konstruktion von Kettenmodellen, Kontaktformen, und Topologie in den Dimensionen 2,3 und 4. Letzterer galt besonderes Interesse: In der Hälfte aller Vorträge wurden Fragen aus diesem Spezialgebiet behandelt. Dabei standen insbesondere geometrische Untersuchungen im Vordergrund, etwa über die Geometrie von Knoten und Verkettungen, über die Beziehungen zwischen diskreten Gruppen und Geometrie, und der Hyperbolisationssatz von Thurston. Dies spiegelt die großen Fortschritte wider, die hierbei in den letzten Jahren erzielt worden sind.

Vortragsauszüge

A.H. ASSADI:

Concordance of finite group actions on S^n

Let C_n be the abelian group of concordance classes of semifree smooth G-actions on S^n with tangential representation ρ such that $\dim\rho - \dim\rho^G > 2$. Let C_n^{AL} be the almost linear concordance classes of almost linear smooth actions on S^n (almost line means $(S^n,(S^n)^G)$ is diffeomorphic to (S^n,S^k)). Let $\Theta_k(0)$ be the mod q h- cobordism classes of mod q k- spheres with ρ- structure on their normal bundle and with vanishing Swan invariant in $\tilde{K}_0(\mathbb{Z}G)$, where $q = |G|$.

Theorem. There exists a homomorphism Δ such that the sequence

$$\cdots \longrightarrow C_n^{AL} \xrightarrow{i} C_n \xrightarrow{\text{fixed set}} \Theta_k(0) \xrightarrow{\Delta} C_{n-1}^{AL} \longrightarrow \cdots$$

is exact.

Corollary. If two such actions on S^n have diffeomorphic fixed point sets, then they are G- homeomorphic.

Corollary. An action $\varphi: G \times S^n \to S^n$ is G- homeomorphic to a smooth G- action $\psi: G \times S^n \to S^n$ which bounds a smooth G- action on D^{n+1} if and only if $\mathrm{Fix}(\varphi)$ bounds a mod q homology sphere with zero Swan invariant.

EVA BAYER- FLUCKIGER:

Doubly sliced knots

This is a report on joint work with Neal W. Stoltzfus.

A knot $K^n \subset S^{n+2}$ is said to be doubly sliced if there exists a trivial $(n+1)$-knot $L^{n+1} \subset S^{n+3}$ such that $L^{n+1} \cap S^{n+2} = K^n$.

This notion is due to Sumners. A basic problem concerning this notion is whether stably doubly sliced knots are doubly sliced. (A knot K^n is said to be stably doubly sliced if there exists a doubly sliced n- knot such that the connected sum of this knot with K^n is doubly sliced.) We prove the following.

Theorem. Let K be a simple (2q-1)- knot, $q \geq 2$, such that the knot module of K is annihilated by a square- free polynomial. If K is stably doubly sliced, then K is doubly sliced.

F. BONAHON:

Ends of hyperbolic 3- manifolds

We study the geometric behaviour of the ends of hyperbolic 3-manifolds with finitely generated fundamental group. The simplest of these manifolds are the so- called geometrically finite ones, which are quotients of the hyperbolic 3-space $\mathbb{H}^3$ by a discrete group of isometries admitting a finite polyhedron as fundamental domain. To study limits of these geometrically finite manifolds, Thurston introduced the notion of a "geometrically tame hyperbolic 3- manifold", proved that such manifolds enjoy many interesting properties, and conjectured that any hyperbolic 3-manifold with finitely generated fundamental group is geometrically tame. We prove this conjecture under the hypothesis that the fundamental group is indecomposable as a free product. As a corollary, this proves the so- called "Ahlfors conjecture" on measures of limit sets for indecomposable Kleinian groups, and provides a different approach to the proof of Thurston's hyperbolisation theorem.

R. FENN:

Homotopy linking of two spheres in 4-space

In the homotopy theory of links components are allowed to pass through themselves in a homotopy but not through different components. In this talk it was shown that for various cases two 2-spheres in $\mathbb{R}^4$ are homotopy trivial if one of them is embedded, e.g. a spun knot, and the question was asked if this is always true. An example was given of two 2-spheres each with one transverse self intersection which is homotopically non trivial.

