3.4 The Cherednik algebra

Objekttyp: **Chapter**

Zeitschrift: **L'Enseignement Mathématique**

Band (Jahr): **49 (2003)**

Heft 1-2: **L'ENSEIGNEMENT MATHÉMATIQUE**

PDF erstellt am: **29.04.2024**

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Let us now return to the algebra $\mathcal{A}$ of operators on U generated by $\mathcal{D}(U)$ and W. This algebra contains the Dunkl operators

$$D_y := \partial_y + \sum_{s\in\Sigma} c_s \frac{(\alpha_s, y)}{\alpha_s}(s-1).$$

LEMMA 3.10. *The following relations hold:*

$$[x_i, x_j] = [D_{x_i}, D_{x_j}] = 0, \quad \forall 1 \le i,j \le n$$

$$[D_{x_i}, x_j] = \delta_{i,j} + \sum_{s\in\Sigma} c_s \frac{(x_i,\alpha_s)(x_j,\alpha_s)}{(\alpha_s,\alpha_s)} s, \quad \forall 1 \le i,j \le n$$

$$wxw^{-1} = w(x), \quad wD_yw^{-1} = D_{w(y)}, \quad \forall w \in W,\ x \in \mathfrak{h}^*,\ y \in \mathfrak{h}.$$

Proof. The proof is an easy computation, except for the relations $[D_{x_i}, D_{x_j}] = 0$, which follow from Theorem 2.6. □

This lemma motivates the following definition.

DEFINITION 3.11 (see e.g. [EG]). The *Cherednik algebra* H_c is an associative algebra with generators $x_i, y_i, i = 1, \ldots, n$, and $w \in W$, with defining relations

$$[x_i, x_j] = [y_i, y_j] = 0, \quad \forall 1 \le i,j \le n$$

$$[y_i, x_j] = \delta_{i,j} + \sum_{s\in\Sigma} c_s \frac{(x_i,\alpha_s)(x_j,\alpha_s)}{(\alpha_s,\alpha_s)} s, \quad \forall 1 \le i,j \le n$$

$$wxw^{-1} = w(x),\ wyw^{-1} = w(y),\ w\cdot w' = ww',\ \forall w,w' \in W,\ x \in \mathfrak{h}^*,\ y \in \mathfrak{h}.$$

This algebra was introduced by Cherednik as a rational limit of his double affine Hecke algebra defined in [Ch]. Notice that if $c = 0$ then $H_0 = \mathcal{D}(\mathfrak{h}) \rtimes \mathbf{C}[W]$.

Lemma 3.10 implies that the algebra H_c is equipped with a homomorphism $\phi\colon H_c \to \mathcal{A}$, given by $w \to w$, $x_i \to x_i$, $y_i \to D_{x_i}$.

Cherednik proved the following theorem.

THEOREM 3.12 (Poincaré-Birkhoff-Witt theorem). *The multiplication map*

$$\mu\colon \mathbf{C}[\mathfrak{h}] \otimes \mathbf{C}[\mathfrak{h}^*] \otimes \mathbf{C}[W] \to H_c$$

given by $\mu(f(x)\otimes g(y)\otimes w) = f(x)g(y)w$ *is an isomorphism of vector spaces.*

Proof. It is easy to see that the map μ is surjective. Thus, we only have to show that it is injective. In other words, we need to show that monomials $x_1^{i_1} \dots x_n^{i_n} y_1^{j_1} \dots y_n^{j_n} w$ are linearly independent in H_c. To do this, it suffices to show that the images of these monomials under the homomorphism ϕ, i.e. $x_1^{i_1} \dots x_n^{i_n} D_{x_1}^{j_1} \dots D_{x_n}^{j_n} w$, are linearly independent.

Given an element $A \in \mathcal{A}$, writing $A = \sum_{w \in W} P_w w$ with $P_w \in \mathcal{D}(U)$ we define the order of A, ord$A$, as the maximum of the orders of the P_w's. Notice that ord$AB \leq$ord$A$+ord$B$. We now remark that for any sequence of non negative indices $(i_1, \dots, i_n)$,

$$D_{x_1}^{i_1} \cdots D_{x_n}^{i_n} = \partial_{x_1}^{i_1} \cdots \partial_{x_n}^{i_n} + l.o.t.$$

Indeed this is true for D_{x_i}. We proceed by induction on $r = i_1 + \cdots + i_n$. We can clearly assume $i_1 > 0$, so by induction,

$$D_{x_1}^{i_1} \cdots D_{x_n}^{i_n} = (\partial_{x_1} + l.o.t.)(\partial_{x_1}^{i_1 - 1} \cdots \partial_{x_n}^{i_n} + l.o.t.) = \partial_{x_1}^{i_1} \cdots \partial_{x_n}^{i_n} + l.o.t.$$

From this we deduce that for any pair of multiindices $I = (i_1, \dots, i_n)$, $J = (j_1, \dots, j_n)$, $w \in W$, setting $x_I = {x_1}^{i_1} \cdots {x_n}^{i_n}$, $D_J = D_{x_1}^{j_1} \cdots D_{x_n}^{j_n}$, $\partial_J = \partial_{x_1}^{j_1} \cdots \partial_{x_n}^{j_n}$, we have

$$x_I D_J w = x_I \partial_J w + l.o.t.$$

Using this and the linear independence of the elements $x_I \partial_J w$, it is immediate to conclude that the elements $x_I D_J w$ are linearly independent, proving our claim. □

REMARK 1. We see that the homomorphism ϕ identifies H_c with the subalgebra of $\mathcal{A}$ generated by $\mathbf{C}[\mathfrak{h}]$, the Dunkl operators D_y, $y \in \mathfrak{h}$ and W.

REMARK 2. Another way to state the PBW theorem is the following. Let $F^\bullet$ be a filtration on H_c defined by $\deg(x_i) = \deg(y_i) = 1$, $\deg(w) = 0$. Then we have a natural surjective mapping from $\mathbf{C}[\mathfrak{h} \times \mathfrak{h}^*] \rtimes W$ to the associated graded algebra gr(H_c). The PBW theorem claims that this map is in fact an isomorphism.

3.5 THE SPHERICAL SUBALGEBRA

Let us now introduce the idempotent

$$e = \frac{1}{W} \sum_{w \in W} w \in \mathbf{C}[W].$$