MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

Tagungsbericht 35/1982

Transformationsgruppen

22.8. bis 28.8.1982

Die diesjährige Topologie-Spezialtagung fand unter der Leitung von Herrn tom Dieck (Göttingen) und Herrn Oliver (Arhus) statt. Insbesondere jüngeren und ausländischen Teilnehmern wurde Gelegenheit gegeben, ihre Forschungsgebiete darzustellen. Konstruktionen von Gruppenoperationen auf Mannigfaltigkeiten mit vorgegebener Fixpunktmenge standen neben dem Einbringen neuer Formulierungen und Techniken, aus homologischer Algebra, rationaler Homotopietheorie und algebraischer Geometrie, im Mittelpunkt des Interesses. Die Tagung wurde abgeschlossen durch einen Versuch, zentrale Probleme auf dem Gebiet der Transformationsgruppen zu benennen und zu formulieren.

Vortragsauszüge

R. Schultz:

Almost extremal torus actions on homotopy spheres

If T^r acts smoothly and effectively on a homotopy sphere Σ^n, then the fixed point set is at most $(n-2r)$-dimensional. If the dimension is exactly n-2r (the extremal case) then the action is completely determined by orbit space data, and one knows that Σ^n is diffeomorphic to S^n. If the dimension of the fixed point set is (n-2r-2) - the second highest possibility - then examples produced around 15 years ago imply that Σ^n can be exotic. We shall present some fairly precise estimates for the Pontrjagin-Thom invariants of all Σ with T^r actions having (n-2r-2)-dimensional fixed point sets. If r = 1, the Pontrjagin-Thom invariants are the classes of the form $\langle A, \nu, \eta \rangle$ where $A \in \pi_{n-5}$ consists of all elements desuspending to S^3. If $r \geq 2$, lower and upper estimates are given by $\pi_{n-r} \cdot \eta^r$ and $\pi_{n-r} \cdot \eta^{r-1}$. In particular, if $r \geq 5$ then Σ must bound a parallelizable manifold.

H. Abels

Proper transformation groups

A continuous action of a locally compact topological group G on a locally compact topological space X is called proper if, for any two compact subsets K, L of X the subset $\{g \in G;\ gK \cap L \neq \emptyset\}$ is compact. Examples are groups of decktransformations, of isometries, left translation action of G on G/K (K a compact subgroup of G), actions of a finitely generated group on its Cayley diagram. A necessary condition for a space X to admit a proper action of some non-compact group G was given: The number of ends of X must be 1,2 or ∞. The structure of G in the resp. cases was discussed. One of the results generalizes Stallings' theorem giving the structure of finitely generated groups with infinitely many ends. For G almost connected (i.e. G mod its connected component G_o of e is compact) a classification of proper actions of G on a space X was given reducing it to two problems, namely to determine all spaces S with $S \times \mathbb{R}^n$ homeomorphic to X (here $\mathbb{R}^n$ homeomorphic to G mod a maximal compact subgroup K) and to determine all actions of K on S. Finally, some remarks concerning the concept of non-compact dimension of a group were made.

J. Tornehave:

Units in the Burnside ring

The group of units $\Omega^{\cdot}(G)$ in the Burnside ring of a finite group can be identified with the group $\mathcal{H}_G = \varinjlim_V \mathcal{H}_G(S(V))$, where $\mathcal{H}_G(S(V))$ denotes the group of G-homotopy equivalences $S(V) \longrightarrow S(V)$, V a real representation. There is a homomorphism $\Delta : RO(G) \longrightarrow \Omega^{\cdot}(G)$ carrying [V] onto the unit corresponding to the antipodal map on S(V).

Theorem I: Δ is onto for every 2-group G.

Theorem II: (unstable version of Theorem I). Let G be a 2-group and V be a real representation of G. Then any G-homotopy equivalence $S(V) \longrightarrow S(V)$ is G-homotopic to an isometry.

Let $j : \Omega(G) \longrightarrow R_{\mathbb{Q}}(G)$ be the ring homomorphism sending a finite G-set X into the permutation representation $\mathbb{Q}X$, and let N(G) be the kernel of j. For a subquotient K/H of G we let $\mathrm{Ind}^G_{K/H} : \Omega(K/H) \longrightarrow \Omega(G)$ be the composite of pullback by the projection $K \longrightarrow K/H$ with induction from K to G. The main tool of theorem I is the following

Induction theorem For every 2-group G

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$$N(G) = \sum_{K/H} \mathrm{Ind}^G_{K/H} N(K/H),$$

where K/H runs through all dihedral subquotients. This induction theorem combined with Segal's result that j is onto for every 2-group provides a description of $R_{\mathbb{Q}}(G)$ by generators and relations, which is used to construct an epimorphism $F : R_{\mathbb{Q}}(G) \longrightarrow \mathrm{Hom}(\Omega^*(G), \{\pm 1\})$. Induction techniques for representations over $\mathbb{Q}$ are used to identify Ker F and theorem I follows by a variant of Frobenius reciprocity.

