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Zusammenfassung

Die Doktorarbeit studiert unendliche Ensembles gewöhnlicher Differentialgleichungen mit gemeinsamen Monotonieeigenschaften, wie sie in der Nachhaltigkeitsforschung auftreten. Es werden neue Verfahren zur Behandlung von solchen Ensembles entwickelt und an verschiedenen Problemen des nachhaltigen Umgangs mit natürlichen Ressourcen erprobt.

Qualitative Differentialgleichungen (QDEs) und Differentialinklusionen werden in den neu formalisierten Rahmen der Modellensembles eingebettet. Unter einem Modellensemble versteht man eine Menge $\mathcal{M}$ von Funktionen f auf einem Zustandsraum $X \subseteq \mathbb{R}^n$, die Anfangswertprobleme $\dot{x} = f(x,t), x(0) = x_0$ definieren. Der mengenwertige Lösungsoperator weist einem Anfangszustand die Lösungen für alle $f \in \mathcal{M}$ zu, und liefert im allgemeinen sehr große Lösungsmengen. Für eine QDE schreibt man eine Matrix von Vorzeichen Σ vor und definiert das monotone Modellensemble $\mathcal{M}$ als die Menge aller Funktionen $f \in C^1(X, \mathbb{R}^n)$, so dass für alle $x \in X$ die Einträge der Jacobimatrix $\mathcal{J}(f)(x)$ dem Vorzeichen nach mit Σ übereinstimmen.

Die erste Anwendung betrifft die Armuts-Degradations-Spirale in Entwicklungsländern. Die zweite und dritte behandelt Fischereimanagement, insbesondere die industrialisierte Hochseefischerei und partizipatorische Managementansätze. Die vierte untersucht Wassermanagement zur Vermeidung von Eutrophierung. Die Anwendungen sind Bestandteil der Syndromforschung, die nach typischen Mustern sozial-ökologischer Veränderungen sucht. Sie stellen besondere Anforderungen an die Modellierung, insbesondere Unsicherheiten im Wissen und der Bedarf nach verallgemeinerbaren Resultaten.

Es wird gezeigt, dass Modellensembles hierfür geeignet sind. Überwiegend kommen QDEs zum Einsatz, die in der neu eingeführten graphentheoretischen Formulierung einen endlichen Zustandsgraphen als Lösung haben. Dies legt den Grundstein für die Entwicklung von vier neuen Verfahren zum Umgang mit großen QDEs. Hierbei kann die Viabilitätstheorie begrifflich wie methodisch für Abstraktions- und Restriktionsverfahren eingesetzt werden. (i) Die graphentheoretische Fassung viabler Mengen führt zur No-return Abstraktion, die einen engen Bezug zu starken Zusammenhangskomponenten aufweist. Damit lassen sich Zustandsgraphen aggregiert darstellen und bezüglich Nachhaltigkeitsfragen evaluieren. (ii) Die Restriktion der zulässigen Lösungen erlaubt es, Kanten von untergeordneter Bedeutung aus dem Zustandsgraphen zu eliminieren. (iii) Die Restriktion auf Systeme, bei denen die Einträge der Jacobimatrix eine vorgegebene partielle Ordnung aufweisen, ermöglicht die Elimination weiterer Pfade. (iv) Zuletzt werden Intervallschranken für die Einträge der Jacobimatrix berücksichtigt.

Die Anwendungen zeigen, dass mit diesen Methoden neue und robuste Eigenschaften auch sehr allgemeiner Modelle zum Management natürlicher Ressourcen gewonnen werden können. Zudem werden ihre Stärken für den Entwurf alternativen Politikoptionen deutlich.