Annotated Bibliography on Polynomial Maps

Compiled by Gary Hosler Meisters*

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Contents

Part I: Annotated Bibliography on Polynomial Maps

This bibliography includes the seven subjects listed below; merged into one list, alphabetical by author. Your comments and suggestions for corrections or additions are appreciated. The LaTeX dvi-file is available on my World-Wide-Web Home-Page at the Web Address (URL):

http://www.math.unl.edu/~gmeister/

I. Polynomial maps of affine n-space $\mathbf{k}^n$, for $n \geq 2$.

II. Polynomial maps of affine 2-space.

III. The Groups $GA[\mathbf{k}^n]$ and $Aut[\mathbf{k}[x_1, x_2, \ldots, x_n]]$.

IV. Nilpotent matrices of homogeneous polynomials.

V. Polyflows in $\mathbf{k}^n$ and derivations on $\mathbf{k}[x]$.

VI. Injectivity and surjectivity for maps of $\mathbf{k}^n$.

VII. Global behavior of polynomial vector fields: Global attractors, almost periodic orbits, stability, etc. The Markus-Yamabe Conjecture about the global asymptotic stability of a stationary point is true only on $\mathbb{R}^2$ [78, 160, 198, 274]. So now the foundation is laid and the stage is set for the more detailed investigation of this area. Indeed, it has already begun [71, 86, 87, 88, 89, 90, 98, 129, 137, 195, 197, 273].

Part II: Contributors & Their Addresses

There are many results and open questions about polynomial maps. Here is a partial list of contributors: M. Abate, S. Abhyankar, K. Adjamagbo, P. Ahern, J. Alev, H. Alexander, V. Alexandrov, E. Andersén, G. Angemüller, D. Anick, H. Appelgate, V. Arnold, J. Ax, K. Baba, N. Barabanov, B. Barkee, H. Bass, E. Bedford, J. Bernat, G. Buzzard, A. Campbell, J. Chadzyński, Z. Charzyński, N. Chau, C. Cheng, C. Chicone, A. Cima, E. Connell, B. Coomes, S. Cynk, C. Dean, C. De Fabritiis, G. De Marco, B. Deng, R. Dennis, H. Derksen, J. Deveney, F. Dillen, P. Dixon, L. v.d. Dries, L. Drużkowski, C. Eggermont, W. Engel, A. v.d. Essen, J. Esterle, R. Feßler, D. Finston, E. Formanek, J. Fornæss, F. Forstneric, L. Fourrier, G. Freudenburg, S. Friedland, D. Gale, A. Gasull, M. Gehrke, M. Gerstenhaber, A. Glutsuk, W. Gordon, G. Gorni, D. Greenig, R. Guralnick, C. Gutierrez, J. Hadamard, H. Hauser, R. Heitman, M. Hénon, X. Huang, E. Hubbers, Z. Jelonek, S. Kaliman, O.-H. Keller, H. Kestelman, M. Kirezci, K. Kishimoto, H. Kraft, T. Krasiński, W. v.d. Kulk, K. Kurdyka, M. Kwieciński, J. Lang, J. LaSalle, L. Lempert, M. Letizia, W. Li, V. Lin, J. Llibre, A. Magnus, F. Mañosas, L. Markus, J. McKay, R. McLeod, J. Milnor, J. Mitchell, M. Miyanishi, T. Moh, D. Moldavanski, J. Molluzzo, J. Moser, G. Müller, M. Nagata, Y. Nakai, D. Newman, H. Niitsuma, A. Nijenhuis, H. Nikaidô, P. Nousiainen, A. Nowicki, S. Oda, Cz. Olech, H. Onishi, S. Orevkov, T. Parthasarathy, R. Peretz, S. Pinčuk, A. Płoski, V. Popov, P. Rabier, M. Radulescu, S. Radulescu, J. Randall, G. Ravindran, R. Rentschler, R. Richardson, L. Robbiano, J.-P. Rosay, I. Rosenholtz, M. Rosenlicht, L. Rubel, W. Rudin, L. Rudolph, K. Rusek, M. Sabatini, A. Sathaye, B. Segre, J.-P. Serre, N. Sibony, P. Skibiński, J. Smillie, M. K. Smith, D. Snow, J. Sotomayor, S. Spodzieja, Y. Stein, S. Sternberg, M. Suzuki, M. Sweedler, O. Taussky, J. Towber, H. Tutaj, В. И. Васюнин (V. Vasyunin), E. Velasco, A. Vitushkin, S. Walcher, S. Wang, T. Ważewski, T. Winiarski, D. Wright, X. Wu, F. Xavier, A. Yagzhev, H. Yamabe, K. Yoshida, J. Yu, G. Zampieri, V. Zurkowski, and J. Zweibel.

*Thanks to all who have helped. Please send corrections or additions to me at Dept Math & Stat, U Nebraska, Lincoln, NE 68588–0323. E-mail: gmeister@math.unl.edu Tel: OFFICE (402) 472–7261; HOME (402) 488-1583; UNL-FAX (402) 472–8466.

Part I. Annotated Bibliography on Polynomial Maps

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$$\begin{aligned} \dot{x}_1 &= \sum_{j=1}^{n} a_{1j} x_j + f(x_k) \\ \dot{x}_i &= \sum_{j=1}^{n} a_{ij} x_j \\ (i &= 2,\ 3,\ \ldots,\ n) \end{aligned}$$

has the origin as a globally asymptotically stable rest point provided that $f(x)$ is continuous, $f(0) = 0$, and, for each $x \neq 0$, $\alpha < f(x)/x < \beta$ for every pair of real numbers α, β for which all the characteristic roots of the companion linear system

$$\begin{aligned} \dot{x}_1 &= \sum_{j=1}^{n} a_{1j} x_j + a x_k \\ \dot{x}_i &= \sum_{j=1}^{n} a_{ij} x_j \\ (i &= 2,\ 3,\ \ldots,\ n) \end{aligned}$$

have negative real parts whenever $\alpha < a < \beta$. See Barabanov, Fitts, Funnin, Kalman, Pliss, Singh, and Yakubovich.