Kojun Abe:

Pursell-Shanks type theorem for orbit spaces of G-manifolds

Pursell and Shanks proved that a Lie algebra isomorphism between Lie algebras of all smooth vector fields with compact support on smooth manifolds yields a diffeomorphism between the manifolds. Similar results hold for some structures on manifolds. In this talk we consider Pursell-Shanks type theorem for orbit spaces of smooth G-manifolds. The orbit space of a smooth G-manifold M can be given a smooth structure such that the functional structure of the orbit space M/G is induced from that of M. This structure has been studied by many people. Under these results we shall study the above theorem.

G. Carlsson:

On the homology of finite free $(\mathbb{Z}/2)^n$-complexes

Let $G = (\mathbb{Z}/2)^n$, let M be a (graded) $\mathbb{Z}/2[G]$-module, I its

augmentation ideal. The length of M is defined by
$\lambda(M) = \max \{ j \mid I^{j+1} M = 0 \}$.

<u>Theorem.</u> Let G act freely on a finite complex X. Then
$$\sum_{i=0}^{\infty} \lambda(H_i(X;\mathbb{Z}/2)) \geq n.$$

The proof consists in comparing a given $\mathbb{Z}/2[G]$-chaincomplex C with a differential graded module $\beta(C)$ over $\mathbb{Z}/2[x_1,\dots,x_n]$ whose underlying module is $C \otimes_{\mathbb{Z}/2} \mathbb{Z}/2[x_1,\dots,x_n]$.

A. Assadi:

<u>Finite transformation groups of bounded compact manifolds</u>

(joint work with P. Vogel)

Let W^n be a compact manifold such that $\partial W = \partial_+ W \cup \partial_- W$, $\partial_+ W \cap \partial_- W = \partial(\partial_+ W) = \partial(\partial_- W)$, and $\pi_1(\partial W) \longrightarrow \pi_1(W) =: \pi$. Suppose G is a finite group acting freely on $\partial_+ W$. The main result concerns the situations under which this G-action extends to a free G-action on W. Under the condition that

1) $H(W, \partial_+ W; \mathbb{Z}_{(q)} \pi) = 0$, where $q = |G|$,

2) G acts trivially on $H_*(\partial_+ W/G, \mathbb{Z}(\pi \times G) \otimes \mathbb{Z}[\frac{1}{q}])$,

3) there exists a homomorphism $\pi_1(\partial_+ W/G) \longrightarrow \pi$ such that the following diagram commutes

$$\begin{tikzcd}
\pi_1(\partial_+ W/G) \arrow[r] & \pi \\
\pi_1(\partial_+ W) \arrow[u] \arrow[ur] &
\end{tikzcd},$$

an obstruction in a group $Wh^T(\pi \subset \pi \times G)$ is defined which vanishes iff a smooth extension of this action on W exists. This obstruction group is related to the other algebraic invariants via an exact sequence

$$Wh(\pi \times G) \xrightarrow{T} Wh(\pi) \xrightarrow{\alpha} Wh^T(\pi \subset \pi \times G) \xrightarrow{\beta} \tilde{K}_0(\pi \times G) \longrightarrow \tilde{K}_0(\pi)$$

and the obstruction is the image of a certain homomorphism γ which makes the following diagram commute

$$\begin{tikzcd}
Wh(\pi) \arrow[rr, "\alpha"] \arrow[dr] & & Wh^T(\pi \subset \pi \times G) \\
& K_1(\mathbb{Z}_{(q)}\pi)/\{\pm\pi\} \arrow[ur, "\gamma"'] &
\end{tikzcd}$$

S. Illman:

The equivariant triangulation theorem for actions of compact Lie group

Let G be a compact Lie group acting smoothly on a smooth manifold M. More than a decade ago Takao Matumoto and the present author, independently of each other, showed how to lift a well-behaved triangulation of the orbit space M/G so that one gets a G - CW complex structure on M. In my version of this M was in fact given an equivariant triangulation, which then in particular provides M with a G - CW complex structure. By a well-behaved triangulation of M/G we mean a triangulation obtained by taking the first barycentric subdivision of a triangulation of M/G in which each open simplex lies in one orbit type. Although one in Takao Matumoto's version gets a G - CW complex structure on M, and in my version gets an equivariant triangulation of M, the method of proof we use is basically the same.