I. HAMBLETON:

Local surgery and space forms

Let $\pi = \mathbb{Z}/m \rtimes \sigma$ be a metacyclic group with m odd, $\sigma = \mathbb{Z}/2^k$ and $\ker(t\colon \sigma \longrightarrow (\mathbb{Z}/m)^{\times}) \neq 1$. Then π has a free linear representation V with $\dim V = 2q = 2^{l+1}$ and k- invariant for $N = S(V)/\pi$, $g(N) \in H^{2q}(\pi;\mathbb{Z})$. If $(r,|\pi|) = 1$ then $rg(N)$ is the first k- invariant (defining the homotopy type) of a free simplicial action of π on S^{2q-1}. We study when such actions can be smoothed.

Theorem 1. Let $2q = 2^{l+1} \geq 6$ and $r \equiv 1 \bmod 4$. Assume $|\ker t| = 2$. and $-1 \in \operatorname{Im} t$. Then π acts freely on S^{2q-1} with k-invariant $rg(N)$ if and only if $r \in (\mathbb{Z}/m)^{\times} 2^{l}$.

Theorem 2. Let $\pi = Q(4m)$ be a quaternionic group of the above type $(k = 2, l = 1)$. Then if π acts freely on S^{4s-1} for any $s \geq 1$, the action is homotopically linear.

From the first result many non- linear homotopy types of smooth actions occur. The second is an essential step in studying the existence of free actions of general periodic groups on spheres.

J. HOWIE:

Equations over groups and singular surfaces in 3-manifolds

The following is a well known conjecture in group theory.

Conjecture 1. Let Σ be a system of n equations in n unknowns over a group G whose exponent-sum matrix is nonsingular. Then Σ has a solution in some overgroup of G.

Let $a_0,\ldots,a_n \in G$ such that $a_0\ldots a_n \in [G,G]$. Then there exist $x_1,\ldots,x_n,y_1,\ldots,y_k,z_1,\ldots,z_k \in G$ such that $a_0(x_1^{-1}a_1x_1)\ldots(x_n^{-1}a_nx_n)[y_1,z_1]\ldots[y_k,z_k] = 1$. The least integer k for which such an expression holds is called $\text{genus}_G(a_0,\ldots,a_n)$.

Conjecture 2. Let $S \subset F$ be free groups such that $S^{ab} \longrightarrow F^{ab}$ is an isomorphism. Then $\text{genus}_S(a_0,\ldots,a_n) \leq \text{genus}_F(a_0,\ldots,a_n)$ for all $a_0,\ldots,a_n \in S$ with $a_0\ldots a_n \in [S,S]$.

Stallings proved that Conjecture 2 implies Conjecture 1, and is in turn implied by a geometric Conjecture. Let $M^3 \subset N^3$ be a tame embedding of 3-manifolds such that $H_2(N,M) = 0$. Let $f:S \longrightarrow N$ be a smooth immersion of a compact orientable surface S into N, with $f(\partial S) \subset M$. Then there is a compact, orientable surface T, a homeomorphism $h:\partial T \longrightarrow \partial S$, and a smooth immersion $g:T \longrightarrow M$ such that $g|\partial T = (f|\partial S)\circ h$.

Conjecture 3. The surface T may be chosen with $\text{genus}\, T \leq \text{genus}\, S$.

We show that Conjectures 2 and 3 are equivalent.

J. HUEBSCHMANN:

Perturbation theory and small models for the chains of certain spaces

Given a fibre square $\begin{matrix} E_f & \longrightarrow & E \\ \downarrow & f & \downarrow\pi \\ X & \xrightarrow{f} & B \end{matrix}$, under suitable strong hypotheses a model for the singular chains of E_f can be constructed which only involves H_*X, $H_*\Omega B$, H_*E, H_*f, $H_*\pi$, and as an additional ingredient a "twisting cochain" $H_*B \longrightarrow H_*\Omega B$ which is essentially the transgression in the Serre spectral sequence of the path fibration of B. Away from the prime 2, the obvious diagonal map on this model yields a correct diagonal map in the sense that in homology and cohomology the correct map is induced. An application of this is the determination of the cohomology rings of almost all homogeneous spaces of compact connected Lie groups away from the prime 2. Even without the invertibility hypothesis of 2, a complete description of the cohomology ring of $GL_n(\mathbb{F}_q)$ can be given away from the characteristic of $\mathbb{F}_q$; the description is in terms of a model of the above kind, with a diagonal arising from the obvious one by a suitable perturbation.