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[71] N. V. Chau. Global attractor of a differentiable autonomous system on the plane. *Ann. Polon. Math*, **LXII**(2):143–154, (1995). Thm 1 *generalizes* Olech's result [315], and Thm 2 is an interesting *variation* of the Markus-Yamabe Global Asymptotic Stability Jacobian Conjecture for the polynomial case, the original version of which was proved by Meisters & Olech [274]. Thm 1: If (i) $f(0) = 0$ and zero is a regular value of f (i.e., $\det f'(x) \neq 0$ at each $x \in \mathbb{R}^2$ where $f(x) = 0$), (ii) $\| f(x) \| >$ const > 0 for $\| x \| >$ const, (iii) $\text{div} f(x) \leq 0$ for $\| x \| >$ const, and (iv) $\int_{\mathbb{R}^2} \text{div} f(x)\, dx < 0$; then either (a) there is a trajectory with empty positive limit set which tends to a saddle point as $t \to -\infty$, or (b) $x = 0$ is a global attractor. Thm 2: If f is a polynomial map of $\mathbb{R}^2$ into itself which satisfies (i)–(iii) of Thm 1, then either (a) or (b) of Thm 1 holds, or (c) every trajectory is either a centre, a saddle point, a closed curve, or a curve joining two saddle points. Neither of these results *contains* the earlier results of Olech or of Meisters & Olech because the author's assumptions are different: Thm 1 has weaker assumptions and weaker conclusions than Olech's 1963 result; while Thm 2 has both weaker & stronger assumptions and different conclusions than the 1988 result of Meisters & Olech. Next the author deduces two injectivity results (his Thms 3 & 4) which are now of even more interest since Pinčuk has given a counterexample to the Strong Real Jacobian Conjecture on $\mathbb{R}^2$ [343]. Set $I_f := \{a \in \mathbb{R}^2 : 0 < \# f^{-1}(a) < \infty$ and $\det f'(x) > 0$ for all $x \in f^{-1}(a)\}$. Thm 3: If $\text{int}\, I_f \neq \emptyset$ and (ii) of Thm 1 holds, then f maps $f^{-1}(\text{int}\, I_f)$ one-to-one onto $\text{int}\, I_f$. Thm 4: If f is a polynomial map of $\mathbb{R}^2$ into itself, $\det f'(x) > 0$ on $\mathbb{R}^2$, and (ii) of Thm 1 holds, then f is a homeomorphism of $\mathbb{R}^2$. The paper ends with an example of a 1-parameter family of vector fields on $\mathbb{R}^2$, namely $f_\mu(x_1, x_2) = (x_2 - x_1({x_1}^2 + {x_2}^2 - \mu), -x_1 - x_2({x_1}^2 + {x_2}^2 - \mu))$, which exhibits four different types of behavior depending on whether $\mu \leq 0$, $0 < \mu < \sqrt{3}$, $\mu = \sqrt{3}$, or $\mu > \sqrt{3}$.

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[89] B. A. Coomes. On the Torsion Part of $\mathbb{C}^{[n]}$ with respect to the Action of a Derivation. *Proc. Amer. Math. Soc.*, **123**(7):2191–2197, July (1995). If $F : \mathbb{C}^n \to \mathbb{C}^n$ is a polynomial mapping, $\det F'(x) \equiv 1$, $F(0) = 0$, and D denotes the derivation associated with the vector field $V(y) := -[F'(y)]^{-1}F(y)$; then F is a polynomial automorphism iff the torsion part $T(D)$ of $\mathbb{C}^{[n]}$ is algebraically closed in $\mathbb{C}^{[n]}$.

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[96] B. Deng, G. H. Meisters, and G. Zampieri. Conjugation for polynomial mappings. *(ZAMP) Z. angew. Math. Phys.*, **46**:872–882, (1995). **MR 96m**:32022.

[97] Bo Deng. Analytic Conjugation, Global Attractor, and the Jacobian Conjecture. TEX preprint, (1995). Four pages, University of Nebraska-Lincoln, U.S.A. ⟨`bdeng@ode.unl.edu`⟩. Bo proved that the dilation λf of an analytic map f of $\mathbb{C}^n$ into itself with $f(0) = 0$, $f'(0) = I$, and $|\lambda| > 1$, has an *analytic* conjugation to its linear part λx if and only if f is a *holomorphism* (i.e., a holomorphic automorphism) of $\mathbb{C}^n$ and $x = 0$ is a global attractor for the inverse of λf. This is a Corollary of the more general **Theorem:** Suppose $F : \mathbb{C}^n \to \mathbb{C}^n$ is an analytic map, $F(0) = 0$, $\det F'(0) \neq 0$, and all eigenvalues of $F'(0)$ are in the open unit disk and not resonant; then F has an *analytic* conjugation to its linear part $F'(0)$ iff F is an analytic automorphism of $\mathbb{C}^n$ and the fixed point $x = 0$ is a global attractor, i.e., $\forall x \in \mathbb{C}^n$, $F^k(x) := F \circ F^{k-1}(x) \to 0$ as $k \to \infty$. Compare this with the theorem in the appendix of the 1988 paper [368] by Rosay & Rudin on holomorphic maps (listed in this PolyMapBib). The latter was kindly brought to our attention by Franc Forstneric, January 10, 1996. Bo Deng had not seen this earlier paper by Rosay and Rudin; and Meisters had not noticed that their theorem was relevant to what Bo Deng, Gaetano Zampieri, and I were then considering about the possible *global conjugation of dilations of polynomial maps* to their linear part. However, it was after seeing this paper of Bo Deng, not that of Rosay & Rudin, that Arno van den Essen and his colleagues were lead to write [78].

[98] H. G. J. Derksen. The Kernel of a Derivation. *J. Pure Appl. Algebra*, **84**:13–16, (1993). Nijmegen Report **9123** November 1991. Derksen wrote this as an undergraduate student of Arno van den Essen. Nagata and Nowicki showed in 1988 that the kernel of a derivation on $K_\infty[X_1, \ldots, X_n]$ is of finite type over K_∞ if $n \leq 3$. Derksen constructs a derivation of a polynomial ring in 32 variables (using Nagata's counterexample to Hilbert's 14th Problem) whose kernel is not of finite type over K_∞.

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[100] H. G. J. Derksen. Quotients of Algebraic Group Actions. In A. van den Essen, editor, *Automorphisms of Affine Spaces*, pages 191–200, P.O. Box 17, 3300 AA Dordrecht, The Netherlands, 1995. Caribbean Mathematical Foundation, and Kluwer Academic Publishers ISBN 0–7923–3523–6. Proceedings of the July 4–8, 1994, Conference on *Invertible Polynomial Maps* held at Curaçao, The Netherlands Antilles.

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[114] L. M. Drużkowski. The Jacobian Conjecture in case of rank or corank less than three. *J. Pure Appl. Algebra*, **85**:233–244, (1993). **MR 93m**:14011. Proves (I): Every complex matrix A is cubic-similar to a complex matrix D with the properties (1) $D = H'_D(c)$, for some vector c, and (2) the nilpotence index of $H'_D(x) := 3[diag(Dx)]^2 D$ is the same as the nilpotence index of D itself. Also proves (II): If $rank(A)$ or $corank(A) := n - rank(A)$ is less than three, then $F_A := x - H_A(x)$ is tame; i.e., $F(x) - F(0)$ is a finite composition of linear automorphisms and nonlinear shears $T(x_1, \ldots, x_n) = (x_1, \ldots, x_{i-1}, x_i + f(x_1, \ldots, x_{i-1}, x_{i+1}, \ldots, x_n), x_{i+1}, \ldots, x_n)$. In particular, every cubic-admissible matrix A is cubic-similar to a nilpotent matrix D.

[115] L. M. Drużkowski. On Different Approaches to the Jacobian Conjecture. In Marco Sabatini, editor, *Recent Results on the Global Asymptotic Stability Jacobian Conjecture*, Università di Trento, I–38050 POVO (TN) ITALY, September 14–17 1993. Dipartimento di Matematica, Università di Trento, Italia. The third lecture on Tuesday, September 14, 1993.