The history of the result that M/G admits a well-behaved triangulation has been somewhat confusing, and this has apparently also caused some confusion concerning the question of what exactly Matumoto and I did prove more than a decade ago. In this talk we try to clarify the situation by giving an account of the lifting procedure used by Matumoto and myself.

More precisely we will do the following. First we define the notion of an equivariant n-simplex $\Delta_n(G;H_o,\dots,H_n)$ of type $(H_o,\dots,H_n)$, where $H_o \supset H_1 \supset \dots \supset H_n$ are closed subgroups of G. The key result that we prove is then the following.

Lemma. Let X be a G-space with orbit space $X/G = \Delta_n$ such that the orbit type is constant in each of the sets $\Delta_m - \Delta_{m-1}$, $0 \leq m \leq n$. Then X is G-homeomorphic to an equivariant n-simplex $\Delta_n(G;H_o,\dots,H_n)$ for some closed subgroups $H_o \supset H_1 \supset \dots \supset H_n$ of G.

The proof of this lemma uses the above mentioned lifting procedure. That a G-space whose orbit space admits a well-behaved triangulation can be given an equivariant triangulation is an immediate consequence of the above lemma.

M. Raußen:

Symmetries on simply-connected manifolds

(joint work with Peter Löffler)

Let M^n be a closed n-dimensional manifold, let G be a Lie group. A G-symmetry on M is a G-action on M such that $M^G \neq M$. Question: Does there exist a G-symmetry on a given M for some G? The general answer is no: there are manifolds with large $\pi_1(M)$ and no G-symmetry on M at all (R. Schultz). But we get the following positive result:

If $\pi_1(M) = 0$, $H_i(M^n;Q) = 0, 3i + 1 \leq n$, and, for n even, additionally $\chi(M) = 0$, $\mathrm{ind}(M) = 0$, $\sum_{i=0}^{n} \dim H_i(M;Q) \equiv 0(4)$, then there is a manifold M' homotopy-equivalent to M, admitting free $\mathbb{Z}/p$-symmetries for almost all primes p. Such free $\mathbb{Z}/p$-symmetries exist even on M itself, if a condition on the distribution of non-vanishing Pontrjagin-classes of M holds.

The proof consists in the construction of a free S^1-operation on a manifold M^n rationally homotopy-equivalent to M, a method of pulling back and pushing forward free $\mathbb{Z}/p$-operations over rational homotopy equivalences f for all primes p prime to the $|H_i(f)|$, and finally surgery techniques to find free $\mathbb{Z}/p$-operations on M itself.

G. Lewis:

Introduction to Mackey Functors

Properly understood, a G-equivariant cohomology theory is RO(G)-graded and takes values in the category of Mackey functors. The RO(G)-grading is essential for the existence of transfers and duality.

For any finite group G, there is a small additive category B such that a Mackey functor is contravariant additive from B to Ab. There is a tensor-product-like operation $M \square N$ defined on a pair of Mackey functors M and N. A pairing of Mackey functors in the sense of Dress is just a map $M \square N \longrightarrow L$. $\square$ has a right adjoint: it follows that $\square$ and this hom-functor have derived functors which behave like Tor and Ext.

One can define Mackey-functor valued singular chains of a G-space, Mackey-functor valued homology and cohomology, for which universal coefficient and Künneth theorems exist. These are in general in terms of spectral sequences. This difficulty can be cirumvented by working with coefficients in a Mackey-functor-field. Of particular interest are the "prime fields" coming from the Mackey functor prime ideals of the Burnside ring Mackey functor.

V. Hauschild:

<u>Deformations of fat points in the cohomology theory of transformation groups</u>

Let $G = T^r$ be a torus, X a nice G-space (finitely many orbit types). What information do we have on the fixed space X^G?

If the Serre-s.s. of $X \hookrightarrow EG \times_G X \downarrow BG$ collapses we have a commutative diagram

$$\begin{tikzcd} H_G^*(X) \arrow[r] & H^*(X) \\ H^*(BG) \arrow[u] \arrow[r] & k \arrow[u] \end{tikzcd}$$

such that $H_G^*(X)$ is a free $R(G)$-module. Moreover, by Eilenberg-Moore, it follows that $H^*(X) \cong H_G^*(X) \otimes_{R(G)} k$. This shows $H_G^*(X)$ to be a deformation of the k-algebra $H^*(X)$, which is a fat point.