M. KERVAIRE:

Jones' invariant of oriented links

This was a purely algebraic exposition of the recent definition by V. Jones of an invariant of isotopy classes of oriented links. It was shown that the invariant is a Laurent polynomial $V_L(t) \in \mathbb{Z}[t,t^{-1}]$ if L has an odd number of components, and $V_L(t) \in \sqrt{t}\,\mathbb{Z}[t,t^{-1}]$ if this number is even.

Some examples were discussed.

N.H. KUIPER:

On the total curvature of a knotted torus

An embedded torus T in euclidean 3-space $\mathbb{R}^3$ divides the one point compactification $S^3 = \mathbb{R}^3 \cup \infty$ into two parts, one of which (Alexander) is a standard solid torus. Let γ ($\infty \notin \gamma$) be a core- curve of that solid torus, with bridge number $B(\gamma)$.

Theorem (joint work with W.H. Meeks III). If T is knotted, then the infimum of the total absolute curvature $\tau(T')$ for T' isotopic to T is $4B(\gamma)$, and this infimum is never attained. Thus

$$\tau(T) \underset{\text{def}}{=} \int \frac{|K d\sigma|}{2\pi} > 4B(\gamma).$$

This generalises a theorem of Fenchel-Fary-Fox-Milnor for knots.

P. LÖFFLER:

The simplicity of some Poincaré complexes

When one tries to construct non-trivial cyclic group actions on simply connected manifolds by using rational homotopy theory one has to deal with the following situation: Suppose $f: X \to M^n$ is a map where

a) X is an n-dimensional PD-space with a free $\mathbb{Z}/k$- action;

b) M^n is a 1-connected manifold with a free $\mathbb{Z}/k$- action;

c) f respects the $\mathbb{Z}/k$- actions;

d) the groups H_*f are finite of order prime to k;

e) $\mathbb{Z}/k$ acts 1/k- trivially on X and M.

In this case we have the following:

Proposition (J. Davis, P. Löffler). The space X may be taken as a simple PD- space (whence X has the homotopy type of a manifold if $n \geq 5$).

S. MARDESIC:

Strong shape and Steenrod-Sitnikov homology

Let $\underline{X} = (X_\lambda)$ and $\underline{Y} = (Y_\mu)$ be inverse systems of spaces over directed sets Λ and M respectively. A coherent map $\underline{X} \to \underline{Y}$ consists of an increasing function $\varphi : M \to \Lambda$ and of maps $\Delta^n \times X_{\varphi(\mu_n)} \to Y_{\mu_0}$, $\mu_0 \leq \ldots \leq \mu_n$, satisfying suitable compatibility relations. Inverse systems and classes of coherently homotopic coherent maps form the coherent prohomotopy category CPHTop. A morphism $p:X \to \underline{X}$ of pro-Top of a space X into an ANR- system is called a resolution provided every map $f:X \to P$, $P \in$ ANR, factors approximately through $\underline{X}$ and any two sufficiently near factorisations are arbitrarily close. The strong shape category SSh has spaces as objects and the morphisms $X \to Y$ are given by ANR- resolutions $X \to \underline{X}$, $Y \to \underline{Y}$ and by a morphism $\underline{X} \to \underline{Y}$ of CPHTop. The Steenrod homology H^S is a functor on SSh and satisfies all the Eilenberg- Steenrod axioms. The groups $H_p(X)$ are defined as homology groups of a certain chain complex $C(\underline{X})$. This research is joint work with Ju.T. Lisica.

R.C. PENNER:

Teichmüller spaces of punctured surfaces

Let T_g^s be the Teichmüller space of the genus g surface with s punctures. The overall goal is to recognise the classical pictures of T_0^4 and T_1^1 (as tesselated Poincaré discs) as special cases of a general phenomenon in the Teichmüller theory of punctured surfaces.

Theorem. There is a modular-group-invariant cell decomposition of T_0^s , $s \geq 4$.

In this result the restriction g=0 is not believed to be necessary. The proof involves a convex hull construction in Minkowskii space and relies on a new coordinatisation of T_g^s (on which the modular group acts real algebraically). Each cell in the decomposition has a natural complex structure which is hopefully compatible with the global complex structure on T_g^s.

This is joint work with D.B.A. Epstein.

V. PUPPE:

On the torus rank of certain spaces

Using a "cochain complex" version of the localisation theorem for singular equivariant cohomology it is shown that the torus rank(i.e. the maximal dimension of those tori that act almost freely) of a "resonable"space X with $\pi_{even}(X) \otimes \mathbb{Q} = 0$ is bounded by the dimension of the centre of the rational homotopy Lie algebra $\pi_*(X) \otimes \mathbb{Q}$. This generalises a result of S. Halperin's (the case where the centre is zero). Moreover, the $(\mathbb{Z}/p)$- version of the localisation theorem can be applied to give a simple and unified proof of results of G. Carlsson and W. Browder concerning free p- torus actions on products of spheres. This is joint work with C. Allday.