[116] L. M. Drużkowski. The Jacobian Conjecture: Some Steps Toward Solution. In A. van den Essen, editor, *Automorphisms of Affine Spaces*, pages 41–54, P.O. Box 17, 3300 AA Dordrecht, The Netherlands, 1995. Caribbean Mathematical Foundation, and Kluwer Academic Publishers ISBN 0–7923–3523–6. Proceedings of the July 4–8, 1994, Conference on *Invertible Polynomial Maps* held at Curaçao, The Netherlands Antilles.

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[120] L. M. Drużkowski and K. Rusek. The Real Jacobian Conjecture for Cubic Linear Maps of Rank Two. *Universitatis Iagellonicae Acta Mathematica*, **32**:17–23, (1995). Every polynomial mapping of $\mathbb{R}^n$ into itself of the cubic-linear form with rank of its homogeneous part ≤ 2 and positive Jacobian determinant is bijective with an analytic inverse. This is interesting in light of Pinčuk's non-injective example of a polynomial mapping of $\mathbb{R}^n$ with positive Jacobian determinant.

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[123] W. Engel. Ein Satz über ganze Cremona-Transformationen der Ebene. *Math. Ann.*, **130**:11–19, (1955).

[124] A. van den Essen. A Criterion to Decide if a Polynomial Map is Invertible and to Compute the Inverse. *Communications in Algebra*, **18**(10):3183 – 3186, (1990).

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[128] A. van den Essen. Polynomial maps and the Jacobian Conjecture. In *Computational Aspects of Lie Group Representations and Related Topics, Proceedings of the 1990 Computational Algebraic Seminar, C. W. I. Tract*, volume **84**, pages 29–44, (1991). Nijmegen Report **9034** August 1990.

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[130] A. van den Essen. Meromorphic differential equations having all monomials as solutions. *Arch. Math.*, **59**:42–49, (1992). Nijmegen Report **8930** December 1989. **MR 93m**:34002 (L. A. Campbell).

[131] A. van den Essen. An Algorithm to Compute the Invariant Ring of a G_a-Action on an Affine Variety. *Journal of Symbolic Computation*, **16**:551–555, (1993). Nijmegen Report **9202** January 1992. Describes an algorithm for the invariants of all G_a-actions on affine varieties, with finitely generated invariant ring; based on a study of the kernel of a locally nilpotent derivation and some algorithms from the theory of Gröbner bases.

[132] A. van den Essen. Conjectures and Problems Surrounding the Jacobian Conjecture. In Marco Sabatini, editor, *Recent Results on the Global Asymptotic Stability Jacobian Conjecture*, Università di Trento, I–38050 POVO (TN) ITALY, September 14–17 1993. Dipartimento di Matematica, Università di Trento, Italia. The first lecture on Tuesday, September 14, 1993.

[133] A. van den Essen. Eulerian Operators and the Jacobian Conjecture II. *Proc. A. M. S.*, **118**(2):373–378, (1993). Nijmegen Report **9106** April 1991.

[134] A. van den Essen. The Exotic World of Invertible Polynomial Maps. *Nieuw Archief voor Wiskunde*, **11**(1):21–31, March (1993). Nijmegen Report **9204** February 1992.

[135] A. van den Essen. A counterexample to a conjecture of Drużkowski and Rusek. Report **9440**, Mathematics Department, University of Nijmegen, The Netherlands, October 1994. It was conjectured by Drużkowski and Rusek that $\deg F^{-1} \leq 3^{p-1}$ if $F(x) = I + H(x)$ is a cubic-homogeneous polynomial automorphism of $\mathbb{C}^n$ and the Jacobian matrix $H'(x)$ has nilpotence index p. The authors prove that this is true if $n \leq 4$ but false if $n \geq 5$.

[136] A. van den Essen. A counterexample to a conjecture of Meisters. Report **9441**, Mathematics Department, University of Nijmegen, The Netherlands, October 1994. At the July 4th, 1994, Curaçao Conference, Meisters offered \$100 to the first person to give an example of a cubic-homogeneous polynomial mapping $F(x) = I + H(x)$ of $\mathbb{C}^n$ into itself with $\det H'(x) = 1$ for which the complex s-parametered conjugation $h_s \circ s\,F \circ h_s^{-1} = s\,I$ fails (for $|s| \neq 1$) for *polynomial* automorphisms h_s. (See Meisters' Curaçao paper for details and explicit examples.) Arno van den Essen shows in this paper that, while such polynomial conjugations do hold in dimensions $n \leq 3$, there are counterexamples in dimensions $n \geq 4$. On Monday, September 19, 1994, I found two e-mail messages from Arno van den Essen, dated September 16 and 19, in which he described two cubic-homogeneous counterexamples! On September 19 he FAXed to me (Meisters) a proof that $h(s,x)$ defined by the eq. $h_s \circ s\,F \circ h_s^{-1} = s\,I$ when $F(x) = (x_1 + p(x)x_4, x_2 - p(x)x_3, x_3 + {x_4}^3, x_4)$, where $p(x) = x_3x_1 + x_4x_2$, *can not be polynomial*. (However, the $h(s,x)$ for this example is *entire*!) See also [148] by van den Essen & Engelbert Hubbers. **Now also settled is the \$200 (until February 17, 1996) question:** Will each $h_s(x)$ be a polyomorphism (or at least a holomorphic automorphism) of $\mathbb{C}^n$ if $F(x)$ is *cubic-linear* (not merely cubic-homogeneous)? If this question had no *cubic-linear* counterexample, then Keller's (complex) Jacobian Conjecture would be true! But see van den Essen [146] and Gorni & Zampieri [192].

[137] A. van den Essen. Locally Finite and Locally Nilpotent Derivations with Applications to Polynomial Flows, Morphisms and G_a-actions, II. *Proc. A. M. S.*, **121**(3):667–678, July (1994). Nijmegen Report **9206** March 1992.

[138] A. van den Essen. A Counterexample to a Conjecture of Meisters. In A. van den Essen, editor, *Automorphisms of Affine Spaces*, pages 231–233, P.O. Box 17, 3300 AA Dordrecht, The Netherlands, 1995. Caribbean Mathematical Foundation, and Kluwer Academic Publishers ISBN 0–7923–3523–6. Proceedings of the July 4–8, 1994, Conference on *Invertible Polynomial Maps* held at Curaçao, The Netherlands Antilles. See also Nijmegen Report **9441** October 1994.

[139] A. van den Essen, editor. *Automorphisms of Affine Spaces*. Kluwer Academic Publishers, P.O.Box 989, 3300 AZ Dordrecht, The Netherlands, 1995. Proceedings of the Conference on Polynomial Automorphisms, organized by A. van den Essen, and held at the Princess Beach Resort Casino, Willemstad, Curaçao, The Netherlands Antilles, July 4–8, 1994. Price US \$132. ISBN 0-7923-3523-6.

[140] A. van den Essen. Locally nilpotent derivations and their applications, III. *J. Pure Appl. Algebra*, **98**:15–23, (1995). Nijmegen Report **9330** August 1993.