Which deformations over the line (= Spec $H^*(B_{S^1};k)$) can arise as equivariant cohomology rings? We call a deformation

$$\xi = \begin{array}{ccc} X_o & \longrightarrow & X \\ \downarrow & & \downarrow \\ A & \longrightarrow & V \end{array} \qquad \text{geometric } (V = \mathbb{A}_k^T) \text{ iff } X = \bigcup_{i=1}^{s} X_i,$$

$X_i \cong \mathbb{A}_k^r \times_k Y_i$, Y_i a fat point for all i.

<u>Theorem 1.</u> A G_m-equivariant graded deformation ξ of A_o over the line is geometric iff ξ yields an equivariant cohomology ring of an S^1-action on a finite CW-complex X with $H^*(X;k) \cong A_o$.

<u>Theorem 2.</u> Let X be a space s. t. $H^*(X;k) = k[x_1,\dots,x_n]/I_o$, $|x_i| = 2$, a complete intersection; let φ_i be a family of circle actions on the F_i with corresponding fixed spaces $F_{i1}+\dots+F_{i,r_i}$. Then there is a finite S^1-CW-complex X', $H^*(X';k) \cong H^*(X;k)$ such that

$$(X')^{S^1} = \sum_{i=1}^{r} \sum_{j=1}^{r_i} F_{ij}.$$

F. Connolly:

<u>Normal Fibrations and normal maps for Poincaré G-complexes</u>

We introduce the concept of a Poincaré G-complex and then look for an analogue of Spivak's theorem. We show that each Poincaré G-complex has a unique "normal fibration" which is a spherical G-fibration in a very strong sense.

We then show that the liftings of this fibration to a G-vector bundle correspond to G-normal maps of a certain sort.

Finally, we show that the theory of this sort of normal map can be carried out without resort to the so-called "gap hypothesis" which has arisen in other approaches to equivariant surgery theory.

A. Bojanowska

The Spectrum of Equivariant K-Theory

Let G be a compact Lie group and X a compact G-ENR. We relate the properties of the prime ideal spectrum of the equivariant complex K-theory ring $K_G(X)$ with the topological properties of the action which are revealed by the category C(G,X) of the connected components of the fixpoint sets on X of topologically cyclic subgroups of G. The results and methods are analogous to those of D. Quillen concerning equivariant Borel cohomology with mod p-coefficients. They provide also a different approach to G. Segal's results on the spectrum of the representation ring of a compact Lie group. It is shown how the category C(G,X) determines Spec $K_G(X)$ and also conversely that the equivariant morphism of spaces with actions inducing bijection of spectra of equivariant K-theory induces an equivalence of corresponding categories of components of fixpoint sets. This result applied to homomorphisms of compact Lie groups gives a generalization of an elementary theorem saying that for finite groups only isomorphisms induce isomorphisms of representation rings.

K. Pawałowski:

On some problems in compact transformation groups

(lecture given by R. Oliver)

Let G be a compact Lie group. The question of the equivalence of the representations at two fixed points induced by smooth actions of G on disks, spheres, and euclidean spaces, and the weaker question of the equality of the dimensions of two fixed point set connected components of smooth actions of G on these spaces go back to P. A. Smith and G. E. Bredon. We show that except for the distinguished case of smooth actions of G on spheres with exactly two fixed points the answer to these questions is affirmative if and only if each element of the quotient group G/G_o has prime power order, where G_o denotes the identity connected component of G.

T. Petrie has announced that he knows of no smooth nonabelian group actions on disks, spheres, or euclidean spaces with isolated fixed points at which the induced representations are distinct. For some finite nonabelian groups G, we obtain such examples of actions by showing what sets of complex representations of G can be realized (stably) at isolated fixed points of smooth actions of G on disks.

We also deal with Problems 1, 2, 3, and 4 posed on page 205 in the Bredon's book: Introduction to compact transformation groups, Academic Press, 1972. In particular, we completly solve all four problems in the case of smooth finite cyclic group actions.

G. Katz:

Multiplicative structures in equivariant surgery groups

Let G be a finite group, M a G-manifold, $\dot{M}^H \subset M^H$ - the closure of the set of points in M with stabilizer $H < G$, $\{M^H_\alpha\}$ an enumeration of its connected components. We denote by $\psi_\alpha(H)$ the natural H-representation in the fibres of the normal bundle $\nu_\alpha^H = \nu(\dot{M}^H_\alpha, M)$, by $\rho_\psi(M)$ the subset $\{\alpha\} \subset \pi_0(M^H)$ such that ψ^H_α is isomorphic to a given H-representation ψ.