P.B. SHALEN:

Dehn surgery and 3- manifolds with cyclic fundamental group

Let M be a compact, irreducible, orientable 3-manifold whose boundary is a torus. A simple closed curve $\mu \subset \partial M$ is called a weak meridian if $|\pi_1(M):[\mu]|$ is finite cyclic. The following result is joint work with M. Culler and C. Gordon.

Theorem. Suppose that M is not Seifert- fibred. If μ and ν are weak meridians then the algebraic intersection number $\mu \cdot \nu$ has absolute value ≤ 5. If $|\pi_1(M):\mu|$ and $|\pi_1(M):\nu|$ are each of order $\neq 2$ then $|\mu \cdot \nu| \leq 4$.

As a consequence one sees that there are at most five classical knots whose complements are of a given topological type. It is conjectured that the bound in this theorem can be reduced to 1. Examples due to Fintuchel- Stern and Pryzytycki show that this would be best possible.

W. SINGHOF:

Compact nilmanifolds and stable homotopy

Let G be a connected Lie group of dimension m and Γ a discrete subgroup such that G/Γ is compact. The tangent bundle of G/Γ admits a left- invariant trivialisation, and thus we get an element $[G/\Gamma] \in \pi_m^S$ by the Thom- Pontrjagin construction. We concentrate on the case where G is nilpotent and simply connected. Using the Atiyah- Singer index theorem, it is shown that if $m \equiv 1$ or 2 mod 8 and $m > 2$ then $d[G/\Gamma] = 0$. In other words, compact nilmanifolds of dimension ≥ 3 bound as spin manifolds. Then the Adams e- invariant is computed in special cases, using the theorem of Atiyah- Patodi- Singer. For instance, the following is obtained: Let $H(n)$ be the Heisenberg group (of dimension $2n+1$) and $\Gamma(n)$ its standard arithmetic subgroup. Then $e[H(n)/\Gamma(n)]$ is essentially given by the value of the Riemann ζ - function at the place $-n$ for n odd. This was proved in collaboration with Ch. Deninger.

A. SZÜCZ:

Multiple points and singular points

Using normal forms of singularities one can generalise the Pontrjagin- Thom construction to cobordisms of some singular maps. The classifying spaces for cobordisms of singular maps provide a model for the loop space of the Thom space. This model can be applied to the following question:

Fix a set $\alpha = \{\alpha_1, \dots, \alpha_r\}$ of Boardman symbols of singularity types. Can a map of an n- manifold into $\mathbb{R}^{n+k}$ have a single point $P \in f(M)$ such that $f^{-1}(P)$ consists of r points which are of types $\alpha_1, \dots, \alpha_r$?

Examples:

1) $\alpha_1 = \dots = \alpha_r = \Sigma^0$ (non- singular points). This case was solved by Eccles in codimension $k = 1$ for immersions. We can extend part of his results to singular maps (of "almost any type").

2) $\alpha = \{\Sigma^1, \Sigma^0\}$. No such a map.

3) $\alpha = \{\Sigma^1, \Sigma^0, \Sigma^0\}$. No such a map.

L. SIEBENMANN:

Exotic quasi-3-spheres in S^4 arising from Gromov's horizon of certain Coxeter- Davis groups