[141] A. van den Essen. Polynomial Automorphisms and the Jacobian Conjecture. Report **9540**, U Nijmegen, Toernooiveld 6525 ED Nijmegen, The Netherlands., October 1995. A beautifully written, up-to-date survey, of recent results; accessible to beginners.

[142] A. van den Essen. Seven Lectures on Polynomial Automorphisms. In A. van den Essen, editor, *Automorphisms of Affine Spaces*, pages 3–39, P.O. Box 17, 3300 AA Dordrecht, The Netherlands, 1995. Caribbean Mathematical Foundation, and Kluwer Academic Publishers ISBN 0–7923–3523–6. Proceedings of the July 4–8, 1994, Conference on *Invertible Polynomial Maps* held at Curaçao, The Netherlands Antilles. Also Nijmegen Report **9442** October 1994 pages 1–38. A very nice introduction to and survey of polynomial maps and the Jacobian Conjecture.

[143] A. van den Essen. A Counterexample to a Conjecture of Shpilrain and Yu. Report **9639**, Mathematics Dept, University of Nijmegen, Toernooiveld 6525 ED Nijmegen, The Netherlands, December (1996). A counterexample is given to a conjecture of V. Shpilrain & J.-T. Yu (in [387]): Namely, if $p \in k[X,Y]$ has a unimodular gradient (i.e., 1 belongs to the ideal in k[X,Y] generated by the partial derivatives

of p), then van den Essen shows that $k[p]$ *need not be* a retract (see [91]); and then deduces, for every pair of integers (n, m) with $n > m$, the *falsity* of the "Generalized Jacobian Conjecture" $GJC(n, m)$: If $F : \mathbb{C}^n \to \mathbb{C}^m$ is a polynomial map such that the Jacobian matrix $F'(x)$ has maximal rank for all $x \in \mathbb{C}^n$, then F has a left inverse.

[144] A. van den Essen. A Criterion to Decide if a Polynomial has a Jacobian Mate of Bounded Degree. Report **9625**, Mathematics Dept, University of Nijmegen, Toernooiveld 6525 ED Nijmegen, The Netherlands, September 1996. Gives a criterion to decide whether or not, to a given polynomial Q in $k[X, Y]$ of degree $n \geq 2$ and a given positive integer s, there corresponds a polynomial P in $k[X, Y]$ of degree $\leq ns$ such that $[P, Q] := P_x Q_y - P_y Q_x = 1$. In case such a polynomial P (called a **Jacobian mate of** Q) exists, it is shown how to construct it. The method uses and extends the work of Magnus [244]. This problem was treated in [72] when the mate P of Q has degree smaller than deg$Q$; and in [401] when the mate P has some fixed degree.

[145] A. van den Essen. Nilpotent Jacobian matrices with independent rows. Report **9603**, University of Nijmegen, February 1996. Let k be a field with characteristic zero and $n \geq 3$. Polynomial maps $H : k^n \to k^n$ are described such that $H'(x)$ is nilpotent for all x in k, and $H_1, \ldots, H_n$ are linearly independent over k. It can happen that no iterate of H is equal to zero.

[146] A. van den Essen. A counterexample to Meisters' cubic-linear linearization conjecture. *Nederl. Akad. Wetensch. Indag. Math.*, to appear 1997. Nijmegen **Report 9635** (November 1996). For each $n \geq 5$ a cubic-homogeneous and a quadratic homogeneous counterexample to the DMZ-Conjecture is given, and the existence of a counterexample in dimension 17 to Meisters' Cubic-Linear Linearization Conjecture (stated at bottom of page 85 of [265]) is deduced. A cubic-homogeneous counterexample to the Markus-Yamabe Conjecture in dimension 5 is also given. See [150] and the elegant paper [192].

[147] A. van den Essen et al. See also Adjamagbo, Derksen, and Eggermont. Nijmegen Reports.

[148] A. van den Essen and E. Hubbers. Polynomial maps with strongly nilpotent Jacobian matrix and the Jacobian Conjecture. Report **9444**, Mathematics Department, University of Nijmegen, The Netherlands, 1994. To appear in *Linear Algebra Appl.* The conjugation equation $h_s \circ s\, F \circ h_s^{-1} = s\, I$, conjectured by Deng, Meisters, and Zampieri for a one-parameter (complex s off the unit circle) family of polynomial automorphisms h_s, is true when $F = I + H$ and $H'(x)$ is **strongly nilpotent**, but not in general. Now *also settled* (but not in this paper) is the question: Is this conjugation equation valid for *polynomial in* x (or at least *entire in* x) automorphisms $h_s(x)$ when the mapping $x \mapsto F(x)$ is of Drużkowski's *cubic-linear* type? As a reward for a counterexample, Meisters had offered \$200 until February 17, 1996. In April 1996, van den Essen & Hubbers thought they had found such a counterexample, but found a mistake; nevertheless, they soon did prove the existence of such a counterexample [146] with the help of the beautiful results [192] of Gorni & Zampieri.

[149] A. van den Essen and Engelbert Hubbers. A New Class of Invertible Polynomial Maps. Report **9604**, University of Nijmegen, February 1996. Presents a new large class of polynomial maps $F = X + H$ for which the Jascobian Conjecture is true. In particular H does not need to be homogeneous. It is also shown that for all H in this class satisfying $H(0) = 0$, the nth iterate $H \circ \ldots \circ H = 0$.

[150] A. van den Essen and Engelbert Hubbers. Chaotic Polynomial Automorphisms; counterexamples to several conjectures. *Adv. in Appl. Math.*, **18**(3):382–388, April 1997. Nijmegen **Report 9549** (November 1995). Gives a counterexample, of the form $f(x) = x + H(x) \in \mathbb{Z}[x_1, x_2, x_3, x_4]$ where H is homogeneous of degree 5, to the DMZ-conjecture (of Bo Deng, G. H. Meisters, and Gaetano Zampieri) to the effect that if $f : \mathbb{C}^n \to \mathbb{C}^n$ is a polynomial map with $f(0) = 0$ and $f'(0) = I$, then for all $\lambda > 1$, λ large enough, there exists an *analytic* automorphism $h_\lambda : \mathbb{C}^n \to \mathbb{C}^n$ such that $h_\lambda \circ \lambda f \circ h_\lambda^{-1} = \lambda I$; i.e., h_λ conjugates λf to its linear part. The authors show that this same example is also a counterexample to the **discrete Markus-Yamabe Question** of J. P. LaSalle [238], revived by Cima, Gasull, and Mañosas [80]. This paper still does not settle the **cubic-linear linearization conjecture** which Meisters mentioned in his 1994 Curaçao paper [265]; but see the more recent papers of van den Essen [146] and Gorni & Zampieri [192] which do!

[151] A. van den Essen and Theo Janssen. Kernels of Elementary Derivations. Report **9548**, U Nijmegen, Toernooiveld 6525 ED Nijmegen, The Netherlands., November 1995.

[152] A. van den Essen and M. Kwieciński. On the reconstruction of polynomial automorphisms from their face polynomials [via Gröbner Bases]. *J. Pure Appl. Algebra*, **80**:327–336, (1992). Nijmegen Report 9103 March 1991. **MR 93j**:14015 (Ludwik Drużkowski).