Two G-manifolds M_1, M_2 are called L-equivalent if for every H-representation ψ, $H < G$, the two sums

$$\sum_{\alpha \in \mathcal{S}_\Psi(M_i)} \mathrm{Ind}_{N_\alpha H}^{NH} \, (\mathrm{Sign}[N_\alpha H, (\dot{M}_i)_\alpha^H]), \quad (i = 1,2),$$

are equal. Here $N_\alpha H$ is the maximal subgroup normalizing the component $\dot{M}_\alpha^H$.

This equivalence relation is compatible under disjoint union and cartesian product, equivalence classes thus forming a commutative ring $\mathcal{L}\mathfrak{S}(G)$. We prove that the groups of G-equivariant surgery ${}_GL_*$ become an $\mathcal{L}\mathfrak{S}(G)$-module (after tensoring with $\mathbb{Z}[\frac{1}{2}]$). The subgroups of all elements in G-surgery groups realizable by closed G-manifolds is (after tensoring with $\mathbb{Z}[\frac{1}{2}]$) isomorphic to some subgroup in $\mathcal{L}\mathfrak{S}(G)$, and thus has a nice ring structure.

K. Kawakubo:

Equivariant algebraic K-theory

We give a definition of an equivariant algebraic K-theory and investigate its fundamental properties.

We first show an equivariant Swan theorem and study relations with cohomology with non-abelian group coefficient in the sense of J. P. Serre. Especially the vanishing theorem of Galois co-homology induces interesting results.

Next we define an "induction" and show Mackey and Frobenius properties. Accordingly, Dress induction theorem is applicable. These are generalized to the case of sheaf theory with group actions.

Finally, Brauer theory is developed in the case of valuation rings with group actions.

E. Straume:

Actions of unitary groups whose number of orbit types is not too "astronomical"

(joint work with Wu-Yi Hsiang)

We study the possibilities of geometrical behaviour of a $G = SU(n)$-action φ on homology spheres or acyclic spaces. Let

$$I(\varphi) = \{\text{orbit types of } \varphi\}, \quad \mu(\varphi) = \# I(\varphi).$$

$\mu(\varphi)$ is only known for a few linear representations of $SU(n)$, $n \geq 4$, namely $\varphi = k\mu_n$, $\Lambda^2\mu_n$, $S^2\mu_n$, Ad_G, $\Lambda^2\mu_n + k\mu_n$, $S^2\mu_n + k\mu_n$, $Ad_G + k\mu_n$ and one extra case for $n = 4,6,8$.

An action ψ is orthogonally modelled on the representation φ iff

1) $I(\varphi) = I(\psi)$
2) φ, ψ have the same slice representation $\forall\, G_x$.

Theorem. Let ψ be a smooth action of $SU(n)$ on $X \sim_{\mathbb{Z}} S^N, \mathbb{R}^N$ and assume $\mu(\psi) \leq p(n)$ = partition function at n. Then ψ is orthogonally modelled on φ + (trivial repr.), φ coming from the list above.

Unless the (geometric) weight system $\Omega'(\psi)$ is quite simple, the number of conjugacy classes of max, tori at isotropy groups is already too large. Hence, one can show $\Omega'(\varphi) = \Omega'(\psi)$ for some well-known linear representation φ. It follows that $\varphi + k\cdot 1$ must be the orthogonal model.

K. H. Dovermann:

Induction theorems in equivariant surgery

(joint work with T. Petrie)

We show that (under appropriate assumptions, in particular the acting group is nilpotent of odd order) the surgery obstruction $\sigma(W_o)$ of a normal map W_o vanishes if it does so restricting the action of G on W_o to actions of groups in a class of subgroups of G (not containing G): those which extend a p-group by a cyclic or a cyclic by a p-group . This theorem should be compared with Dress' result that Wall groups satisfy 2-hyperelementary induction. The main application are Petrie's actions on homotopy spheres with exactly one fixed point and those actions on homotopy spheres with two fixed points having distinct slice representations at these points.

P. Löffler:

Semilinear $\mathbb{Z}/p$-actions on homotopy spheres

We reviewed semilinear $\mathbb{Z}/p$-actions on spheres from the point of view of equivariant frameability. Implications for the possible differentiable structures of the fixed point spheres were discussed. Finally we indicated how to circumvent the "gap hypothesis" in these cases.

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