Let W^4 be a compact contractible 4- manifold with non- simply connected boundary M^3. One can so triangulate M^3 that it becomes a full simplicial 3- complex, in which every quadrilateral in the 1- skeleton (a cycle of 4- simplices) has at least one diagonal present as a 1- simplex of M^3. The Coxeter group Γ with one generator of order 2 for each vertex v, say x(v), $x(v)^2 = 1$, and one relation for each edge $e = [v,v']$, namely $(x(v)x(v'))^2 = 1$, is combinatorially hyperbolic in the sense of Gromov (ICM Warsaw, 1983). Following M. Davis (Annals early '80's) we make the Poincaré dual 3-cells into mirrors of reflection for an action of Γ on an open contractible 4- manifold X^4, with fundamental region $W^4 \subset X^4$. Davis observed that X^4 is not homeomorphic to $\mathbb{R}^4$. We show that the space which is formed from two copies of (say) $\hat{X} = X \cup Gr(\Gamma)$ by identifying the two copies of $Gr(\Gamma)$ is homeomorphic to S^4; here $\hat{X}$ is Gromov's compactification of X by the horizon $Gr(\Gamma)$ of the combinatorially hyperbolic group Γ. Further, the resulting pair $(S^4, Gr(\Gamma))$ is topologically homogeneous, i.e. given x and y in $Gr(\Gamma)$ there exists a homeomorphism h of S^4 respecting $Gr(\Gamma)$ and sending x to y. $Gr(\Gamma)$ can be identified as a homogeneous infinite connected sum of copies of M^3 of a sort constructed (initially for $M^3 = S^3$) by W. Jacobsche about 1977 (see Fund. Math. 1981). The same holds in higher dimensions as soon as the special triangulation can be found. This is joint work with R. Ancel.

C.B. THOMAS:

Contact forms on (n-1)-connected (2n+1)-manifolds

The odd dimensional manifold M^{2n+1} is said to be contact if there exists a globally defined 1- form ω such that $\omega\wedge(d\omega)^n \neq 0$. Classically the energy levels in a Hamiltonian system are contact, and a necessary condition for the existence of a contact form ω is the reducibility of the structural group of the tangent bundle of M^{2n+1} (oriented) from $SO(2n+1)$ to $U(n)+(1)$. We study the sufficiency of this condition for closed manifolds.

Theorem 1 (R. Lutz, W. Thurston, E. Winkelnkempfer). If M^3 is closed and orientable then it is contact.

Remark. The different classes of contact forms on M^3 would seem to provide a new tool for the study of M^3 - see the lecture of S. Chern at the 1984 Bonner Arbeitstagung.

Theorem 2. Let M^{2n+1} be an (n-1)-connected (2n+1)-manifold.
(a) If $n = 2$, $w_2M = 0$ and $H_2(M,\mathbb{Z})$ contains no elements of order 3 then M is contact.
(b) If $n \equiv 5 \bmod 8$ and M is an odd torsion manifold with an even number of prime summands, then for some smooth structure on M there is a contact form ω.

The proof of Theorem 2 uses the classification of highly connected manifolds, the description of the prime summands in terms of Brieskorn varieties, and a theorem of C. Meckert on connected sums. It should not be regarded as the final word on the subject.

T. tom DIECK:

Geometric representation theory of finite groups

Geometric representation theory is part of the theory of transformation groups and emphasises the following view points:

1. Group actions on spheres, disks, Euclidean spaces (possibly up to homotopy).
2. Systematic results for large classes of groups.
3. Methods, results, view points from ordinary (algebraic) representation theory.
4. The study of unit spheres SV of orthogonal representations V.
5. Analysis of the role of SV for general actions on spheres.

This view point was explained in the homotopy category for homotopy representations X. These are G- complexes such that all fixed point sets X^H, $H \subset G$ a subgroup, are $(n(H)-1)$- dimensional spaces homotopy equivalent to the sphere $S^{n(H)-1}$. The main invariant of the homotopy type is the dimension function $\operatorname{Dim} X : H \mapsto n(H)$. Necessary and sufficient conditions for a function on conjugacy classes to be a dimension function were explained.

C. WEBER:

Integral monodromy of some plane curve singularities

Let $f: \mathbb{C}^{n+1} \longrightarrow \mathbb{C}$ be a polynomial map, $f(0) = 0$, 0 being an isolated singularity. Let Σ be the Milnor fibre and let h be the monodromy. The induced map h_* is an automorphism of $H_n(\Sigma, \mathbb{Z})$, giving this last group the structure of a $\mathbb{Z}[t,t^{-1}]$-

module. Call if $M(f)$. P. Orlik conjectured that $M(f)$ is a direct sum of cyclic modules, at least if h_* is of finite order.

<u>Theorem.</u> This conjecture is false.

Counterexamples: Take $f(X,Y) = (X^a - Y^b)(X^c - Y^d)$ with $\gcd(a,b) = 1 = \gcd(c,d)$, $c/d < a/b$. Suppose b and c are two distinct primes such that $a+c = b^k$, $b+d = b^{k'}$, $k < k'$. Then $M(f)$ is not a direct sum of cyclic modules. The simplest example arises from $(X - Y^2)(X^3 - Y^{14})$.

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Gefördert durch
DFG Deutsche Forschungsgemeinschaft