[153] A. van den Essen and G. H. Meisters. A Computational Approach to the Jacobian Conjecture. Report **9318**, Mathematics Dept, Catholic Univ, Nijmegen, The Netherlands, April 1993. Where one must look for counterexamples to Keller's complex Jacobian Conjecture.

[154] A. van den Essen and T. Parthasarathy. Polynomial Maps and a Conjecture of Samuelson. *Linear Algebra and its Applications*, **177**:191–195, (1992). Nijmegen Report **9119** September 1991. **MR 93i**:14013.

[155] A. van den Essen and Vladimir Shpilrain. Some Combinatorial Questions About Polynomial Mappings. Report **9535**, U Nijmegen, Toernooiveld 6525 ED Nijmegen, The Netherlands., September 1995.

[156] A. van den Essen and H. Tutaj. A remark on the two-dimensional Jacobian Conjecture. Report **9226**, Mathematics Department, University of Nijmegen, The Netherlands, November 1992.

[157] A. van den Essen and J.-T. Yu. The D-resultant and a remark on the epimorphism theorem. Report **9221**, Mathematics Department, University of Nijmegen, The Netherlands, October 1992.

[158] R. Feßler. A Solution of the Global Asymptotic Stability Jacobian Conjecture and a Generalization. In M. Sabatini, editor, *Recent Results on the Global Asymptotic Stability Jacobian Conjecture*, Univ. Trento, I–38050 POVO (TN) Italy, Sept. 14–17, 1993. Dipart. Mat. U. Trento, Italia. Feßler presented his proof (for class C^1 vector fields on $\mathbb{R}^2$) as the 3rd lecture on Thursday, Sept. 16, 1993.

[159] R. Feßler. On the Markus-Yamabe Conjecture. In A. van den Essen, editor, *Automorphisms of Affine Spaces*, pages 127–135, P.O. Box 17, 3300 AA Dordrecht, The Netherlands, 1995. Caribbean Mathematical Foundation, and Kluwer Academic Publishers ISBN 0–7923–3523–6. Proceedings of the July 4–8, 1994, Conference on *Invertible Polynomial Maps* held at Curaçao, The Netherlands Antilles.

[160] R. Feßler. A Proof of the two dimensional Markus-Yamabe Stability Conjecture. *Annales Polonici Mathematici*, **62**:45–75, (1995). See also [158, 159] and [196, 198].

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[162] L. Flatto. Invariants of finite reflection groups. *Enseign. Math.*, **24**:237–292, (1978). A nice account of a beautiful subject, discussed further by Walter Rudin in [372, this Bib]. A linear transformation L of $\mathbb{C}^n$ into itself is called a **reflection** if it has finite period and its set of fixed points forms an $(n–1)$-dimensional subspace of $\mathbb{C}^n$. With respect to an appropriate basis, such an L can be represented by a diagonal matrix of $(n–1)$ 1's and a root of unity $\neq 1$. A **finite unitary reflection group** is a finite group of unitary transformations that is generated by the reflections it contains. Hilbert: *To each finite unitary group G on $\mathbb{C}^n$ corresponds a finite set of homogeneous G-invariant polynomials $p_1, \ldots, p_N$ such that every G-invariant polynomial f can be expressed in the form $f(z) = q(p_1(z), \ldots, p_N(z))$, $\forall z \in \mathbb{C}^n$, where q is some polynomial on $\mathbb{C}^n$*. Chevalley [76, this Bib] added that *one can take $N = n$ if G is a reflection group*; Shephard & Todd [386, this Bib] showed $N > n$ *except when G is a reflection group.*

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[165] F. Forstneric. Actions of $(\mathbb{R}, +)$ and $(\mathbb{C}, +)$ on complex manifolds. (to appear).

[166] F. Forstneric and J.-P. Rosay. Approximation of biholomorphic mappings by automorphisms of $\mathbb{C}^n$. *Invent. Math.*, **112**:323–349, (1993).

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[174] A. Gasull, J. Llibre, and J. M. Sotomayor-Tello. Global asymptotic stability of differential equations in the plane. *Journal of Differential Equations*, **91**(2):327–335, June (1991).

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[188] G. Gorni. Injectivity of Local Homeomorphisms via Lyapunov Functions. In Marco Sabatini, editor, *Recent Results on the Global Asymptotic Stability Jacobian Conjecture*, Università di Trento, I–38050 POVO (TN) ITALY, September 14–17 1993. Dipartimento di Matematica, Università di Trento, Italia. The first lecture on Wednesday, September 15, 1993.

[189] G. Gorni and G. Zampieri. Global Sinks for Planar Vector Fields. In **The Evolution Equation and Nonlinear Problems**, *Proceedings of the RIMS Symposium*, pages 134–138. RIMS Kokyuroku 785, Kyoto University, May (1992).

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[191] G. Gorni and G. Zampieri. On the existence of Global Analytic Conjugations for Polynomial Mappings of Yagzhev Type. *J. Math. Anal. Appl.*, **201**:880–896, (1996).

[192] G. Gorni and G. Zampieri. On cubic-linear polynomial mappings. *Nederl. Akad. Wetensch. Indag. Math.*, to appear 1997. **UDMI/43/96/RR** (September 1996), 21 pages, Udine, Italy. Elegant results.

[193] D. Greenig. *Ph.D. Thesis supervised by Charles Pugh.* On the Markus-Yamabe Conjecture, Berkeley, California, 1994? A very nice piece of work! **Chapter Headings:** 1. Introducton, 2. Background (Theorems of Hartman, Olech, and Gasull-Llibre-Sotomayor), 3. Space of Markus Vector Fields, 4. Completeness and Univalence, 5. Convexity. Can anyone tell me where Doug Greenig is now?

[194] R. M. Guralnick. Triangularization of Sets of Matrices. Linear and Multilinear Algebra, **9**:133–140, (1980).

[195] C. Gutierrez. Dissipative vector fields on the plane with infinitely many attracting hyperbolic singularities. *Bol. Soc. Brasil. Mat.*, **22**:179–190, (1992). IMPA Preprint Série A-090-Dez./91.

[196] C. Gutierrez. A Solution to the bidimensional Global Asymptotic Stability Conjecture. In Marco Sabatini, editor, *Recent Results on the Global Asymptotic Stability Jacobian Conjecture*, Università di Trento, I–38050 POVO (TN) Italy, September 14–17 1993. Dipartimento di Matematica, Università di Trento, Italia. Gutierrez presented his proof of the Global Asymptotic Stability Jacobian Conjecture in dimension two for class C^1 vector fields as the second lecture on Wednesday, September 15, 1993.

[197] C. Gutierrez. Asymptotic Stability at Infinity of Planar Vector Fields. *Bol. Soc. Brasil. Mat.*, **26**(1):57–66, (1995).

[198] C. Gutierrez. A Solution to the bidimensional Global Asymptotic Stability Conjecture. *Ann. Inst. H. Poincaré Anal. Non Linéaire*, **12**(6):627–671, (1995). See also [196] and [158, 159, 160].

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[200] A. Halanay. *Differential Equations: Stability, Oscillation, Time Lags*, volume **23** of *Mathematics in Science and Engineering, Ed. Richard Bellman.* Academic Press, Inc., 111 Fifth Avenue, New York, NY 10003; 24/28 Oval Road, London NW1, First English (from 1963 Romanian) edition, 1966.

[201] P. Hartman. On Stability in the Large for Systems of Ordinary Differential Equations. *Canad. J. Math.*, **13**:480–492, (1961).

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[205] X. Huang. Application of the Meisters-Olech Criteria to Quadratic and Cubic Differential Systems. Master's thesis, Southern Illinois University, Carbondale, Illinois, June 1988. Directed by Prof. C. E. Langenhop.

[206] Engelbert Hubbers. *Cubic Similarity in Dimension Five.* Doctors thesis, University of Nijmegen, Nijmegen, The Netherlands, July 1996. An incredible and beautiful piece of work. Hubbers gives in this 50-page paper a complete classification of all Drużkowski **cubic-linear** maps $F := X + (diag[AX])^2 AX$ of k^5 into itself with nilpotent Jacobian $3(diag[AX])^2 A$ of the homogeneous part $(diag[AX])^2 AX$, where k is any algebraically closed field. He then uses this classification to find all representatives of the **cubic-similarity** relation in dimension five. This is an important and difficult step in the program outlined by Meisters at the October 1992 Luminy Conference on Polynomial Maps.

[207] Engelbert-M. G. M. Hubbers. The Jacobian Conjecture: Cubic Homogeneous Maps in Dimension Four. Master's thesis, Katholieke Universiteit Nijmegen, Department of Mathematics and Computer Science, Nijmegen, The Netherlands, February 17, 1994. This thesis contains an excellent summary of results on the Jacobian Conjecture and presents many interesting and useful examples of polynomial maps with various properties. **Chapter 1:** A short historical summary including a proof that the general Jacobian Conjecture reduces to the case where $F = I - H$ with H cubic-homogeneous; and David Wright's result that this case holds for $n = 3$. **Chapter 2:** Hubbers generalizes Wright's result to $n = 4$ by means of a complete classification of all cubic-homogeneous polynomial maps in dimension 4 when $\det F'(x) = 1$; all these F turn out to be injective! **Chapter 3:** Proof that all cubic-homogeneous maps in two dimensions with coefficients in a uniform factorization domain can be written in a very simple way. **Chapter 4** takes up the four-dimensional case again, but for those special $F = I - H$ where H is in Drużkowski's **cubic-linear** form. (Drużkowski has shown that to prove the Jacobian Conjecture it suffices to prove it, *but in all dimensions*, for maps of this special type.) Hubbers gives **a complete classification of cubic-linear maps in four dimensions**; and uses this to prove Meisters' conjecture about the *cubic-similarity representatives* in dimension four. Hubbers then proves that the Jacobian Conjecture is true for cubic-linear maps in dimensions $n \leq 7$. **Chapter 5** discusses locally nilpotent derivations; and gives examples of quadratic-homogeneous Jacobian matrices in dimension four that are not strongly nilpotent. Finally, in **Chapter 6** Hubbers begins to investigate these matters in dimension five. Now see his newer 50-page paper (his Doctors Thesis?) [206].

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[213] S. I. Kaliman. Extensions of isomorphisms between affine algebraic subvarieties of $\mathbf{k}^n$ to automorphisms of $\mathbf{k}^n$. Preprint, February (1990).

[214] S. I. Kaliman. On the Jacobian Conjecture (the 2-dimensional case). Preprint, 1990.

[215] R. E. Kalman. See Barabanov: According to the **Math Review** of Barabanov's paper, "By strengthening the assumptions in Aizerman's Problem, R. E. Kalman conjectured that if $\varphi'(\sigma) \in (\alpha, \beta)\ \forall\sigma$, then the origin is globally asymptotically stable".

[216] R. E. Kalman. On physical and mathematical mechanisms of instability in nonlinear automatic control systems. *Journal of Applied Mechanics Transactions ASME*, **79**(3):553–566, (1957) **MR 19**:517.

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[219] M. Kirezci. The Jacobian Conjecture I. *Bull. Tech. Univ. Istanbul*, **43**:421–436, (1990). **In brief:** This paper gives a formal inverse $G = (G_1, \ldots, G_n)$ in the ring $\mathbf{k}[[X]]$ of formal power series in $X = (X_1, \ldots, X_n)$ for mappings of the form $F = X - H$ where each component H_i is a cubic homogeneous polynomial and the jacobian matrix $J(H)$ is nilpotent; and a recursion formula for the homogeneous parts of the components of G.

[220] M. Kirezci. The Jacobian Conjecture II. *Bull. Tech. Univ. Istanbul*, **43**:451–457, (1990). **In brief:** Shows that if $J(H)^2 = 0$, then F is invertible with $G = X + H$. See [§4 and §6.4 in Meisters and Olech, Strong Nilpotence Holds in Dimensions up to Five Only, *Linear and Multilinear Algebra* **30**(1991), 231–255.].

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[223] H. Kraft. G-vector bundles and the linearization problem. In *Proceedings of the Conference on Group Actions and Invariant Theory, Monteal, 1988*, volume **10**, pages 111–123. Canad. Math. Soc., Amer. Math. Soc., (1989).

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[225] H. Kraft and G. Schwarz. Finite Automorphisms of Affine N-Space. In A. van den Essen, editor, *Automorphisms of Affine Spaces*, pages 55–66, P.O. Box 17, 3300 AA Dordrecht, The Netherlands, 1995. Caribbean Mathematical Foundation, and Kluwer Academic Publishers ISBN 0–7923–3523–6. Proceedings of the July 4–8, 1994, Conference on *Invertible Polynomial Maps* held at Curaçao, The Netherlands Antilles.

[226] T. Krasiński. Bifurcation points of polynomials and the Jacobian Conjecture in $\mathbf{C}^2$. Preprint, (1990).

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[231] Kwieciński. Automorphisms from face polynomials via two Gröbner bases. *J. Pure Appl. Algebra*, **82**:65–70, (1992). Same as **Nijmegen Report 9105 (April 1991)**. Shows how to recover a polynomial automorphism from its face polynomials using only two Gröbner basis computations.

[232] M. Kwieciński. A Gröbner basis criterion for isomorphisms of algebraic varieties. *J. Pure Appl. Algebra*, **74**:275–279, (1991).

[233] M. Kwieciński et al. See van den Essen.

[234] T. J. Laffey. Simultaneous Triangularization of a Pair of Matrices. *J. Algebra*, **44**:550–557, (1977).

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[236] J. Lang. Jacobian Pairs, II. *J. Pure Appl. Algebra*, **74**:61–71, (1991).

[237] J. Lang. Newton Polygons of Jacobian Pairs, I. *J. Pure Appl. Algebra*, **72**:39–51, (1991).

[238] J. P. LaSalle. *The Stability of Dynamical Systems*, volume **25** of *CBMS-NSF Regional Conference Series in Applied Mathematics*. Society for Industrial and Applied Mathematics, Philadelphia, Pennsylvania, second printing 1993 edition, January 1976. An introduction to the relationship between Liapunov functions and Birkoff limit sets. Systematic treatment of questions of stability of both discrete and continuous dynamical systems. States many problems that were open in 1976 (some still open in 1996) including discrete versions of the Markus-Yamabe Conjecture on Global Asymptotic Stability (see pages 20–21). The later has been solved by A. van den Essen & E. Hubbers [80, 150]. There is a 20-page Appendix by Zvi Artstein on stability of *nonautonomous* ordinary differential equations.

[239] M. Letizia. A simple solution of the Jacobian Problem in the quadratic case. *J. Algebra*, **81**:70–71, (1983). **MR 85b**:13023. See also: S. S.-S. Wang, *ibid.* **65** (1980), **MR 83e**:14010; A. V. Yagzhev, Siberian Math. J. **21**(1980); and S. Oda & K. Yoshida, C. R. Math. Rep. Acad. Sci. Canada **5** (1983). Note that for quadratic maps g of $\mathbf{k}^n$ into itself, we have $g(x) - g(y) = g'(\frac{x+y}{2})(x-y)$; so $det g'(x) \neq 0$ implies that g is $1-1$ (injective).

[240] B.-H. Li. The Jacobian Problem in Differential Equations on $\mathbb{R}^2$ and the Jacobian Conjecture in Algebraic Geometry. 1995 preprint. Gives an algebraic-geometric proof of the Markus-Yamabe Conjecture in the plane. It seems interesting and rather different from the proof given by Meisters & Olech [274].

[241] W. Li. On a problem about face polynomials. *J. Pure Appl.Algebra*, **60**:269–272, (1989).

[242] W. Li and J.-T. Yu. Computing Minimal Polynomials and the Degree of Unfaithfulness. *Communications in Algebra*, (Preprint 1992):1–14, (to appear). Uses Gröbner basis computation.

[243] W. Li and J.-T. Yu. Reconstructing Birational Maps from Their Face Functions. *Manuscripta Mathematica*, (Preprint 1992):1–14, (to appear).

[244] Arne Magnus. Volume-preserving transformations in several complex variables. *Proc. Amer. Math. Soc.*, **5**:256–266, (1954).

[245] Arne Magnus. On polynomial solutions of a differential equation. *Math. Scand.*, **3**:255–260, (1955). **MR 17**:1195.

[246] L. Markus and H. Yamabe. Global Stability Criteria for Differential Systems. *Osaka Math. J.*, **12**:305–317, (1960). **MR 23**#A3316. Hidehiko Yamabe [1923–1960].

[247] R. Daniel Mauldin, Editor. *The Scottish Book: Mathematics from the Scottish Café*. Scottish Book Conference, North Texas State University, May 1979. Birkhäuser, Boston-Basel-Stuttgart, First U. S. edition, 1981. "**Problem 79** (Mazur, Orlicz): A POLYNOMIAL $y = U(x)$ MAPS, in a one-to-one fashion, a space X of type (B) onto a space Y of type (B); the inverse of this mapping $x = U^{-1}(y)$ is also polynomial. Is the polynomial $y = U(x)$ of first degree? Not decided even in the case when X and Y are a Euclidean plane." An "Addendum" states "Trivial" and gives the triangular example in n dimensions. CURIOUS! Did they hear about Keller's Conjecture from someone, but somehow get it wrong? They have taken the *conclusions* as the *hypotheses*, and lost Keller's hypothesis that $det\, U'(x)$ be a nonzero constant! It is Keller's Question that is not decided even in two dimensions; nonlinear polyomorphisms exist in all dimensions ≥ 2, but have been *classified* only in dimension two.

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[249] J. H. McKay and S. S.-S. Wang. An inversion formula for two polynomials in two variables. *J. Pure Appl. Algebra*, **40**:245–257, (1986).

[250] J. H. McKay and S. S.-S. Wang. An elementary proof of the Automorphism Theorem for the polynomial ring in two variables. *J. Pure Appl. Algebra*, **52**:91–102, (1988).

[251] J. H. McKay and S. S.-S. Wang. On the inversion formula for two polynomials in two variables. *J. Pure Appl. Algebra*, **52**:103–119, (1988).

[252] J. H. McKay and S. S.-S. Wang. A chain rule for the resultant of two polynomials. *Arch. Math (Basel)*, **volume**, (1989).

[253] R. M. McLeod. Mean value theorems for vector valued functions. *Proc. Roy. Soc. Edinburgh Sect. A*, **14**:197–209, (1965).

[254] R. M. McLeod and G. H. Meisters. Smooth Polynomial Paths with Nonanalytic Tangents. *Proc. Amer. Math. Soc.*, **107**:697–700, (1989). **MR 90b**:26020.

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[260] G. H. Meisters. Invariants of Cubic-Similarity. In Marco Sabatini, editor, *Recent Results on the Global Asymptotic Stability Jacobian Conjecture*, Università di Trento, I–38050 POVO (TN) ITALY, September 14–17 1993. Dipartimento di Matematica, Università di Trento, Italia. The second lecture on Tuesday, September 14, 1993.

[261] G. H. Meisters. Inverting a Cubic-Linear Mapping in 15-Dimensions. A *Mathematica* Notebook, *Mathematica* Version 2.1 for NeXT Computers, Wolfram Research, Inc., 1993, July 1993. A 6 page *Mathematica* Notebook. This inversion is also easy by hand!

[262] G. H. Meisters. The Markus-Yamabe Conjecture Implies the Keller Jacobian Conjecture. In Massimo Furi, editor, *Proceedings of the* **International Meeting on Ordinary Differential Equations and their Applications***, at Firenze, Italy, to celebrate the 70th Birthdays of Roberto Conti and Gaetano Villari.* **IMODEA**, September 20 1993. A counterexample to the Keller Jacobian Conjecture in some dimension allows one to construct also a *polynomial* vector field counterexample to the Markus-Yamabe Conjecture on Global Asymptotic Stability in some larger dimension. This has been known for several years by several people including the author, Czesław Olech, Gilles Fournier, and Mario Martelli.

[263] G. H. Meisters. Characteristic Polynomial of $\mathcal{B}(A)(x, y)$ for a Good But Not Wonderful Matrix A in 15-Dimensions. A *Mathematica* Notebook, *Mathematica* Version 2.2 for NeXT Computers, Wolfram Research, Inc., 1993, January 1994. Computation of the coefficients of the characteristic polynomial of $\mathcal{B}(A)(x, y)$ shows that all but those of t^{15} and t^{13} are zero. Total computing time was approximately 15 hours 10 minutes 50 seconds. After closing 42 pages of uninteresting intermediate output, the notebook has 9 remaining pages, including 1 page of references.

[264] G. H. Meisters. The Cubic-Linear Linearization Conjecture. Available on my World-Wide-Web Page at `http://www.math.unl.edu/~gmeister/`, November 1995. A fresh 2-page self-contained statement of a simple linearization conjecture whose truth would imply the Jacobian Conjecture.

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July 4–8, 1994, Conference on *Invertible Polynomial Maps* held at Curaçao, The Netherlands Antilles. This paper shows by examples and calculations that many, even if not all, *dilations* of polyomorphisms are conjugate to (the same dilation of) their linear part by means of another polyomorphism. Thus various questions arise as to which polyomorphisms are **dilation-conjugate** to their **dilated linear part** by polyomorphisms, holomorphisms, diffeomorphisms, or at least homeomorphisms. In particular, the **cubic-linear linearization conjecture**, stated in the last sentence of the penultimate paragraph on page 85, has been settled by van den Essen [146] and Gorni & Zampieri [192]. The easier **cubic-homogeneous** case was settled by a counterexample found by van den Essen soon enough after the Curaçao Conference to be included at the end of the conference proceedings [139] as item [138]. This cubic-homogeneous counterexample first appeared as a **Nijmegen Report** [136], and Meisters paid van den Essen $100, as publicly promised at the Curaçao Conference, for this cubic-homogeneous counterexample. But the **cubic-linear linearization counterexample** was harder to obtain.

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Bourbaki, Nicolas. Pseudonym of a society of French mathematicians formed to write a multi-volumed treatise covering all parts of mathematics systematically. Membership was tested by lectures in which the theorems bore the names of famous generals and were wrong in nontrivial ways: To pass the test one had to catch the errors. Once in, the only rule: Out at age 50. Charles Denis Sauter Bourbaki was a 19th century Greek general in the army of Napoléon III. In 1948 an official of the Greek Embassy named Nicolaïdes-Bourbaki contacted Henri Cartan to find out how it could be that French mathematical works were being published under the name "Bourbaki". **The founding members: Henri Cartan [1904–], Claude Chevalley [1909–], Jean Delsarte [1903–1968], Jean Dieudonné [1906–1992], André Weil [1906–]**. Some others who have been members: René de Possel, Charles Ehresmann, Charles Chabauty, Samuel Eilenberg, Serge Lang, John Tate, Jean Dixmier, Roger Godement, Jean Louis Koszul, Pierre Samuel, Laurent Schwartz, and Jean-Pierre Serré. References: [1] Nicolas Bourbaki, *The Architecture of Mathematics*, **Amer. Math. Monthly 57** (1950) 221–232; [2] Paul Halmos, *Nicolas Bourbaki*, **Scientific American** (May 1957) 88–99; [3] Nicolas Bourbaki, *Éléments d'historie des mathématiques*, Hermann, Paris 1960; [4] Jean Dieudonné, *The Work of Nicolas Bourbaki*, **Amer. Math. Monthly 77** (1970) 134–145; [5] André Weil, *The Apprenticeship of a Mathematician*, English translation by Jennifer Gage, Birkhuser, Basel 1992.

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Ważewski, Tadeusz. [Wrzesień 24, 1896 – Wrzesień 5, 1972] (Wrzesień = September). He was born in Wygnanka, a village near Tarnów, Poland. After graduating from Tarnów High School in 1914 he enrolled in the Jagiellonian University in Kraków where he studied physics and mathematics; then spent the years 1921–1923 as a graduate student at the University of Paris where he received his doctor's degree in 1924 with a thesis about connected continua not containing simple closed curves: *Sur les courbes de Jordan ne renfermant aucune courbe simple fermée de Jordan* **Ann. Soc. Polon. Math. 2** (1923) 49–170. His doctoral examination committee consisted of Emil Borel, Arno Denjoy, and Paul Montel. He received his second (habilitation) degree from the Jagiellonian University in 1927 on the basis of a paper on *rectifiable continua in connection with absolutely continuous functions and mappings.* In 1933 he was appointed an extraordinary professor at the Jagiellonian University. On November (Listopad) 6, 1939, Tadeusz Ważewski, along with a large group of university professors of various schools in Kraków, was arrested by the Nazi occupation forces in Poland and deported to a concentration camp. He was released before the end of the war and spent the rest of the German occupation in Kraków teaching in the underground university and continuing his research activity. He was promoted to ordinary professor (full professor) in 1945. When the Polish Academy of Sciences was founded in 1952, he became its correspnding member and was elected a full member in 1957. Ważewski was one of the founders of the Mathematical Institute of the Polish Academy of Sciences and was head of its Kraków branch for many years. He was President of the Polish Mathematical Society for 1957–59; and a long time editor of the journal **Annales Polonici Mathematici**. **The Ważewski Equation** [420] $dx/dt = F'(x)^{-1}a$, for x and vector parameter a both in $\mathbb{R}^n$, plays an important role in several papers in this Bibliography: E.g., in [273], [257], [453], and [89]. He has long been famous for a powerful topological-geometric method that he introduced, known as "**The Ważewski Method**", for establishing the existence of certain types of solutions of ordinary differential equations. *Reference*: TADEUSZ WAŻEWSKI, SELECTED PAPERS, PWN-Polish Scientific Publishers, Warszawa 1990, ISBN 83-01-09733-7.

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Zariski, Oscar [1899–1986]. Born "Ascher Zaritsky", April 24, 1899, in Kobrin (Kobryń), a small Polish-Russian-Jewish town (only 140 miles east of Warszawa) in "The Jewish Pale of Settlement" in Belorussia, which borders on Poland, Lithuania & Latvia. (Poland has been partitioned repeatedly by her neighbors—Russia, Austria, and Germany; at the time of Zariski's childhood, this region was ruled by Russia.) He was the sixth child and third son of Bezalel Zaritsky, a Talmudic scholar, and Hannah Tannenbaum; at 7 & 8 he eagerly learned chess, arithmetic, and algebra from his oldest brother, Moses. His older brother, Shepsel, taught him to ice-skate on the Mukhavets, a small tributary of the Bug river. His first studies were in the Ukraine (at Vladimir-Volynskiy in 1910, moved to Chernigov in 1914, and entered the University of Kiev in 1918); he chose the name "Oscar Zariski" when he was a graduate student in Rome where he studied with Guido Castelnuovo, Federigo Enriques, and Francesco Severi, in the 1920's—and where he met Yole Cagli, whom he married in the garden of his mother's old stone house in Kobryń on September 11, 1924, " ... on the sixth day after the Sabbath, the thirteenth day of the month of Elul, the year 5684 after creation ... ", just days before receiving his Rome doctorate. Then came a Rockefeller Fellowship at Rome in 1926; and, with help from Solomon Lefschetz, a postgraduate Johnston Scholarship at Johns Hopkins for 1927–28; winding-up as chair at Harvard in 1958. His students include Abhyankar, Artin, Mumford, and Hironaka. He was about 25 when he published his first paper; almost 50 when he did his great work on holomorphic functions; and completed his work on equisingularity when he was almost 80. Zariski lead the way to rigorizing the foundations of algebraic geometry by means of modern abstract algebra—followed quickly by the two revolutions of André Weil (c. 1945) and Alexander Grothendieck (c. 1960). In 1981 Zariski shared the $100,000 Wolf Prize with Lars Ahlfors. Reference: *The Unreal Life of Oscar Zariski*, by Carol Parikh, Academic Press, 1991. ISBN 0-12-545030-3. QA29.Z37P37 1990.

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